

Efficacy of Open Kinematic Chain Exercises Versus Closed Kinematic Chain Exercises on Functional Outcome After Anterior Cruciate Ligament Reconstruction Surgery

Dr. M.Rajani Cartor¹ PT, Dr. P. Mohini Devi² PT, Dr. P.A. Rao³ PT, PhD

1. Research Scholar, Sunrise University, Alwar, Faculty VAPMS College of Physiotherapy, Visakhapatnam

2. Faculty GITAM School of Physiotherapy, Visakhapatnam

3. Supervisor & Guide, Sunrise University, Alwar

Keywords: *open kinematic chain, closed kinematic chain, anterior cruciate ligament, reconstruction*

controls rotation of the tibia on the femur in femoral extensions of 0°-30°.

I. INTRODUCTION

The Anterior Cruciate ligament (ACL) is one of a pair of cruciate ligaments in human Knee. They are also called cruciform ligaments as they are arranged in a crossed formation. [6]

The ACL provides 85% of the restraining forces to anterior tibia displacement at 30 degrees and 90 degrees of knee flexion.[10] Anterior cruciate ligament attaches to the end of the femur (thighbone), at the back of the joint and passes down through the knee joint to the front of the flat upper surface of the tibia (Shin Bone). It passes across knee in a diagonal direction and with Posterior Cruciate Ligament passing in the opposite direction.[31]

The Role of Anterior Cruciate Ligament is to prevent forward movement of tibia from underneath the femur. This ligament is vitally important to the stability of the knee joint especially in sports and those that involve fast changes in direction and twisting and pivoting movements.[5] The Biomechanical function of the Anterior Cruciate Ligament is complex as it provides both mechanical stability and proprioceptive feedback to the knee. Disruption of the ACL is among the most frequent musculoskeletal injuries affecting physically active men and women. ACL serves as a secondary restraint to tibial rotation and any Varus / valgus angulation that occurs when the knee is at full extension.[5] ACL Prevents hyperextension of the knee and acts as a secondary stabilizer to stress, Reinforcing the medial Collateral Ligament. ACL

The Anterior Cruciate Ligament is most commonly injured ligament in trauma victims because of the large moments that can be generated through the forces acting on long lever arms of the femur and tibia. The injury mechanism is a Valgus/External Rotation trauma with a slightly Bend Knee.

When the Anterior Cruciate Ligament is either stretched, partially torn or completely torn, injuries are most commonly complete tears. 70% Anterior Cruciate ligament injuries occur through Non-Contact mechanisms, while 30% result from direct contact with object. Anterior Cruciate Ligament injury may also make the knee more prone to develop meniscal and articular cartilage injuries, which in turn cause pain in the knee.

The Prevalence is 48 per 1,000 patients per year. Symptoms of ACL include hearing a sudden popping sound, swelling, instability of knee. Pain is a major symptom in ACL injury and can range from moderate to severe.[18] The Anterior Cruciate Ligament is responsible for holding the outside (Lateral) compartment of the knee together. When the Anterior Cruciate Ligament tears the lateral femoral condyle is released, and it then dislocates over the back of lateral tibial plateau. This leads to a stretching or tearing of the outside structures of the knee.

Once the Diagnosis of ruptured ACL is made, management can be divided into conservative and surgical. Correct choice of treatment depends on assessment of the patient's three factors, which include age, functional disability and the functional requirements of the patient.

ACL Reconstruction is a common operation. Aim of operation is to restore functional stability to the ACL deficient knee. The functional stability provided by normal ACL is both in resisting Antero-posterior translation as well as in rotational subluxation.[4]

The surgical treatment of the torn ACL usually involves an arthroscopic surgical reconstruction of injured ligament. The ACL reconstruction is a surgical tissue graft replacement of the ACL injury. The torn ligament is removed from the knee before the graft is inserted through a hole created by a single whole punch. The surgery is performed arthroscopically.[26] The overall rate of disturbance of growth after ACL reconstruction was 2.6%, with no statistical difference between transphyseal and physeal-sparing techniques. Physeal-sparing techniques had a lower rate of post-operative complications compared with transphyseal techniques.[4]

The goals of physical therapy rehabilitation after ACL surgery is to build the strength of ACL, reduce pain and swelling and to improve stability. Two different Regimes have been used in post-operative rehabilitation of ACL injuries these include Open kinematic chain exercises (OKCE) and Closed kinematic chain exercises (CKCE).[16] Open kinematic chain exercises are those in which foot is not in touch with solid surface. The resistive loads are applied to tibia and are transferred directly to the knee. While Closed kinematic chain exercises are those, in which foot is in touch with solid surface. The foot is opposed by a ground reaction force, which is transmitted to all the joints in the lower limb.[30]

The aim of the study is to find the efficacy of Open kinematic chain exercises (OKCE) versus Closed kinematic chain exercises (CKCE) on functional outcome after Anterior Cruciate Ligament Reconstruction Surgery.

