



Analysis of Kinetic Chain Exercises, Both Closed and Open, in the Context of ACL Reconstructive Recovery

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DOI: 10.31080/ASOR.2024.07.0919

Received: January 25, 2024

Published: February 24, 2024

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Abstract

Anterior cruciate ligament torn are prevalent musculoskeletal injuries among physically active individuals and are most frequently seen in the population aged 15-25 years [4].

The ACL functions as the primary restraint to limit anterior tibial displacement for both 30° and 90° of knee flexion. It provides approximately 85% of the total ligamentous restraining force during Anterior tibial displacement. Confirm this notion by showing that normal, in vivo weight bearing in the knee induces tensile strain in the ACL due to anterior position shift of the tibia relative to the femur [9].

Keywords: Kinetic; Chain Exercises; ACL; Reconstructive Recovery

Introduction

The Anterior cruciate ligament is the most frequently injured ligament in the knee and is often injured during athletic activities. The knee is the one of the most frequently injured joints in the human body. The studies reported that 70% of ACL tears are due to non-contact type of injury. These injuries are mainly associated with twisting from a jump with flexed knee [2].

Post operative rehabilitation is a major factor in the success of an Anterior cruciate ligament reconstruction period. Clinical investigation of patient after ACL reconstruction have shown that immobilization at the knee or restricted motion without muscle contraction, leads to undesired outcome for the articular ligamentous and musculature structures that surround the knee [3].

Muscles can be strengthened through resistance training which can be divided into Open Kinetic Chain (OKC) and Closed Kinetic Chain (CKC) exercise. The term 'Kinetic Chain' is used to describe how the body moves with the limbs functioning either in an open kinetic chain or closed kinetic chain condition [7].

Open kinetic chain exercise occurs when the movement allows the distant part of the limbs to move freely while the proximal part is fixed. It tends to generate more distraction and rotational forces and is often used with concentric muscle contraction. Closed kinetic chain exercise is a movement where in the distal part is fixed, as when the sole of the foot makes contact with the ground or the exercise equipment. Thus, both proximal and distal parts receive resistance training at the same time [3].

CKC exercises are mainly used to train the quadriceps muscle group to improve muscle strength, coordination, and proprioception while putting the least amount of tensile strain on the ACL; For these reason it has been suggested that CKC exercises are safer than open kinetic chain (OKC) exercises for rehabilitation of both ACL deficient and reconstructed knees, decreasing the likelihood of injurious stresses being placed on the injured or reconstructed ligament. The use of OKC exercise with ACL pathologies has been proposed to increase the anterior shear forces at the knee, to a greater extent than CKC exercises. 'With an increased demand placed on the ACL by greater shear forces, the injured or reconstructed ACL

graft undergoes a substantial amount of strain due to the anterior translation of the tibia on the femur which may result in increased damage to the ligament.⁸

Open kinetic chain leg extension exercise have been the traditional means of strengthening the Quadriceps. The clinical use of closed kinetic chain exercise have significantly increased during the past several years. One of the reason there exercises have recovered increased attention with in the rehabilitation commonly is that they stimulate and replicate many functional movements.

There is a lack of clinical data comparing open kinematic chain (OKC) and closed kinematic chain (CKC) training method.

Need of study

There is a lack of clinical data comparing open kinematic chain (OKC) and closed kinetic chain (CKC) training method

Objectives

- To find out the affect of Open kinetic chain exercise after ACL reconstruction.
- To find out the affect of closed kinetic chain exercise after ACL reconstruction.
- Rehabilitation of patient after ACL reconstruction by Open kinematic chain (OKC) and closed kinematic chain exercise (CKC) exercise.
- To evaluate both outcome.

Hypothesis

- **Null hypothesis:** There will be no significant difference in effects and outcomes when compared between open kinematic (OKC) and closed kinematic chain (CKC) exercise in rehabilitation following ACL reconstruction.
- **Alternate hypothesis:** There will be a significant difference in effects and outcome when compared between open kinematic (OKC) and closed kinematic chain (CKC) exercise in rehabilitation following ACL reconstruction.

