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By Rizka Salsabila Putri

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Effectiveness of open and close kinetic chains after anterior cruciate ligament reconstruction: A systematic review and meta-analysis

Rizka Salsabila Putri[1], Suryo Saputra Perdana[1]*, Amalia Nur Azizah[2]

[1]Fakultas Kedokteran, Universitas Muhammadiyah Surakarta, Indonesia.
[2]Departemen Fisioterapi, Komite Paralimpiade Nasional Indonesia
*Email: j120200062@student.ums.ac.id

Abstract

Background: The Anterior Cruciate Ligament (ACL) is a ligament that has the function to maintain the stability of the knee so that it does not shift excessively towards the front. ACL injuries are injuries that are often experienced by sports athletes, especially those who often make fast and sudden movements. There are non-operative and operative methods for treating ACL. Non-operative methods are considered less effective because they usually require a slightly longer recovery period. One of the most frequently used surgical methods is reconstruction. After reconstruction, there is a need for exercises to speed up recovery and improve its function. Some examples of exercises that can be used are Open Kinetic Chain (OKC) and Close Kinetic Chain (CKC) exercises.
Purpose: To determine the level of effectiveness between OKC and CKC for individual after ACL reconstruction
Method: This research was a systematic review and meta-analysis with the PRISMA diagram to filter supporting articles. To assess the quality of Randomized Controlled Trial (RCT) design studies, the Critical Appraisal Checklist was used. Meanwhile, the Characteristics for Included Studies were used to assess the feasibility. The article search came from the Pubmed database with the keywords "Close Kinetic Chain" AND "Open Kinetic Chain" AND "Anterior Cruciate Ligament" AND "Reconstruction". Inclusion criteria were full text articles in Indonesian or English with an RCT study design. The relationship measure used was Mean Difference, and Revman 5.4. was used for analysis.
Results: There were five articles from UK, US and Turkey for this study. The results of the study showed that there was an increasing effect after carrying out OKC and CKC exercises. However, the difference in exercise benefits between OKC and CKC exercises was not notably significant, which were shown by a p-value >0.05 (MD= -1.66; 95% CI=-18.71 to 5.42; P=0.65).
Conclusion: OKC and CKC exercises had been proven to have an effect on improving ACL recovery after reconstruction, but the difference in effect between OKC and CKC had not been found.

Keywords: Anterior Cruciate Ligament Reconstruction; Close Kinetic Chain; Open Kinetic Chain

INTRODUCTION

The Anterior Cruciate Ligament (ACL) is a ligament within the knee joint. Its role is to stabilize the tibia bone against the femur to prevent excessive forward movement of the tibia bone. ACL injuries mainly occur due to excessive movements and rapid actions, causing the ligament to be unprepared to maintain stability. The ACL is one of the most common knee injuries experienced by athletes (Zein, 2013). Based on its causes, athletes have a high likelihood of experiencing ACL injuries due to frequent use of their knees in sports activities. Examples of sports with a high likelihood of ACL injuries include basketball, soccer, volleyball, and other sports requiring rapid changes in leg movements, particularly in individuals aged 15 to 25 years. This indicates that the majority of sufferers are

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within their productive age (Uçar, Koca, Eroglu, Eroglu, Sarp, Arik, & Yetisgin, 2014).

The management of ACL injuries should be precise considering that the productive age range is crucial in this phase of life. Mistakes in management can have fatal consequences for the patient's ability to lead a normal life, as all activities requiring mobility invariably involve the use of the legs. There are two rehabilitation methods available for treating ACL injuries: non-operative and operative methods. However, according to some opinions, the non-operative method is less effective in treating knee stability (Zein, 2013). ACL injury reconstruction using operative methods can be performed with various options, such as graft techniques, fixation techniques, and post-operative rehabilitation programs. In surgery, the most preferred method for ACL injury reconstruction involves arthroscopy using autograft and allograft methods (Uçar, Koca, Eroglu, Eroglu, Sarp, Arik, & Yetisgin, 2014).

After operative rehabilitation, exercises are necessary to support the patient's recovery progress. Returning to normal functional activities is the goal of these exercises. Treatment focuses on OKC and CKC exercises. CKC exercises are used to train the quadriceps muscle group, improve muscle coordination, and proprioception while placing minimal pressure on the ACL. OKC exercises are believed to increase anterior shear force on the knee, greater than CKC exercises (Glass, Waddell, & Hoogenboom, 2010).