II. OBJECTIVES

1. To find effect of Open kinematic chain exercises (OKCE) on functional outcome of patients after Anterior Cruciate Ligament reconstruction surgery.
2. To find effect of Closed kinematic chain exercises (CKCE) on functional outcome of patients after Anterior Cruciate Ligament reconstruction surgery.

3. To compare the effect of Open kinematic chain exercises (OKCE) versus Closed kinematic chain exercises (CKCE) on functional outcome of patients after Anterior Cruciate Ligament reconstruction surgery. To know the efficacy of Open kinematic chain exercises (OKCE) versus Closed kinematic chain exercises (CKCE) on functional outcome after Anterior Cruciate Ligament reconstruction surgery.

III. MATERIALS AND METHODOLOGY

All steps performed in the present study involving human participation were in accordance to the ethical standards and patients' consent. Informed consent was taken from the subjects before including into the study. Subjects were explained about the interventions they are going to be given. They are requested for their persistence and co-operation during the study. Approval for this study was obtained from College's review board.

This study is an experimental study, where randomized controlled sampling method is conducted to collect the data. 43 Patients referred to the Out-Patient Physiotherapy departments of VAPMS College of Physiotherapy and KGH Physiotherapy department, Visakhapatnam are considered for sampling. Subjects were enrolled from September 2015 to November 2016 as patients consecutively. Patients (male and female) with age ranging 18 to 35 years were enrolled. The study was performed prospectively.

Subjects were selected following an inclusion criteria and were rejected if falling under exclusion criterion. The primary criterion to include for the study is that the subject to underwent Anterior Cruciate Ligament Reconstruction Surgery with an isolated acl injury and where the reconstruction is done with quadriceps tendon graft. And the criteria which shall exclude the subjects are those suffering with joint effusion, severe osteoarthritis, diabetes, hypertension skin allergies, malignancies, infections, any other associated problems and those who are in-cooperative.

The eligible candidates were randomly allocated into Group-1 and Group -2. In Group – 1, subjects shall receive Open kinematic chain exercises for a period of 6 weeks and subjects in Group – 2 shall receive Closed kinematic chain exercises for a period of 6 weeks. Both Groups shall receive

conventional physiotherapy for 3days post-operative.

Materials which are used in treating the subjects in order to perform the exercises are as followed couch, ice packs, towel roll, stepper, pedal cycle, balance board, treadmill.

As Conventional Physiotherapy, Cryotherapy is used to decrease edema during rehabilitation, as a low cost technique. Icepacks wrapped in dry or moist towelling is applied between 10 and 20 minutes from two to four times a day. Post cryoapplication, quadriceps isometrics, heel slides, patellar mobilization and ankle movements are exercised.

This is effective in reducing pain and improving knee ROM, during immediate Post-ACL Reconstruction surgery. The various physiologic effects of Ice application includes decreased circulation, local vasoconstriction, decreased

inflammation, decreased spasm, decreased pain, increased tissue stiffness, decreased metabolism.

Open Kinematic Chain Exercises such as Straight Leg Raise, Prone Knee Flexion, Leg Extension, Prone Hangs, Passive Knee Bend and Hamstring Curls are performed by Group -1subjects. And Group - 2 subjects under Closed kinematic chain exercises have performed Wall Slides, Partial Squat, Pedal Cycle, Step Ups, Balance Board, Lunges, and Treadmill.

Data was collected from each group by using Cincinnati knee rating scale.

This is an accurate rating of knee symptoms on a four level scale rating scales assessing pain, swelling, partial giving way, and full giving way based on the patient perception of the overall condition of the knee. This data was collected on post OP day 4 and on the last day of 6th week. Mean of all parameters are calculated i.e., of day 4 and last day of 6th week. t-Test is used to compare two different set of values.