Review of literature

- **Mr Kyoung Kim, PT, et al. (2017):** In this study they investigated the effect of open and closed kinematic chain exercises on the static and dynamic balance of the ankle joints in young healthy women. A sample of 20 women is placed randomly in which 10 women in each group. Each group was given five sets of exercise corresponding to OKC and CKC. A 4 week duration study and the effect of these exercises are measured by Romberg's test. Result shows that OKC and CKC exercises

both improved the balance of the subjects. The CKC exercise was more effective at improving the dynamic balance of young healthy women than the OKC [10].

- **YOO JUNG KWON, et al. (2013):** They conducted experimental study to determine the effect of open and closed kinetic chain exercise on dynamic balance ability of normal healthy adults. 33 healthy adults participated, were subjects are randomly assigned to either an OKC or CKC. Dynamic balance was measured at the beginning and end of the week training period, including anterior-posterior, medial-lateral and total displacement of the center of pressure. Concluding with CKC exercises appears to be more effective at improving of dynamic balance ability than OKC exercises with in 6 week training period [3].
- **Mehmet, et al. (2014):** Conducted a study to evaluate open and closed kinetic chain exercise in rehabilitation following anterior cruciate ligament (ACL) reconstruction, with subjects comprised 11 female and 47 male patients. A randomized control trial concluding with CKC exercise program was more effective than 9KC in improving the knee functions of patients with ACL reconstruction [11].
- **H. Minoonejad (2012):** They conducted a study in combined open and closed kinetic chain exercise for patello femoral pain syndrome(PFPS) , randomized controlled trials 28 patients with PFPS were assigned to exercise and control group randomly. Exercise group were performed combined open and closed kinetic chain exercise for 6 weeks. Results shows that after 6 weeks pain decreased significantly and concluded that a combined open and closed kinetic chain exercise program will result in improved subjective and clinical outcomes in the patient with PFPS [12].
- **Guilherine Lotiero Fehr (2006):** Conducted an experimental study design in Effectiveness of the open and closed kinetic chain exercise in the treatment of the patello femoral pain syndrome (PFPS). For this 24 bearers of PFPS were randomly divided in to two groups: group 1 (n = 12) OKC and group 2 (n = 12) CKC, 8 weeks of duration. Results shows a reduction in the pain intensity after the 8 week intervention, and the CKC exercise presented better performance than OKC exercise [1].
- **Mark C Perret, et al. (2005):** Conducted a study of knee extensors kinetic chain training in ACL deficiency. Sixty four patient with a diagnosis of knee ACLD were participated in this study. Subjects trained using either open or closed kinetic chain resistance of their knee and hip extensors. The groups exhibited no statistically significant differences in outcome [1].