There's disagreement among researchers regarding whether CKC or OKC exercises are more effective. According to Hooper et al., 2001, CKC group participants could return to work faster and were more satisfied with their surgical outcomes than OKC group members. However, other research suggests that OKC exercises lead to persistent post-reconstruction knee flexibility (Perry, Morrissey, King, Morrissey, & Earnshaw, 2005). There's no significant difference in impact between CKC and OKC exercises on patients after ACL surgery (Glass, Waddell, & Hoogenboom, 2010).

Researchers conducted a systematic analysis in this study to assess the effectiveness of OKC and CKC exercises post-ACL repair. The aim of this research is to determine which exercise, OKC or CKC, better aids in improving functional knee mobility using the Lysholm knee score and Hughes Clinical Questionnaire as measurement tools.

RESEARCH METHOD

This study is a systematic review and meta-analysis. In data collection, information was gathered from several databases, namely: PubMed. Literature search used the following keywords: "Close Kinetic Chain" AND "Open Kinetic Chain" AND "Anterior Cruciate Ligament" AND "Reconstruction".

Meta-analysis was conducted in 5 steps as follows: Define and determine the research theme in PICO (Population, Intervention, Comparison, Results); Search for articles relevant to the theme from various electronic databases such as Science, Google Scholar, PubMed, and others; Conduct screening to determine inclusion and exclusion criteria; Extract data from the encompassed studies; Interpret the results and draw conclusions.

The target population in this study included people who had undergone ACL reconstruction and then underwent a trial of OKC versus CKC exercise training. All studies published in this systematic review were comparisons between OKC and CKC groups.

The inclusion criteria in this study were reference articles discussing the comparison of CKC and OKC effects. The subjects used are individuals who have undergone ACL reconstruction using the Hughston Clinic Questionnaire and Lysholm Knee Scoring Scale. The exclusion criteria were reference articles with content not relevant to the chosen theme, studies lacking full-text access, subjects undergoing only acute exercise testing, and articles in languages other than Indonesian and English.

Article search used PICO as a consideration for the suitability of the articles used. In this research, PICO comprises individuals post-ACL reconstruction with intervention through Open and Closed Kinetic Chain exercises. The effectiveness comparison of Open and Closed Kinetic Chain exercises in ACL reconstruction can be observed from knee function questionnaire outcomes. The questionnaires used by the researchers include: Lysholm knee scores and the Hugheston Clinic questionnaire.

Rizka Salsabila Putri[1], Suryo Saputra Perdana[1]*, Amalia Nur Azizah[2]

[1]Fakultas Kedokteran, Universitas Muhammadiyah Surakarta, Indonesia.
[2]Departemen Fisioterapi, Komite Pelimpiade Nasional Indonesia
*Email: j120200062@student.ums.ac.id

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Open Kinetic Chain refers to active movements in a joint involving only one joint or muscle without engaging movement in its proximal part. Close Kinetic Chain refers to active movements involving multiple joints and muscles simultaneously. Anterior Cruciate Ligament Reconstruction is the reconstruction of the ligament connecting the distal femur and tibia that functions to maintain knee stability.

Lysholm Knee Score is a measurement tool reported by patients used to evaluate knee joint functional status. This measurement tool consists of 8 items assessing instability level, pain, swelling, and knee activities. Hugston Clinic Questionnaire is a knee questionnaire designed to measure patient's quality of life after knee injury or surgery. This questionnaire consists of 7 questions concerning pain perception, function, and patient satisfaction.

The instrument used in this study is a published paper evaluating the effects of open and closed kinetic chain exercises on ACL restoration. Article search was conducted through a systematic and comprehensive database from PubMed using Prisma for article identification, screening, and determination of supporting article eligibility.

In this study, Review Manager 5.4 software was used for analysis. The research generated effect size and heterogeneity models. Forest plot and funnel plot are outcomes of the data analysis.

