Differences in Impact of Open Kinetic Chain and Closed Kinetic Chain Exercises on Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis

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Abstract. *Background*: There are differing views on the impact of performing Open Kinetic Chain (OKC) and Closed Kinetic Chain (CKC) on Anterior Cruciate Ligament Reconstruction (ACLR). *Purpose*: This research aims to compare the effects of OKC and CKC exercises on knee function following ACLR. *Method*: Systematic searches were performed in four databases (PubMed, ScienceDirect, ProQuest, and PEDro). Systematic review and meta-analysis used Randomized Controlled Trials (RCT) by comparing OKC exercise with CKC to ACLR, individuals with ACLR, and complete articles in English. Then, study quality was evaluated using the PEDro scale. For the interpretation data, if the p-value < 0.05, it is significant; otherwise, if the p-value > 0.05, it is not significant. *Results*: The review comprised seven studies. Meta-analysis was performed on knee function using the Lysholm knee score and Hughston Clinic Questionnaire and showed weak evidence that OKC exercise was superior to CKC exercise: MD: -4.55% (-8.47, -0.62); p-value $= 0.02$. *Conclusion*: OKC and CKC exercises are beneficial interventions for individuals with ACLR. Compared to the CKC exercise, the administration of the OKC exercise did not demonstrate compelling evidence in people with ACLR.

Keywords: Open Kinetic Chain Exercise · Closed Kinetic Chain Exercise · Anterior Cruciate Ligament Reconstruction

1 *I*ntroduction

Injury is defined as tissue damage caused by an external force acting on the body [1]. With 60% of injuries to the knee and ankle joints, sports have one of the highest injury rates [2]. Specifically, the Anterior Cruciate Ligament (ACL) is the most frequent injury in sports. Severe knee injuries called ACLs typically happen once the knee is bent when landing and twisting [3, 4]. Further, most ACL injuries are caused by non-contact accidents, accounting for 37.5%–85% of all ACL injuries. Changes in movement patterns are connected to the non-contact mechanism [5].

B. Ichsan et al. (Eds.): ICHWB 2022, AHSR 61, pp. 380–391, 2023.
https://doi.org/10.2991/978-94-6463-184-5_34

Annually, more than 120,000 cases of ACL injuries happen in the United States [6]. Meanwhile, the incidence rate of ACL rupture in athletes varies from 0.03% to 1.62% [7]. Approximately 100,000 ACLRs (Anterior Cruciate Ligament Reconstructions) are also conducted annually in the United States. In extensive population studies, the prevalence of ACLR increased sharply from 7.5% in 1980 to 48.5% in 2015 [8]. The main objective of ACL reconstruction is to restore the ACL's dimensions. The options for ACL graft encompass employing the patella tendon, quadriceps tendon, and hamstring tendon autograft [9]. In addition, ACLR's purpose is to reestablish knee function, bolster knee stability, and safeguard the meniscus and articular cartilage from more severe injury [10].

However, factors present during surgery or post-operative therapy may contribute to the failure of ACLR. After ACLR, rehabilitating patients is, therefore, a serious challenge. For post-ACLR care, a systematic, gradual recovery is advised [11]. Hence, post-ACLR rehabilitation needs to be considered. Gradual, structured, progressive rehabilitation is also recommended for post-ACLR management [12]. In particular, Open Kinetic Chain (OKC) exercise or Closed Kinetic Chain (CKC) exercise can safely rehabilitate ACLR. Giving CKC exercise has traditionally been preferred over OKC. Numerous physiotherapists also believe that exercise with OKC causes more strain on the ACL. In addition, there is another opinion that exercise with OKC can cause pain and knee laxity that may occur compared to CKC [13, 14]. Nevertheless, in vivo, clinical trials have shown that OKC exercises produce a similar level of anterior ACL bundle. In other words, OKC can reduce knee laxity by activating co-contraction in the hamstring [15]. Therefore, this systematic review and meta-analysis article aims to determine the difference in the impact of OKC and CKC exercises on knee function ability after ACLR.