- **M C Morrisay, et al. (2000):** Conducted a study on effects of open versus closed kinetic chain training on knee laxity in the early period after ACL reconstruction. In this prospective randomized clinical trial the effects of these two regimes on knee laxity were compared in the early period after ACLR surgery. 36 patients recovering from ACLR surgery (29 males and 7 females) were randomly assigned to either an OKC or CKC group. Concluding with OKC exercises appears to be more effective [15].
- **C Michelson, et al. (2000):** Conducted a study on closed kinetic chain alone compared to combined open and closed kinetic chain exercises for quadriceps strengthening after ACL reconstruction with respect to return to sports. 44 patients with unilateral ACL injury randomly assigned to 2 groups, group 1 (n = 22) carried out quadriceps strengthening only with CKC and group 2 (n = 22) [16].
- **Thiago Yukio Fukuda, et al. (2013):** Conducted a study on open kinetic chain exercises in a restricted ROM after ACL reconstruction. A total of 49 patients were randomly assigned to an early start OKC exercise group (n = 25) or a late start OKC exercise group (n = 24). Concluding with an early start of OKC exercises for quadriceps strengthening in a restricted ROM did not differ from a late start in terms of anterior knee laxity [17].
- **Hyungkyu Kang, et al. (2012):** Conducted a study on comparison of strength and endurance between open and closed kinematic chain exercise after ACL reconstruction. 36 participants were randomly divided in to 2 groups for open or closed kinematic chain exercises. Concluding with open kinematic chain exercise is helpful for the development of strength and endurance of the knee extensor mechanism after ACL reconstruction [18].
- **Sofi Tagesson, et al. (2008):** A comprehensive rehabilitation program with quadriceps strengthening in closed versus open kinetic chain exercise in patients with anterior cruciate ligament deficiency: a randomized clinical trial evaluating dynamic tibial translation and muscle function. 43 Patients were randomized to rehabilitation with CKC quadriceps strengthening or OKC quadriceps strengthening. Functional outcome was evaluated by determining the Lysholm score and the Knee Injury and Osteoarthritis Outcome Score. Rehabilitation with OKC quadriceps exercise led to significantly greater quadriceps strength compared with rehabilitation with CKC quadriceps exercise [19].
- **Dylan Morrissey, et al. (2002):** A randomized single-blind clinical trial on effects of distally fixated versus nondistally fixated leg extensor resistance training on knee pain in the early period after anterior cruciate ligament reconstruction. 43 patients recovering from ACL reconstruction surgery were participated. Knee pain was measured using visual analog scales in a self-assessment questionnaire. Concluded with Open kinetic chain and CKC leg extensor training in the early period after ACL reconstruction surgery do not differ in their immediate effects on anterior knee pain [20].
- **E B Bynum, et al. (1995):** A prospective randomized study on open versus closed chain kinetic exercises after anterior cruciate ligament reconstruction. Pre- and postoperative evaluation included the Lysholm knee function scoring scale, Tegner activity rating scale and KT-1000 arthrometer measurements. concluded that closed kinetic chain exercises are safe and effective and offer some important advantages over open kinetic chain exercises [21].
- **H J Yack, et al. 1993:** This study Compared the effect of closed and open kinetic chain exercises in the anterior cruciate ligament-deficient knee. Anterior tibial displacement and the knee flexion angle were measured during each exercise using matched quadriceps loads and during the Lachman test. concluded that the stress to the anterior cruciate ligament, as indicated by anterior tibial displacement, is minimized by using the parallel squat, a closed kinetic chain exercise, when compared to the relative anterior tibial displacement during knee extension exercise [22].
- **D M Hooper, et al. (2001):** A study on Open and closed kinetic chain exercises in the early period after anterior cruciate ligament reconstruction: Improvements in level walking, stair ascent, and stair descent. 37 patients who had undergone anterior cruciate ligament reconstruction were tested in a gait analysis laboratory at 2 and 6 weeks after surgery. Between test sessions, patients were randomly assigned to a course of either closed or open kinetic chain resistance exercises. The data suggested that there are no clinically significant differences in the functional improvement resulting from the choice of open or closed kinetic chain exercises in the early period after this surgery [23].

Methodology

30 Patient with unilateral ACL tears who underwent arthroscopically assisted ACL reconstruction with an auto graft of hamstring tendon were included in this study. An experimental study was conducted at the outpatient department of Physiotherapy, Aparampar swami college of Physiotherapy, Nanded, Maharashtra for 4 weeks .15 members in each group were divided under a convenient

sampling method. Exclusion Criteria: Previous surgery of lower extremity, Trauma, Inflammatory disorder, Rheumatic diseases, Neurological or psychiatric disorder, Drug therapy other than analgesic, Inflammatory disorder. Outcome measures: Visual Analogue scale Study Materials: Goniometer, Inch tape, Couch, Table, Chair

Procedure

30patients with unilateral ACL tears who underwent arthroscopically assisted ACL reconstruction were participated in this study. Samples were selected on the basis of inclusion criteria. Patients were informed about the treatment protocol and written consent was taken. Demographic information including sex, age, weight, height, body mass index, occupation, education level, pain, intensity and affected side were recorded.

Patients were randomly allocated to Group I (CKC) or Group II (OKC). Outcome measurements were taken before the treatment and after the completion of treatment in both groups. Subjectively perceived pain intensity was assessed using visual analog scale (VAS), active knee flexion was evaluated with a universal goniometer, and thigh circumference difference was calculated from measurements made with a tape measure. The thigh circumference difference was measured 15 cm above the upper rim of the patella and represents the circumference measurement difference between the operated and normal thighs. Lysholm scores were used to assess the knee function, as this is an accepted scale of patient functionality demonstrating patient satisfaction in daily activities of mobility. The following CKC and OKC exercises were performed (3 sets of 20 repetitions).