DIRECTIONS: Using the key below, circle the appropriate boxes on the four scales which indicates the highest level you can reach **WITHOUT** having symptoms.

Scale	Description
6	Able to do light /moderate/strenuous work/sports without symptoms
4	Able to do activities of daily living alone; symptoms with light work/sports
2	Moderate symptoms (frequent, limiting) with activities of daily living
0	Severe symptoms (constant, not relieved) with activities of daily living

1. PAIN

6 ————— 4 ————— 2 ————— 0

2. SWELLING (actual fluid in the knee, obvious puffiness)

6 ————— 4 ————— 2 ————— 0

3. PARTIAL GIVING-WAY (partial knee collapse, no fall to the ground)

6 ————— 4 ————— 2 ————— 0

4. FULL GIVING-WAY (knee collapse occurs with actual falling to the ground)

6 ————— 4 ————— 2 ————— 0

Figure 1: Cincinnati Knee Rating scale

The data was collected from both groups on post OP day 4 and 42 (last day of 6th week). Followed by mean of all the parameters were calculated. Finally, the observed variations in each parameter were

represented in the graphical format for easy understanding. The baseline values prior to the treatment i.e., on 3rd day didn't shown much difference in both the groups.

IV. RESULTS

S No.	Pain		Swelling		Partial Giving Way		Full Giving Way	
	P1	P2	S1	S2	G1	G2	F1	F2
1	0	4	2	6	2	4	2	4
2	0	4	2	8	2	4	2	6
3	2	6	2	6	2	4	2	6
4	0	4	4	6	0	6	0	6
5	2	8	2	6	4	4	2	4
6	2	6	4	8	2	4	2	4
7	2	4	2	6	2	4	2	6
8	0	4	2	8	0	4	2	6
9	0	6	4	6	2	4	2	6
10	0	6	4	6	2	4	0	2
11	2	6	2	6	0	6	0	4
12	0	8	2	6	2	4	2	4
13	2	4	4	8	2	4	2	6
14	2	4	4	8	0	4	0	6
15	2	6	4	10	2	4	2	4

Table No. 1- Group 1 data collection sheet

S No.	Pain		Swelling		Partial Giving Way		Full Giving Way	
	P1	P2	S1	S2	P1	P2	F1	F2
1	2	6	2	10	2	6	0	4
2	0	6	2	8	2	8	2	8
3	2	8	2	8	4	6	2	8
4	0	8	4	6	2	6	0	4
5	2	10	4	10	2	6	4	10
6	0	6	2	8	4	8	0	4
7	2	8	4	6	2	6	2	8
8	0	8	4	8	0	4	2	8
9	2	10	4	6	0	4	2	8
10	2	6	2	8	2	8	2	6
11	2	6	4	8	0	4	2	8
12	0	6	4	8	2	8	2	6
13	0	4	2	6	2	6	2	8
14	0	6	4	6	2	8	2	8
15	0	6	2	8	2	8	2	8

Table No. 2: Group -2 Data collection sheet

Finally, the observed variations in each parameter were represented in the graphical format for easy understanding. The baseline values prior to the

treatment protocol at 3rd day for two groups don't show much difference.

Statistical Analysis:

❖ The formula for t-test

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad \begin{array}{l} \mapsto \\ \mapsto \\ \mapsto \end{array} \quad \begin{array}{l} \text{difference between means} \\ \text{variance} \\ \text{sample size} \end{array}$$

Where $\bar{x}_1$ = mean of sample 1, $\bar{x}_2$ = mean of sample 2

n_1 = number of subjects in sample 1, n_2 = number of subjects in sample 2

UNPAIRED t-test

Knee Rating Scale values - Data	t-value	Mean Difference	Significance	Significant Error
Pain between 6 th week (G-I & GII)	2.8062	1.60	0.01	0.57
Swelling	1.3868	0.67	0.1765	0.48
Partial giving way	4.8558	2.13	0.01	0.439
Full giving way	3.6986	2.113	0.01	0.57

Table No. 3 - UnPaired t-Test

Unpaired t-test has been performed between 6th week scores of pain, swelling, Partial Giving Way and Full Giving Way in Group- 1 & 2.

t- values of pain, Partial Giving Way and Full Giving Way, show that significant difference $P <$

$$s_1^2 = \text{variance of sample1} = \frac{\sum (x_1 - \bar{x}_1)^2}{n_1}$$

$$s_2^2 = \text{variance of sample2} = \frac{\sum (x_2 - \bar{x}_2)^2}{n_2}$$

Paired t-test is used to compare two population means, where two samples of which observation in one sample can be paired with observations in the other sample.