2 *M*ethod

This work employed Preferred Reporting Items of Systematic Reviews and Meta-Analysis (PRISMA).

2.1 Search Strategy

This study was conducted systematically in four databases: PubMed, ScienceDirect, ProQuest, and the Physiotherapy Evidence Database (PEDro). The database search was organized with a publication time ranging from 1992 to 2022. The search strategy was carried out with the keywords "open kinetic chain," "closed kinetic chain," and "anterior cruciate ligament reconstruction."

2.2 Eligibility Criteria

The following inclusion standards were applied in the study: (1) Randomized Controlled Trial (RCT); (2) individuals with ACLR; (3) intervention comparison between open kinetic chain and closed kinetic chain; (4) complete articles in English. On the other hand, other lower extremity injuries and unavailable items were disqualified as criteria for exclusion.

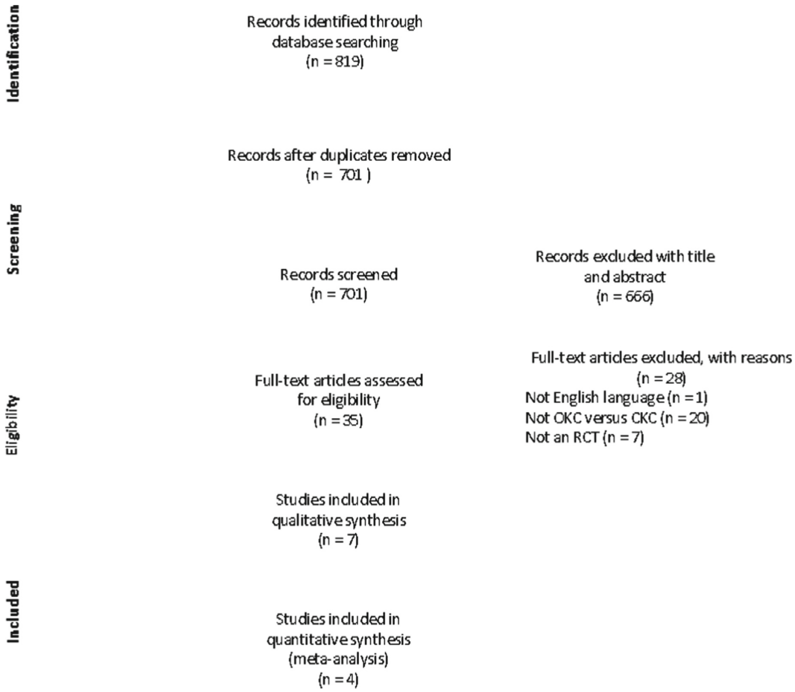

Fig. 1. Flow of studies through the review with PRISMA

Moreover, knee function became the primary outcome measure using the Lysholm knee score (score 0–100) and the Hughston Clinic Questionnaire (percentage). On both outcome measures, a more excellent score or percentage exhibited improved knee function.

2.3 Study Selection

The search findings were entered into the Mendeley software. The viability of the investigation was next checked after duplicates, titles, abstracts, and extraneous publications were removed. Articles with the remaining full text were then selected using the inclusion criteria. Afterward, the researchers and two reviewers (SSP and ANA) conducted the screening process (see Fig. 1).

2.4 Data Extraction

Data were taken from each article, including the author, year, population, study design, intervention, sample size, comparison, outcome measure, and results (see Table 1). Review Manager software version 5.4 was utilized to extract the mean, standard deviation, and total sample, which were then examined by two reviewers (SSP and ANA) to determine how much influence was achieved (SSP and ANA).

2.5 Assessment of Quality Study

Each study's bias potential was evaluated using the PEDro scale. Study quality on the PEDro scale relates to specific eligibility requirements, participant selection, hidden allocation, baseline likeness of prognostic indicators, blinding or ignorance of participants or subjects, therapists, and raters. If the outcome measure obtained was more than 85% of the participants or subjects, the participants or subjects received the treatment as allocated, and the results were statistical comparisons. The bias potential was carried out to assess the used study's quality (see Table 2). For the interpretation, the total 10-point PEDro scale score (items 2 through 11) was used; 0–3 "poor," 4–5 "fair," 6–8 "good," 9–10 "excellent" [16].