Data analysis

30 patients with unilateral ACL tears who underwent arthroscopically assisted ACL reconstruction were participated in this study. The subjects were selected from AKG hospital Kannur. The patients were fully informed about the treatment procedure and written consent was taken.

They were divided into 2 groups in randomized manner and each group contains 15 members. Group A received ckc exercises and group B received okc exercises for a duration of 4 weeks. Data about demographic characteristics were obtained. VAS, universal goniometer and inch tape were used to assess the pain intensity, active knee flexion and thigh circumference difference respectively.

Improvement were observed PRE and post treatment for both groups. The differences in the mean VAS, goniometer and inch tap

measures were analyzed. And the pre test mean values were compared with the post test values within the group.

Result

Analysis of descriptive data

Group I (CKC) N = 15	Group II (OKC) N = 15
Squatting lunges exercise	Isometric quadriceps exercise
Standing weight shift exercise	Flexor-extensor bench
Wall sits exercise	Isotonic quadriceps exercise
One-legged quad dips exercise	Long leg press on-off exercise
Lateral step-ups exercise	Knee flexion-extension
	Stretching exercises

Table 1: Exercises protocols of both groups.

CKC: Closed Kinetic Chain; OKC: Open Kinetic Chain

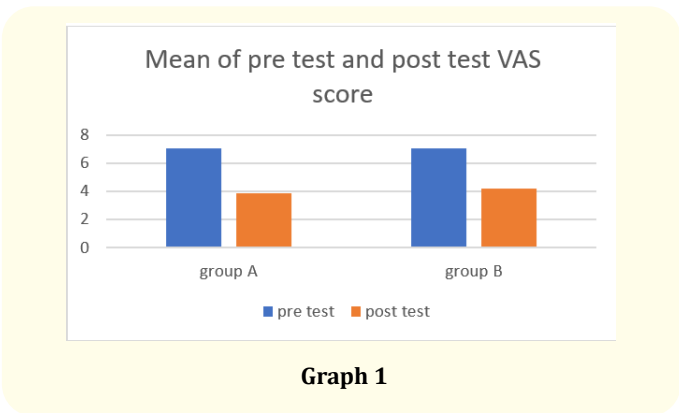
Basic characteristics		Group A		Group B	
Total no. of subjects studied(n)		15		15	
Age in years (mean)		25.5		28.12	
Gender	Female	n = 2	13.3%	n = 1	6.6%
	Male	n = 13	86.6%	n = 14	93.3%

Table 2: Basic characteristics of the subjects studied.

Analysis of scales

		VAS score		
		Minimum	Maximum	Mean
Group A	Pretest	5	9	7.1
	Post test	2	5	3.86
Group B	Pre-test	5	9	7.06
	Post test	3	5	4.2

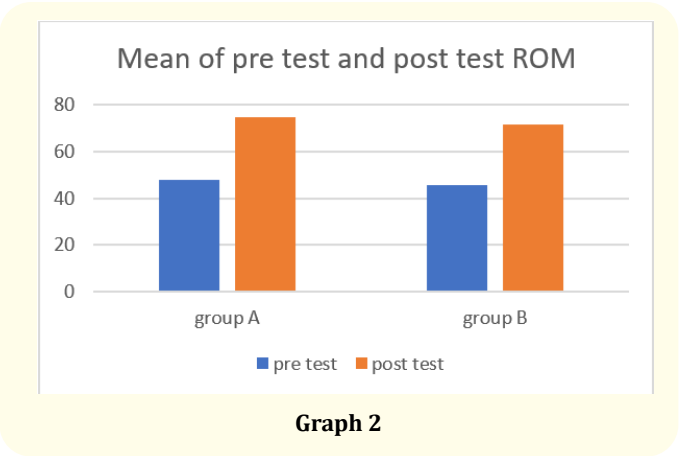
Table 3: Mean of pre test and post test VAS score.