Unpaired t-test the means related to two independent Random Samples are tested.

0.01 exists between post scores (6th week) of both the groups.

t- Value of swelling indicates that insignificant difference exists between the groups.

PAIN	Group – 1	Group – 2
4 th day	1.07	0.93
6 th Week	5.33	6.93
t-value	9.909	15.37
Mean difference	4.27	6
Significance	0.01	0.01

Table No. 4 - Paired t - Test

Table 4 shows mean of pain on 4th day and 6th week of Group – 1, Group – 2 respectively. Paired t-test has been performed between 4th day and 6th week

values in both the Groups separately. t-values shows significant difference $P < 0.01$ between 4th day and 6th week values in both the Groups.

SWELLING	Group – 1	Group – 2
4 th day	2.93	3.07
6 th Week	6.93	7.6
t-value	4	4.53
Mean difference	11.83	9.13
Significance	0.01	0.01

Table No. 5 - Paired t Test

The table 5 shows mean of swelling on 4th day and 6th week of Group – 1 and Group – 2 respectively. Paired t-test has been performed between 4th day

and 6th week values in both the groups separately. t-value shows significant difference $P < 0.01$ between 4th day & 6th week values in both the Groups.

PARTIAL GIVING WAY	Group – 1	Group – 2
--------------------	-----------	-----------

4 th day	1.6	1.87
6 th Week	4.266	6.4
t-value	2.67	4.53
Mean difference	6.324	14.78
Significance	0.01	0.01

Table No. 6 - Paired t Test

The table 6 shows mean of partials giving way on 4th day and 6th week of Group- 1, Group – 2 respectively. Paired t-test has been performed between 4th day and 6th week values in both the

groups separately. t-value shows significant difference $P < 0.01$ between 4th day & 6th week values in both the Groups.

FULL GIVING WAY	Group – 1	Group – 2
4 th day	1.47	1.73
6 th Week	4.93	7.07
t-value	3.47	5.33
Mean difference	9.539	21.16
Significance	0.01	0.01

Table No. 7 - Paired t Test

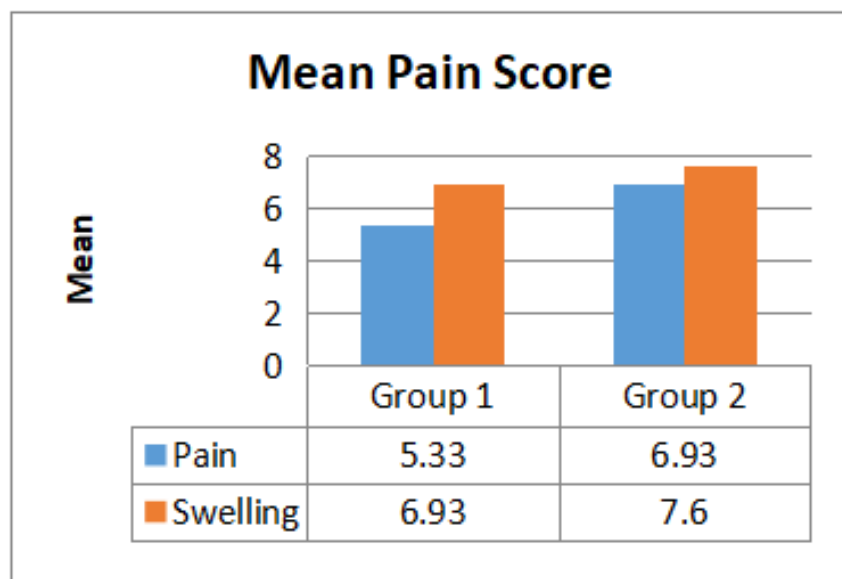
The table 7 shows mean of full giving way on 4th day and 6th week of Group – 1 and Group – 2. Paired t-test has been performed between 4th day

and 6th week values in both the groups separately. t-value shows significant difference $P < 0.01$ between 4th day & 6th week values in both the Groups.

SYMPTOMS - KNEE RATING SCALE	Group – 1	Group – 2
Pain	1.06	0.93
Swelling	2.93	3.06
PGW	1.6	1.86
FGW	1.46	1.73

Table No. 8 -knee rating scale - pre-values means

Table No. 8 shows pre value means of all the variables in the scale. The baseline values are almost same. This indicates homogeneity among groups.