2.6 Data Synthesis

Meta-analysis was carried out using continuous data, i.e., mean, standard deviation, and total. The data needed were (1) 95% confidence interval data changes to pre and post-intervention in each group to determine effect size. (2) The statistical heterogeneity was assessed using the I^2 statistic, and the interpretation indicated 25% (low), 50% (moderate), and 75% (high) heterogeneity levels. (3) Risk of bias (PEDro scale) was employed to grade how strong the evidence was for all meta-analyses. (4) If the p-value < 0.05, it is significant; conversely, if $p > 0.05$, it is not significant [17].

3 *R*esults

The initial search identified 819 articles. Following removing duplicates and filtering titles and abstracts, 51 articles were left. The remaining full-text papers were then evaluated against the inclusion criteria. As a result, 28 were excluded, with one full-text paper not in English, 20 articles did not compare OKC and CKC, and seven studies were not randomized. In the final outcome, seven articles remained, with three articles as a systematic review and four used in the meta-analysis. The PRISMA flowchart is revealed in Fig. 1.

3.1 Study Characteristics

A total of 356 participants were involved in the research. The mean age was between 26 and 33 years, and most participants were male (see Table 1).

OKC: open kinetic chain; CKC: closed kinetic chain; RCT: randomized controlled trials; M: male; F: female.

3.2 Risk of Bias

The bias risk assessment used a PEDro scale ranging from 2 to 11 and was reviewed by two reviewers (SSP and ANA). Differences of opinion were resolved through discussion. The mean score was 6.1 (see Table 2). The most prevalent shortcomings included the therapist's lack of blinding or ignorance in all investigations, the subjects' and raters' lack of blinding or ignorance (five studies), and the lack of an analysis of "participants or subjects getting treatment as allocated (intention to treat)" (six studies).

Table 1. Characteristics of Included Studies

No	Author	Study Design	Sample	Population	Intervention	Comparison	Outcome	Result
1	Bynum et al. (1995)	RCT	N: 97	Mean age: 26.5 y OKC: n = 47 (45 M) CKC: n = 50 (43 M)	OKC (leg raise, isotonic quadriceps)	CKC (seated leg press, stationary bike, knee bend, running)	Laxity: KT-1000 arthrometer Function: Lysholm score	Laxity: OKC (3.3 mm) CKC (1.1 mm) Function: OKC (86); CKC (88)
2	Hooper et al. (2001)	RCT	N: 37	Mean age: Not reported OKC: n = 19 (16 M) CKC: n = 18 (13 M)	OKC (hip & knee extension) Duration: four weeks (three times per week)	CKC (leg press)	Function: Hughston Clinic Questionnaire	Function: OKC (61% ± 15%); CKC (61% ± 14%)
3	Kang et al. (2012)	RCT	N: 36	Mean age: 29 y OKC: n = 18 (12 M) CKC: n = 18 (12 M)	OKC (straight leg raise, leg extension) Duration: 12 weeks (three times per week)	CKC (squat, leg press, lunge)	Strength: isokinetic quadriceps: the knee joint moved from 0° to 90° at a speed of 60°/s	Strength: OKC (69.5 ± 25.7); CKC (55.6 ± 21.4)
4	Morrissey et al. (2000)	RCT	N: 36	Mean age: 30 y (29 M; 7 F) OKC: n = 18 (17 M) CKC: n = 18 (12 F)	OKC (hip & knee extension) Duration: four weeks (3 times per week)	CKC (leg press)	Laxity: Knee Signature System arthrometer, with the knee in 25° of flexion	Laxity: OKC (10.25 mm); CKC (9.98 mm)
5	Morrissey et al. (2002)	RCT	N: 43	Mean age: 29 y (34 M; 9 F) OKC: n = 22 (19 M) CKC: n = 21 (15 M)	OKC (hip & knee extension) Duration: four weeks (three times per week)	CKC (leg press)	Laxity: ligament arthrometer PROM: goniometer Function: Hughston Clinic Questionnaire (1,2,25) Pain: VAS	PROM: OKC (0.47 ± 0.19); CKC (0.50 ± 0.22) Function: Question 1: OKC (2.9 ± 3.0) CKC (4.0 ± 3.9) Question 2: OKC (2.7 ± 2.3) CKC (4.0 ± 3.1) Question 25: OKC (2.9 ± 3.1); CKC (3.4 ± 3.0)