Graph 1

		ROM		
		Minimum	Maximum	Mean
Group A	Pre-test	40	56	47.8
	Post-test	70	81	74.8
Group B	Pre-test	40	54	45.7
	Post-test	65	77	71.8

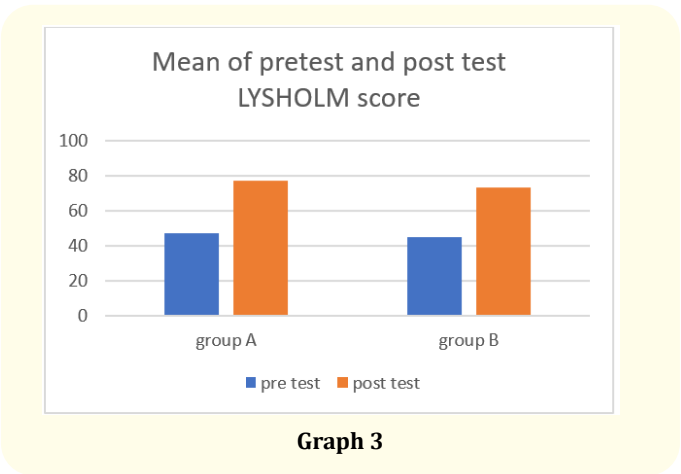
Table 4: Mean of pre test and post test ROM.



Graph 2

		Lysholm Score		
		Minimum	Maximum	Mean
Group A	Pre-test	40	55	47.26
	Post-test	70	84	77.26
Group B	Pre-test	40	50	45
	Post test	70	78	73.2

Table 5: Mean of pre test and post test LYSHOLM score.

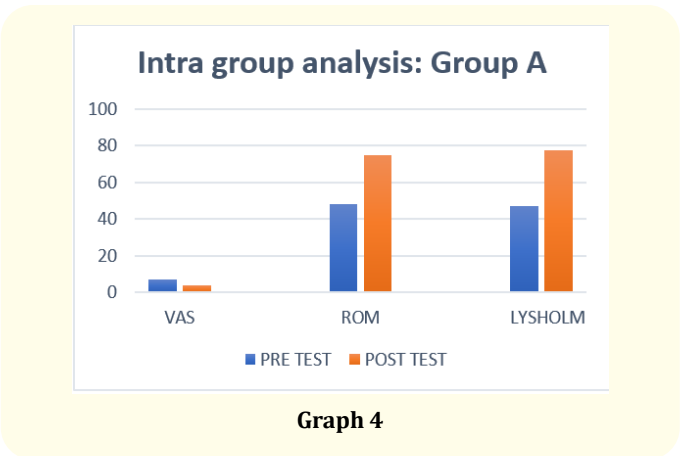


Graph 3

	Pre-test	Post-test
VAS	7.13	3.86
ROM	47.86	74.8
LYSHOLM	47.26	77.26

Table 6: Intra group analysis of VAS, ROM and LYSHOLM score: Group A.

Table 6 shows; (1) The evaluation of VAS score in group A by comparing the mean of pre and post-test values, mean of pre-test was 7 and post-test was 3.86, which indicates there was an improvement in the vas score after treatment. (2) Evaluation of ROM by comparing the pre and post-test values, Mean of pre-test was 47.86 and post-test was 74.8, indicates an improvement in the ROM after the completion of treatment. (3) Evaluation of LYSHOLM score by comparing the pre and post-test values, Mean of pre-test was 42.76 and post-test was 77.26, indicate an improvement in the LYSHOLM score after the completion of treatment.