Fig. 1. Mean Pain Scores on 4th day and 6th week in both the groups

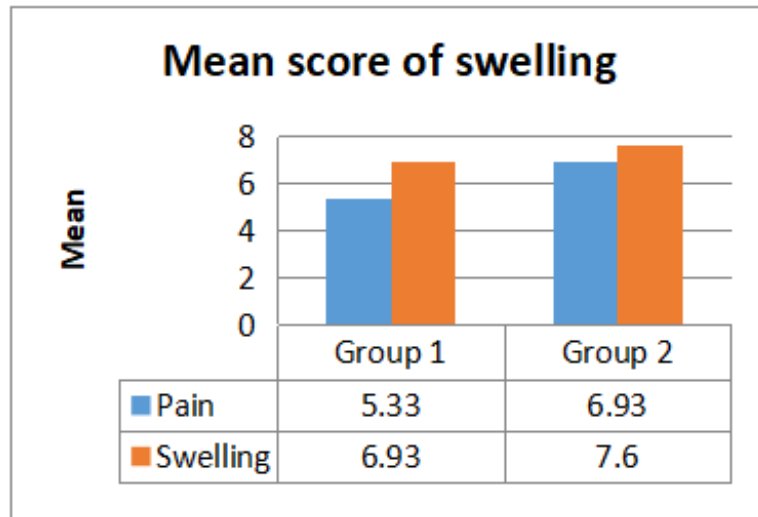


Fig. 2. Mean swelling scores on 4th day and 6th week in both the groups

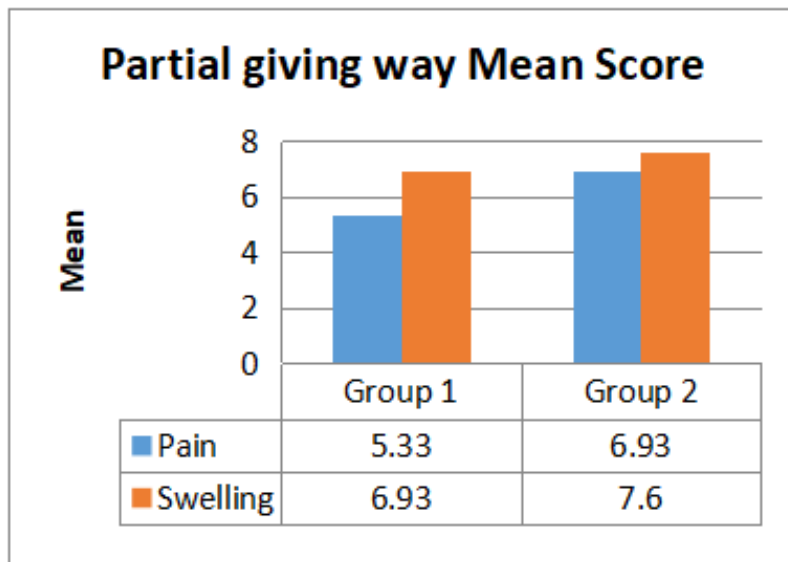


Fig. 3. Mean scores of partial giving way on 4th day and 6th week in both the groups.