(*continued*)

Table 1. (*continued*)

No	Author	Study Design	Sample	Population	Intervention	Comparison	Outcome	Result
6	Perry et al. (2005)	RCT	N: 49	Mean age: 33 y (37 M; 12 F) OKC: n = 24 (17 M) CKC: n = 25 (20 M)	OKC (hip & knee extension) Duration: six weeks (three times per week)	CKC (leg press)	Laxity: knee signature system arthrometer with knee Flexi 25° Function: Hughston Clinic Questionnaire, single leg hop for distance, triple crossover hop test	Laxity: OKC (10 ± 2) CKC (10 ± 3) Function: OKC (29 ± 13) CKC (32 ± 13)
7	Uçar et al. (2014)	RCT	N: 58	Mean age: 27.8 y (47 M; 11 F) OKC: n = 28 (23 M) CKC: n = 30 (24 M)	OKC (isotonic quadriceps, isometric quadriceps, knee flexion-extension, flexor-extensor bench, stretching)	CKC (squatting lunges, wall sit, standing weight shift, one-legged quad dips, lateral step-ups)	Pain: VAS ROM Flexi knee: Universal Goniometer Thigh circumference: tape measure Function: Lysholm score	Pain: OKC (27.2 ± 9.9); CKC (22.1 ± 10.5) Knee Flexion: OKC (128.5 ± 18.1); CKC (135.1 ± 16.1) Thigh circumference: OKC (1.6 ± 1.4) CKC (1.3 ± 1.5) Function: OKC (84.3 ± 9.1); CKC (94.1 ± 8.5)

3.3 Meta-analysis

3.3.1 Lysholm Knee Score

Data from two investigations were used to calculate the Lysholm knee score. The findings showed that exercise patients from OKC and CKC differed significantly from one another: MD: −6.30% (−12.12, −0.47); p-value = 0.03 ($Chi^2 = 1.22$, df = 1, and p-value = 0.27; $I^2 = 18\%$); (see Fig. 2).

3.3.2 Hughston Clinic Questionnaire

Hughston Clinic Questionnaire data were presented in two investigations. The results revealed no critical distinction in patients with OKC exercise compared to patients with CKC exercise: MD: 1.35% (−7.23, 4.54); p-value = 0.65 ($Chi^2 = 0.03$, df = 1, and p-value = 0.87; $I^2 = 0\%$); (see Fig. 2).

Table 2. Risk of Bias with PEDro Scale

Author	Item*											
	1	2	3	4	5	6	7	8	9	10	11	Total**
Bynum et al. (1995)	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	6
Morrissey et al. (2000)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Hooper et al. (2001)	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6
Morrissey et al. (2002)	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	6
Perry et al. (2005)	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	8
Kang et al. (2012)	Y	Y	N	Y	Y	N	N	N	N	Y	Y	5
Uçar et al. (2014)	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6

Y: yes; N: no

*1. Eligibility criteria; 2. Random allocation; 3. Concealed allocation; 4. Baseline comparability; 5. Blinding subject; 6. Blinding therapist; 7. Blinding assessors; 8. Outcome data obtained more than 85%; 9. Intention to treat; 10. Comparisons group result; 11. Point measures