RESEARCH RESULT

The PubMed database was used in the article search process. Researchers discovered 45,237 studies during their initial search. Subsequently, due to the substance of the studies not aligning with the research being conducted, a total of 45,203 articles were sorted out, resulting in 34 articles. The sorting was then repeated, this time separating articles where the intervention did not involve OKC and CKC, the research subjects were not individuals post-ACL reconstruction, and the final measurement outcomes did not use Lysholm knee scores and Hughes Clinic questionnaires, totaling 14 articles, leaving only 20. After obtaining this number of articles, researchers then excluded several articles that were less suitable, as well as those published over ten years ago, resulting in a total of 15 articles, leaving a final set of 5 articles suitable for use in the systematic review and meta-analysis.

The research conducted in this meta-analysis is crucial as it determines its outcomes. The evaluation of this study was done both quantitatively and subjectively. As this research utilized RCT with 111 questions, the quality assessment instrument employed in this study was the Critical Appraisal Checklist for RCT Studies, as indicated in Figure 2. Subsequently, utilizing the Forest Plot from Review Manager 5.4, data from the selected journals were assessed to determine the heterogeneity value and statistical significance of the exercises.

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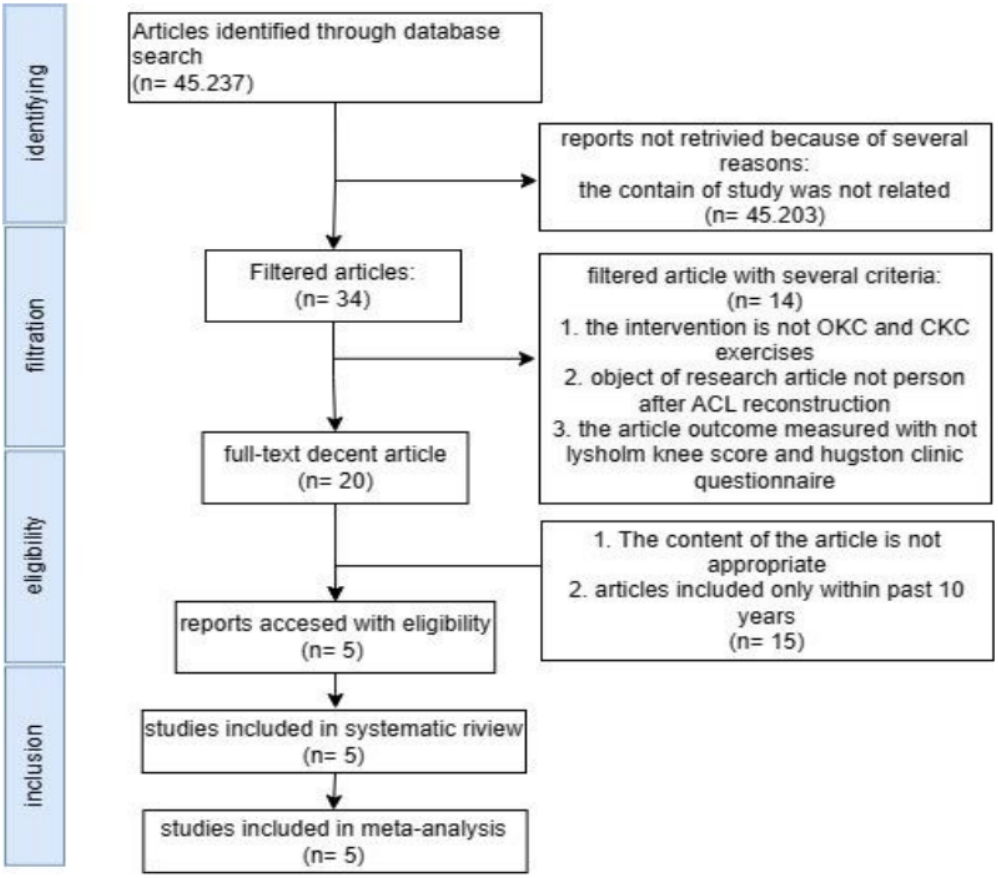

Figure 1. Results of Prisma Flow Diagrams

Rizka Salsabila Putri[1], Suryo Saputra Perdana[1]*, Amalia Nur Azizah[2]

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Table 1. Critical Appraisal Checklist For Randomized Controlled Trial Studies