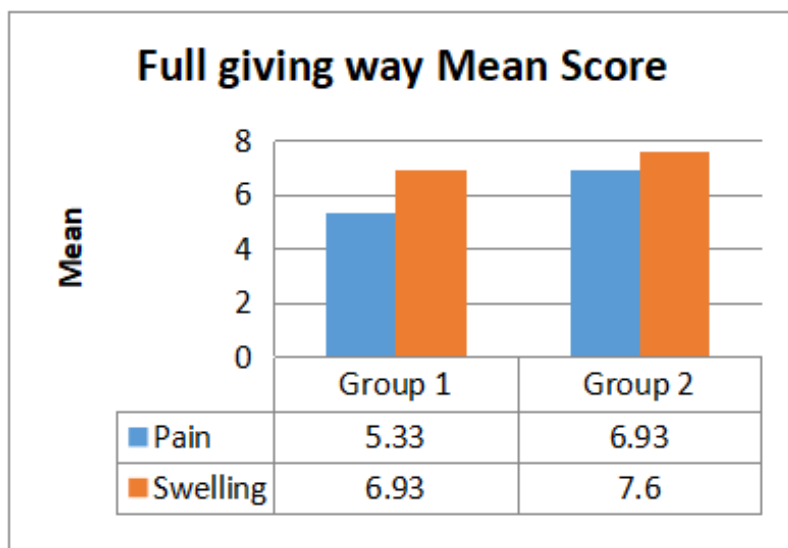


Fig. 4. Mean scores of full giving on 4th day and 6th week in both the groups

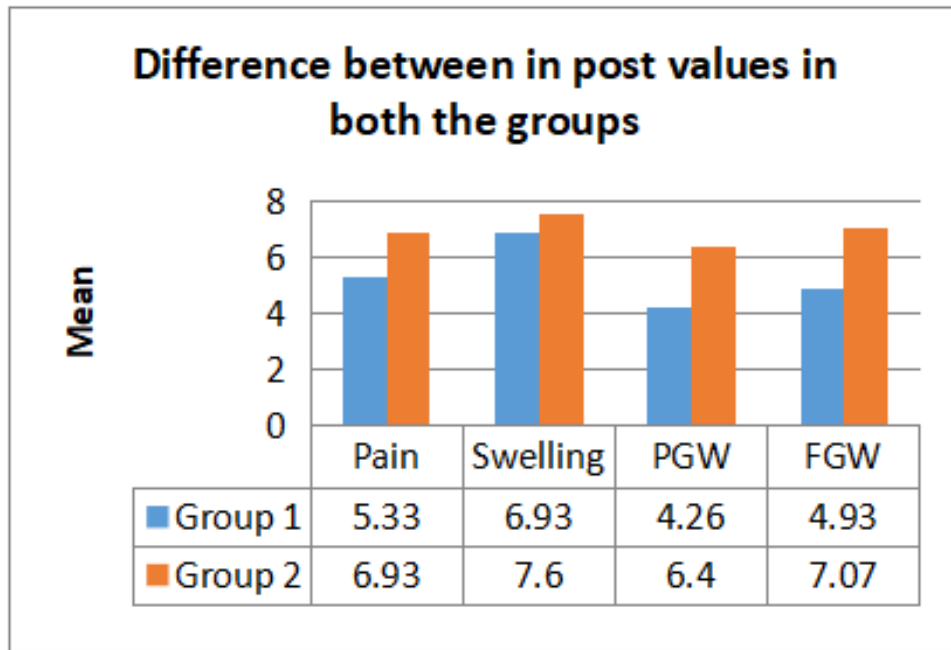


Fig. 5. 6th week mean scores of pain, swelling, partial giving way and full giving way in both the groups

V. DISCUSSION

As groups were selected and there is no interaction between patient selection and two groups were selected independently and randomly. Both groups were assessed for Cincinnati Knee Rating scale. All parameters were measured at baseline (4th Day Post OP) and at the last day of 6th week following completion of intervention. All participants completed the programme. The data was collected and statistical analysed. Cincinnati knee rating scale values significantly improved in Group-2 after 6 weeks of Closed kinematic chain exercise program. The results state that Closed kinematic chain exercises have shown better outcome than Open kinematic chain exercises.

Significant improvement is seen in pain, PGW, FGW mean values after 6 weeks in Group – 2 when compared to Group – 1. The results of this study show that Closed kinematic chain exercise are effective when compared to Open kinematic chain exercise training.

In agreement with above discussed results, alternate hypothesis is accepted and null hypothesis is rejected stating that Closed kinematic chain exercises significantly improves functional outcome in subjects. Our results showed that for this cohort of subjects with Anterior Cruciate Ligament Reconstruction six weeks of Closed kinematic chain exercise training resulted in improved functional outcome. The study result show that the group with Closed kinematic chain exercises training had

improved in pain, partial giving way and full giving way this improvement in functional recovery can be attributed to parallel improvement in muscle strength and stability.

Further studies are needed to be conducted in this direction to examine long-term effect of Closed kinematic chain exercises.

VI. CONCLUSION

The study result show that the Group with Closed kinematic chain exercise training had improved in pain, Partial Giving Way, Full Giving Way.

This improvement in functional recovery can be attributed to parallel improvement in muscle strength and stability.

Further studies are needed to be conducted in this direction to examine long-term effect of Closed kinematic chain exercises.

Conflict of Interest:

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this article.

Funding: The study was performed without financial support.