**Total 10-point PEDro scale score (items 2 through 11); 0-3 "poor," 4-5 "fair," 6–8 "good," 9-10 "excellent."

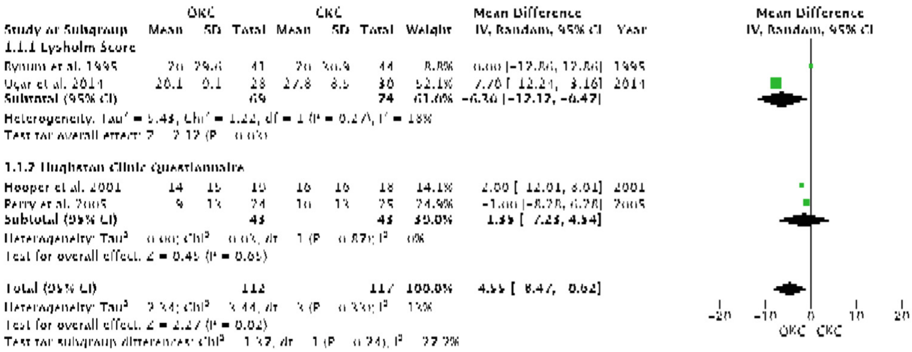

Fig. 2. Forest Plot: Lysholm Score and Hughston Clinic Questionnaire Score

3.4 Systematic Review

3.4.1 Strength and Endurance Knee Extensor

Research conducted by Kang et al. (2012) asserted a sizable disparity between before and after therapy with ($p < 0.05$) in endurance, isokinetic strength, and squat strength. Compared to CKC exercise, OKC exercise exhibited higher differences in isokinetic strength and extensor muscle endurance [18].

3.4.2 Knee Laxity

Studies carried out by Bynum et al. (1995), Morrissey et al. (2000), Perry et al. (2005), and Morrissey et al. (2002) explained that there was no discernable variation with either OKC or CKC exercises on anterior tibia laxity using an arthrometer [19–22].

3.4.3 Knee Pain

Research by Morrissey et al. (2002) explained that the discomfort during the OKC and CKC exercise was the same ($p = 0.67$), while Uçar et al. (2014) said that pain decreased more in the group given CKC compared to OKC [22, 23].

4 *D*iscussion

Systematic review and meta-analysis uncovered that after ACLR, both statistical and descriptive analyses stated that OKC and CKC exercises were beneficial interventions for individuals with ACLR. In this study, the prime focus was to ascertain whether exercising with OKC produced a more significant increase in function than exercising with CKC. Data from four studies that had been collected were then included in the meta-analysis, finding that there was a more significant change in OKC exercise compared to CKC exercise in knee function.

Following ACLR, performing OKC and CKC exercises is crucial to prevent muscle atrophy, maintain knee flexibility, and enhance knee proprioception [23]. Most rehabilitation work done in the initial stages of ACLR is CKC. OKC exercises, on the other hand, are typically performed later [24]. According to Mikkelsen et al. (2000), OKC can dramatically boost quadriceps muscular strength while preventing knee laxity. Although it is not a recent study [25], it is advised to utilize combined workouts of OKC and CKC with caution and under management to prevent undue pressure on the ACL graft. Similar to the research of Bynum et al. (1995), OKC exercises need to be monitored to limit so that there is not much stress on the ACL graft [19].

It contrasts with the research conducted by Fukuda et al. (2013), investigating Early OKC (EOKC) and Late OKC (LOKC) exercises reviewed at 12 weeks, 19 weeks, 25 weeks, and 17 months. Their results demonstrated a statistical increase in Lysholm at 19, 25, and 17 months. Besides, the EOKC and LOKC groups achieved similar findings for discomfort and function, while the LOKC group exposed quicker quadriceps strength recovery. However, this distinction lacked clinical significance [26]. Since there was no negative impact from therapy administered right after ACLR, it is expected that the patient may feel comfortable to begin weight bearing right after the surgery by flexing the knee from 0° to 90° and doing CKC exercises [27]. Nonetheless, different results were obtained in the research of Kang et al. (2012) by finding a type of exercise more effective than only emphasizing structural strength safety. After the experiment was conducted, it was proven that the strength and endurance of knee extensors were improved with OKC exercise [18].