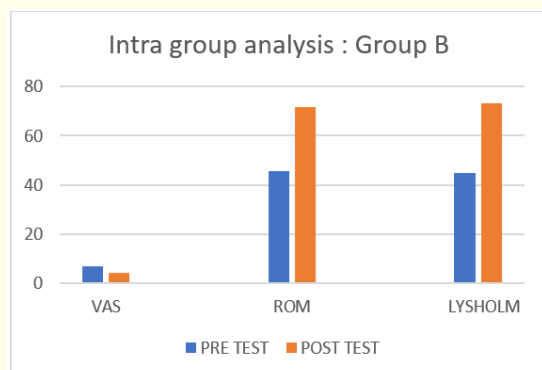


Graph 4

	Pre-test	Post-test
VAS	7.06	4.2
ROM	45.73	71.8
LYSHOLM	45	73.2

Table 7: Intra group analysis of VAS, ROM and LYSHOLM score: Group B

The Table 7 shows; (1) The evaluation of VAS score in group B by comparing the mean of pre and post-test values, mean of pre-test was 7.06 and post-test was 4.2, which indicate there was an improvement in the vas score after treatment. (2) Evaluation of ROM by comparing the pre and post-test values, Mean of pre-test was 45.73 and post-test was 71.8, indicates an improvement in the ROM after the completion of treatment. (3) Evaluation of LYSHOLM score by comparing the pre and post-test values, Mean of pre-test was 45 and post-test was 73.2, indicate an improvement in the LYSHOLM score after the completion of treatment.



Graph 5

Discussion

The purpose of this study conducted was to compare the effectiveness of Open kinematic chain and closed kinematic chain exercises in patients after ACL reconstruction. Visual analogue scale, Knee Flexion Range and Lysholm score was used to find out whether there was significant difference between these two techniques on reducing pain and improving knee movements.

The results showed significant improvement in both the groups. However, the CKC techniques prove to be slightly more beneficial than OKC exercises. Mehmet., *et al.* (2014): Conducted a study to evaluate open and closed kinetic chain exercise in rehabilitation following anterior cruciate ligament (ACL) reconstruction.

A randomized control trial concluding with CKC exercise program was more effective than OKC in improving the knee functions of patients with ACL reconstruction. The essential reasons for performing OKC and CKC exercises are to avoid loss of muscle strength, preserve knee ROM, and to maintain knee functionality and proprioception.

Although both CKC and OKC had positive effects on knee flexion, the CKC exercises were more effective at inhibiting muscle atrophy of the knee flexors and extensors at 3 and 6 months. M C Morrisay, *et al.* (2000): Conducted a study on effects of open versus closed kinetic chain training on knee laxity in the early period after ACL reconstruction. In this prospective randomized clinical trial the effects of these two regimes on knee laxity were compared in the early period after ACLR surgery. 36 patients recovering from ACLR surgery (29 males and 7 females) were randomly assigned to either an OKC or CKC group. Concluding with OKC exercises appears to be more effective.

In this research, before and after the experiment the data were collect to know the effect of CKC and OKC exercises on patients with ACL reconstruction. The VAS, Knee flexion Range and Lysholm score were recorded on the first day prior to treatment and at the end of the treatment.

Mean VAS score calculated for group A in pre test was 7.13 and in post test was 3.86. Mean VAS score for group B in pre test was 7.06 and post-test was 4.2. In group A there was difference of 3.27 in pre and post-test vas score and in group B there was difference of 2.86.

Mean Knee Flexion Range calculated for group A in pre test was 47.86 and in post-test was 74.8. Mean Knee Flexion Range for group B in pre test was 45.73 and post-test was 71.8. In group A there was an increase of 26.94 and in group B there was an increase of 26.07 in the flexion range of knee.

Mean Lysholm score calculated for group A in pre test was 47.26 and the score increased to 77.26 after treatment. Mean Lysholm score for group B in pre and post-test was 45 and 73.2 respectively. There was an increase in the Lysholm score of 30 in group A and 28.2 in group B.

When Closed kinematic chain and open kinematic chain exercises were compared post-treatment, there was statistically significant difference in the outcome measures VAS score, Knee flexion ROM and Lysholm score, in which CKC group demonstrated more improvement.

Both the groups, group A and group B demonstrated significant improvement in VAS, Knee flexion ROM score and Lysholm score after treatment.

Therefore, both types of exercises reduced pain and increased ROM of knee flexion in patients with ACL reconstruction. But the CKC exercise is slightly more beneficial as compare to OKC exercises.

Conclusion

The present study concluded that Closed kinematic chain and Open kinematic chain exercise yielded significant improvement in patients after ACL reconstruction. There is significant difference in CKC and OKC exercise in the treatment of subjects after ACL reconstruction. And CKC exercise is slightly more beneficial than the OKC exercises.

Limitations

Small sample size, Short term follow up.

Future Recommendations

Increase sample size, follow up period may be extended.

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