The authors confirm that they did not use artificial intelligence technologies in creating the submitted work. Data will be made available on reasonable request. The authors bear full responsibility for the final manuscript. Generative AI tools are not credited and are not responsible for the final results.

Declaration submitted by: Medidi Rajani Cartor, Pappu Mohini Devi.

Authors' contributions:

Author1 Medidi Rajani Cartor:

Review & Editing (lead), Conceptualization (lead), Formal analysis(equal), Methodology (equal), Writing – original draft (equal), Writing – Review and editing (lead)

Author2 Pappu Mohini Devi:

Software (lead), Formal analysis (equal), Writing – original draft (equal), Methodology (equal)

Author 3 Dr P.A.Rao:

Guidance and Supervision, Subject support.

REFERENCES

- [1] A.A.S. Meighan: Outcome after Reconstructions of the anterior cruciate ligament in athletic patients J Bone Joint Surg (Br) 2003; 85-B: 521-4. DOI: <https://doi.org/10.1302/0301-620X.85B4.13966>
- [2] Adil Ajuied. A survey of Rehabilitation Regimens following Isolated ACL Reconstruction, JMED Research, 2014; 2014. DOI: <https://doi.org/10.5171/2014.118077>
- [3] Alberto Gobbi. Single Versus Double Bundle ACL Reconstruction is there any difference in stability and function at 3-year follow upclin Orthop Relat Res (2012)470: 824-834. DOI: <https://doi.org/10.1007/s11999-011-2232-2>
- [4] Umiike Giuseppe Longo, Mauro Ciuffreda, Carlo Casciaro et al., Anterior cruciate ligament reconstruction in skeletally immature patients: a systematic review. August 2017, Bone and Joint Journal 99-B(8):1053-1060 DOI: <https://doi.org/10.1302/0301-620X.99B8.BJJ-2016-1150.R1>
- [5] Cabaud He; Biomechanics of Anterior Cruciate Ligament clin orthop Relat Res. 1983 Jan; (172) 16-31. <https://pubmed.ncbi.nlm.nih.gov/6821993/>
- [6] Chaitu malempati current Rehabilitation concepts for Anterior Cruciate Ligament surgery in Athletes: Sports medicine update. <https://pubmed.ncbi.nlm.nih.gov/26558662/>
- [7] Daniel A Shaerf: Anterior Cruciate Ligament Reconstruction best practice world J Orthop 2014 January 18; 5(1) 23-29. DOI: <https://doi.org/10.5312/wjo.v5.i1.23>
- [8] Douglas Adams: Current concepts for Anterior Cruciate Ligament Reconstruction J Orthop Sports Phys Ther.2012; 42(7):601-614. DOI: <https://doi.org/10.2519/jospt.2012.3891> M. Dienst, R. Burks, P. Greis.,Anatomy and biomechanics of the anterior cruciate ligament. Published in The Orthopedic clinics of ... 1 October 2002 DOI: [https://doi.org/10.1016/S0030-5898\(02\)00010-X](https://doi.org/10.1016/S0030-5898(02)00010-X)
- [9] Mehmet Ucar , Irfan Koca , Mehmet Eroglu et al. Evaluation of Open and Closed Kinetic Chain Exercises in Rehabilitation Following Anterior Cruciate Ligament Reconstruction. Phys Ther Sci. 2014 Dec 25;26(12):1875–1878. doi: 10.1589/jpts.26.1875
- [10] Gul Battaci. Comparison between Nintendo Wii fit and conventional rehabilitation on functional performance outcome after hamstring anterior cruciate ligament reconstruction: prospective randomized, controlled, double blind clinical trial. <https://pubmed.ncbi.nlm.nih.gov/22543515/>
- [11] Jonathan S. Mulford: Outcomes for primary anterior cruciate reconstruction with the quadriceps autograft: a systematic review. Jnee surg sports traumator arthrosc (2013) 21: 1882-1888. DOI: <https://doi.org/10.1007/s00167-012-2216-2>
- [12] Keith. W. Lawhron. The effect of graft tissue on Anterior Cruciate Ligament outcomes: A multicentre, prospective, Randomized Controlled trial comparing autograft hamstrings with fresh frozen Anterior tibialis allograft arthroscopy copy the journal of Arthroscopic and related surgery, 28(8) 2012, 1079-1086. DOI: <https://doi.org/10.1016/j.arthro.2012.04.051>
- [13] Kelly. Epidemiology of Meniscal injury associated with ACL Tears in young Athletes. <https://pubmed.ncbi.nlm.nih.gov/22385597/>