Moreover, the vastus medialis, which has more activity than the vastus lateralis, can be stimulated by CKC exercises. Compared to OKC exercise, this advantageous effect is higher. It is also known that OKC exercise is not easy in individuals with patellofemoral joint pain because it produces cruciate ligament hypertonicity. Meanwhile, exercises with CKC combine contractions in the quadriceps and hamstring, such that the patellofemoral joint's increased pressure is reduced, and the joint's stability is increased. This study's findings align with earlier studies showing that both CKC and OKC exercises for the quadriceps significantly impact pain relief and improve joint performance. However, individuals that received CKC exercise, as opposed to OKC exercise, had substantial advantages [23–25, 28–31]. Another study by Nadeem et al. (2022) disclosed that CKC exercise was more effective in increasing strength and reducing pain than OKC exercise. Thus, three weeks after the treatment, engaging in quadriceps and hamstring strengthening exercises is safe. However, more research is required [27].

In the study of Cho et al. (2013), the use of CKC gave significant results on knee joint function and proprioception after six weeks; it also effectively minimized the occurrence of stress on the ligament. As a result, CKC is strongly advised as the first exercise step after ACLR [32]. In addition, OKC or CKC exercises given had the same effects on pain and knee joint function. However, the use of OKC exercises that provide greater advantages following ACLR has not been demonstrated, according to the currently accessible studies. Thus, administering CKC exercises is still a recommendation until there is strong evidence showing that OKC is more effective on knee joint function in ACLR [19]. It is supported by the research of Perry et al. (2005) that giving OKC and CKC exercises did not have different effects on knee laxity or knee joint function, assuming that higher intensity did not have different results. Although using weights to exercise OKC seems safe, this study advises exercising CKC following ACLR. Further research is then needed to compare the impact of OKC or CKC exercise after ACLR [21].

The limitation of this research is that the number of studies obtained was still limited, so the provision of OKC or CKC exercises was still assessed subjectively. Given that males made up nearly all the research participants, it negatively correlated with females' increased risk of ACL damage. To achieve the best results, it is also necessary to reevaluate the type of graft, dose, and intensity of exercise.

5 *C*onclusion

Based on the results of studies observed and carried out, the meta-analysis highlighted weak evidence that OKC exercise is superior to CKC exercise. In addition, given the limited literature and research comparing the two interventions, it is difficult to say that OKC is more effective after ACLR. In this case, the authors still recommend giving CKC exercise as an early stage after ACLR until there is substantial proof that OKC is more effective than CKC exercise. Moreover, future studies are expected to provide more vital evidence by considering more aspects of research and collaborating with other health professionals related to managing ACL injuries so that the results obtained are more maximal and objective.

This study further implies that there is limited current literature comparing OKC and CKC; it should be noted that most studies only involved four weeks of intervention. It makes the results obtained less than optimal. Therefore, in anticipation of giving OKC interventions to the ACLR, it is necessary to pay attention to the degree of the knee movement so as not to re-injure.

Acknowledgments. The researchers thank the Physiotherapy Study Program, Universitas Muhammadiyah Surakarta, for the contribution to the completion of this article. Without their direction and generosity in sharing the new knowledge the researchers have not yet obtained, this project could not have been completed.

Authors' Contributions. JFP understood the presented ideas, developed existing theories, and performed calculations. Meanwhile, SSP and ANA supervised, directed, and confirmed the analytical techniques. Each author also provided input for the final paper and discussed the findings.

References

1. Schuh-Renner A, Canham-Chervak M, Grier TL, Hauschild VD, Jones BH. Expanding The Injury Definition: Evidence for The Need to Include Musculoskeletal Conditions. Public Health [Internet]. 2019;169:69–75. https://doi.org/10.1016/j.puhe.2019.01.002
2. Emery CA, Pasanen K. Current Trends in Sport Injury Prevention. Best Pract Res Clin Rheumatol [Internet]. 2019;33(1):3–15. https://doi.org/10.1016/j.berh.2019.02.009
3. Webster KE, Hewett TE. Meta-Analysis of Meta-Analyses of Anterior Cruciate Ligament Injury Reduction Training Programs. J Orthop Res. 2018;36(10):2696–708.
4. Maliwankul K, Chuaychoosakoon C. Suturing the Anterior Cruciate Ligament Using a No. 16 Intravenous Catheter Needle in Avulsion Anterior Cruciate Ligament Injury. Arthrosc Tech [Internet]. 2020;9(8):e1191–6. https://doi.org/10.1016/j.eats.2020.04.019
5. Fort-Vanmeerhaeghe A, Arboix-Alió J, Montalvo AM. Return-to-Sport Following Anterior Cruciate Ligament Reconstruction in Team Sport Athletes. Part I: From Initial Injury to Return-to-Competition. Apunt Sport Med. 2021;56(212)
6. Kaeding CC, Léger-St-Jean B, Magnussen RA. Epidemiology and Diagnosis of Anterior Cruciate Ligament Injuries. Clin Sports Med. 2016;36(1):1–8.
7. Neal BS, Miller SC, Goodall A, Phillips J, Small C, Lack SD. Variables Associated with Successful Outcome After Anterior Cruciate Ligament Reconstruction in Recreational Athletes: A Prospective Cohort Study. SSRN Electron J [Internet]. 2022;39:29–37. https://doi.org/10.1016/j.knee.2022.08.017
8. Cohen D, Yao PF, Uddandam A, de SA D, Arakgi ME. Etiology of Failed Anterior Cruciate Ligament Reconstruction: a Scoping Review. Curr Rev Musculoskelet Med. 2022;394–401
9. Poget F, Blackburn T, Descloux F, Fiddler H. Participating In an Exercise Group After Anterior Cruciate Ligament Reconstruction (ACLR) is Perceived to Influence Psychosocial Factors and Successful Recovery: a Focus Group Qualitative Study. Physiother (United Kingdom) [Internet]. 2019;105(4):492–500. https://doi.org/10.1016/j.physio.2018.12.001
10. Pache S, Del Castillo J, Moatshe G, LaPrade RF. Anterior Cruciate Ligament Reconstruction Failure and Revision Surgery: Current Concepts. J ISAKOS [Internet]. 2020;5(6):351–8. https://doi.org/10.1136/jisakos-2020-000457
11. Indriastuti & Pristianto A. Program Fisioterapi pada Kondisi Pasca Rekonstruksi Anterior Cruciate Ligament (ACL) Fase I : A Case Report. Physio J. 2021;1(2):1–9
12. Korakakis V, Kotsifaki A, Korakaki A, Karanasios S, Whiteley R. Current Perspectives and Clinical Practice of Physiotherapists on Assessment, Rehabilitation, and Return to Sport Criteria After Anterior Cruciate Ligament Injury and Reconstruction. An Online Survey of 538 Physiotherapists. Phys Ther Sport [Internet]. 2021;52:103–14. https://doi.org/10.1016/j.ptsp.2021.08.012