- [14] Mininder S Kocher et al. Management and Complication of ACL injuries in skeletally immature patients. J. Paed. Orthopedics, July/Aug 2002. <https://pubmed.ncbi.nlm.nih.gov/12131440/>
- [15] L.M. Cruse: Rehabilitation after Anterior Cruciate Ligament reconstruction J Bone Joint Surg Am, 2012; 94: 1737-48 DOI: <https://doi.org/10.2106/JBJS.K.01273>
- [16] Janice K Loudon, JK, Jenkins w; static posture and ACL injury in female athletes. J ortho phy Thev 1996, Aug (24). DOI:10.2519/JOSPT.1996.24.2.91
- [17] Michael D Ross et. Al. Implementation of Open and Closed kinetic chain quadriceps strengthening exercises after ACL Reconstruction, 2012(6) 987-1012. DOI:10.1519/1533-4287(2001)015<0466:IOOACK>2.0.CO;2
- [18] N. Adachi. Reconstruction of the anterior cruciate ligament, J Bone Joint Surg (Br) 2004; 86-B : 515-20 DOI: <https://doi.org/10.1302/0301-620X.86B4.14908>
- [19] Carla van Usen and Barbara Pumberger , Evaluation of the Effect of two-exercise regime in producing forces on ACL: A Systematic review. DOI: 10.46743/1540-580X/2007.1151
- [20] Rebekah Glass: The effects of Open versus Closed kinetic chain exercises on patients with ACL Deficient or Reconstructed knees, June 2010 5 (2); 74 https://www.researchgate.net/journal/North-American-journal-of-sports-physical-therapy-NAJSPT-1558-6162?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19
- [21] Rich. W. Neright: ACL Reconstruction Rehabilitation J Knee scrg. 2008 July; 21(3):225-234. <https://pubmed.ncbi.nlm.nih.gov/18686484/>
- [22] John Nyland, Emily Brand., Update on rehabilitation following ACL reconstruction. Open Access Journal of Sports Medicine. September 2010-1:151-166 DOI: 10.2147/OAJSM.S9327
- [23] Robert G. Marx, N. Engl., Arthroscopy Surgery for Osteoarthritis Knee? J Med. 2008, Oct 9;359(15):1637 DOI: 10.1056/NEJMe0804450
- [24] K. Shelbourne, P. Nitz, Accelerated Rehabilitation after Anterior Cruciate Ligament Reconstructions Published in American Journal of Sports... 1 May 1990 DOI: 10.1177/036354659001800313
- [25] Shaerf Daniel.; Banerjee, A. Assessment and management of posttraumatic haemarthrosis of the knee. Br. J. Hosp. Med. 2008, 69, 459–463. <https://pubmed.ncbi.nlm.nih.gov/18783098/>
- [26] M.Seshagirirao, Sudesh Thalathoti, Sumaiya Kauser Shaik., The effects of Open kinematic chain exercises versus Closed kinematic chain exercises 20kg. DOI: 10.16965/ijpr.2015.188
- [27] Sutantar Singh, rajesh Paul, Reena Arora, Lalit Arora, Aseem Khajuria: Comparison between efficacy of two different accelerated rehabilitation protocols on muscular strength and functional status of the patient after Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial, International Journal of Recent Scientific Research Physiotherapy 2014 5(8) 1412-1415.
- [28] Takanori Intensity of physiotherapy after anterior cruciate ligament reconstruction: A comparison of two-rehabilitation regimen. Arch Orthop Trauma Surg. 2010; 130: 1053-1058. DOI: <https://doi.org/10.1007/s00402-009-1010-5>
- [29] Sai Deepthi.Yarlagadda, A Study to compare the effect of Open versus Closed kinetic chain exercises in Patello-femoral arthritis. IOSR Journal of Sports and Physical Education (IOSR-JSPE), Volume 1, Issue 1 (Sep. – Oct. 2013), PP 34-41. <https://www.iosrjournals.org/iosr-jspe/papers/vol1-issue1/G0113441.pdf>
- [30] Word Ford – Rogers, Lynne; Anterior Cruciate ligament injury in college Athletes J Athl Train 1994. Dec; (29) (4). <https://pubmed.ncbi.nlm.nih.gov/16558298/>