13. 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;10.
14. Perriman A, Leahy E, Semciw AI. The effect of open-versus closed-kinetic-chain exercises on anterior tibial laxity, strength, and function following anterior cruciate ligament reconstruction: A systematic review and meta-analysis. J Orthop Sports Phys Ther. 2018;48(7):552–66.
15. Luque-Seron JA, Medina-Porqueres I. Anterior Cruciate Ligament Strain In Vivo: A Systematic Review. Sports Health. 2016;8(5):451–5.
16. Cashin AG, McAuley JH. Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. J Physiother [Internet]. 2020;66(1):59. https://doi.org/10.1016/j.jphys.2019.08.005
17. Harrer M, Cuijpers P, Furukawa TA, Ebert DD. Doing Meta-Analysis with R A Hands-On Guide. 1st ed. Taylor & Francis Group. Oxon; 2022. 501 p
18. Kang H, Jung J, Yu J. Comparison of Strength and Endurance between Open and Closed Kinematic Chain Exercises After Anterior Cruciate Ligament Reconstruction: Randomized Control Trial. J Phys Ther Sci. 2012;24(10):1055–7.
19. Bynum EB, Barrack RL, Alexander AH. Open Versus Closed Chain Kinetic Exercises After Anterior Cruciate Ligament Reconstruction: A Prospective Randomized Study. Am J Sports Med. 1995;23(4):401–6.
20. Morrissey MC, Hudson ZL, Drechsler WI, Coutts FJ, Knight PR, King JB. Effects of open versus closed kinetic chain training on knee laxity in the early period after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2000;8(6):343–8.
21. Perry MC, Morrissey MC, King JB, Morrissey D, Earnshaw P. Effects of closed versus open kinetic chain knee extensor resistance training on knee laxity and leg function in patients during the 8- to 14-week post-operative period after anterior cruciate ligament reconstruction. Knee Surgery, Sport Traumatol Arthrosc. 2005;13(5):357–69.
22. Morrissey MC, Drechsler WI, Morrissey D, Knight PR, Armstrong PW, McAuliffe TB. Effects of Distally Fixated Versus Nondistally Fixated Leg Extensor Resistance Training on Knee Pain in The Early Period After Anterior Cruciate Ligament Reconstruction. Phys Ther. 2002;82(1):35–43.
23. 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(12):1875–8.
24. Kersante G, Mazeas J, Traullé M, Vandebrouck A, Duffiet P, Ratte L, et al. Benefit of the Early Open Kinetic Chain on the Quadriceps Strength after Anterior Cruciate Ligament Reconstruction in Male Soccer Players in a Context of Return to Running. Int J Physiother. 2021;8(2):105–11.
25. Mikkelsen C, Werner S, Eriksson E. Closed Kinetic Chain Alone Compared to Combined Open and Closed Kinetic Chain Exercises for Quadriceps Strengthening after Anterior Cruciate Ligament Reconstruction with Respect to Return to Sports: A Prospective Matched Follow-Up Study. Knee Surgery, Sport Traumatol Arthrosc. 2000;8(6):337–42.
26. Fukuda TY, Fingerhut D, Moreira VC, Camarini PMF, Scodeller NF, Duarte A, et al. Open Kinetic Chain Exercises in a Restricted Range of Motion after Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Clinical Trial. Am J Sports Med. 2013;41(4):788–94.
27. Nadeem N, Asghar HMU, Fatima I, Fazal MI, Sarfraz AH, Maqbool S. Comparison of Effects of Open Kinetic Chain Exercises with Closed Kinetic Chain Exercises on Quadriceps Strength and Knee Functional Activity Level after ACL Reconstruction - A Randomized Controlled Trial. Pakistan J Med Heal Sci. 2022;16(5):14–7.
28. Rahman F, Nurratri AK, Budi IS, Kurniawan A, Susilo TE. Efektivitas Latihan Closed Chain Untuk Meningkatkan Keseimbangan Dewasa Muda. Univ Res Colloq. 2018;205–14

29. Mustafa M, Fatima I, Tariq A, Fazal MI, Jamal MN, Sarfraz AH. Comparison Between the Effect of Closed Kinetic Chain and Open Kinetic Chain exercises in the strengthening of Vastus Medialis Obliqus in subjects with Patello-Femoral Pain Syndrome - A Randomized Control Trial. Pakistan J Med Heal Sci. 2022;16(6):185–6.
30. Kang JI, Park JS, Choi H, Jeong DK, Kwon HM, Moon YJ. A Study on Muscle Activity and Ratio of The Knee Extensor Depending on The Types of Squat Exercise. J Phys Ther Sci. 2017;29(1):43–7.
31. Chang WD, Huang WS, Lee CL, Lin HY, Lai PT. Effects of Open and Closed Kinetic Chains of Sling Exercise Therapy on The Muscle Activity of The Vastus Medialis Oblique and Vastus Lateralis. J Phys Ther Sci. 2014;26(9):1363–6.
32. Cho SH, Bae CH, Gak HB. Effects of Closed Kinetic Chain Exercises on Proprioception and Functional Scores of The Knee after Anterior Cruciate Ligament Reconstruction. J Phys Ther Sci. 2013;25(10):1239–41.