Checklist of Question	Publication (Author and Year)				
	Uçar, Koca, Eroglu, Eroglu, Sarp, Arik, & Yetisgin, 2014	Perry, Morrissey, King, Morrissey, & Earnshaw, 2005	Morrissey, Drechsler, Morrissey, Knight, Armstrong, & McAuliffe, 2002	Bynum, Barrack, & Alexander, 1995	Hooper, Morrissey, Drechsler, Morrissey, & King, 2001
Did the trial address a clearly focused issue?	2	2	2	2	2
Was the assignment of patients to treatments randomized?	2	2	2	2	2
Were all of the patients who entered the trial properly accounted for at its conclusion?	2	2	2	2	2
Were patients, health workers, and study personnel 'blind' to treatment?	2	2	2	1	2
Were the group similar at the start of the trial?	2	2	2	2	2
Aside from the experimental intervention, were the group treated equally?	2	1	2	2	1
How precise was the estimate of the treatment effect?	2	2	2	2	2
Can the results be applied to the local population, or in your context?	2	2		2	2
Were all clinically important outcomes considered?	2	2	2	2	2
Are the benefits worth the harms and costs?	2	2	2	2	2
Total	22	21	22	21	21
Interpretation	Good	Good	Good	Good	Good

Note: 0=No.1= Can't tell, 2 = Yes

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Table 2. Charting the data

Authors (years)	Title	Country	P Participants	I Intervention	C Comparison	O Outcomes
Uçar, Koca, Eroglu, Eroglu, Sarp, Arik, & Yetisgin, 2014	Evaluation of Open and Closed Kinetic Chain Exercises in Rehabilitation Following Anterior Cruciate Ligament Reconstruction	Turkey	66 subject (OKC=33) and (CKC=33)	OKC (quadriceps isometric and isotonic exercise, flexor-ekstensor bench, stretching exercise for knee, on-off long leg press) CKC (standing with weight shift, squatting lunges exercise, step to the side/lateral, sitting on the wall, and quad position with one leg)	Close Kinetic Chain only	Lysholm score
Perry, Morrissey, King, Morrissey, & Earnshaw, 2005	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	United Kingdom	49 subject (OKC=24) and (CKC=25)	OKC (hip and knee extension using a machine or using weights on the ankle) CKC (resistance training using a leg press machine on the hip and knee extensor muscle groups)	Close Kinetic Chain only	Lysholm score

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Authors (years)	Title	Country	P Participants	I Intervention	C Comparison	O Outcomes
Hooper, Morrissey, Drechsler, Morrissey, & King, 2001	Open and Closed Kinetic Chain Exercises in the Early Period after ACL Reconstruction	United Kingdom	37 subject (OKC=19) and (CKC=18)	OKC (hip and knee extension movements using a machine or using weights on the ankle) CKC (resistance training using a leg press machine on unilateral knee and hip extensor muscles)	Close Kinetic Chain only	Hugston clinic visual analog scale
Morrissey, Drechsler, Morrissey, Knight, Armstrong, & McAuliffe, 2002	Effects of Distally Fixated Versus Resistance Training on Knee Pain in the Early Period After Anterior	United Kingdom	43 subject (OKC=22) and (CKC=21).	OKC (hip and knee extension exercises using ankle weights or a machine for knee and hip extension) CKC (resistance training using a leg press machine on unilateral knee and hip extensor muscles)	Close Kinetic Chain only	Hughston clinic questionnaire (questions: 1, 2 and 25)
Bynum, Barrack, & Alexander, 1995	Open Versus Closed Chain Kinetic Exercises After Anterior Cruciate Ligament Reconstruction	United States	97 subject (OKC=47) and (CKC=50).	OKC (leg raise exercises, isotonic exercises on the quadriceps with minimal load, and jogging using a treadmill backwards and forwards) CKC (knee bending and straightening exercises, sitting while doing leg presses, stationary cycling using equipment, and running exercises)	Close Kinetic Chain only	Lysholm knee function scoring scale

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There were five chosen studies in the table above. Three studies were from the European continent, specifically from the same country, namely the UK (studies 3, 4, and 5), while one research was from the American continent (study 5). Additionally, one study originated from the Asian continent. All five selected papers employed the RCT research strategy. Individuals with post-operative ACL reconstruction conditions were used as research subjects. The patients in studies 1 and 2 underwent ACL recovery aided by arthroscopy and autograft hamstring or hamstring tendon. Studies 3 and 4 utilized patellar tendon determination in patients after ACL recovery with patellar tendon autograft using arthroscopy. In another study (5), patient samples were used after ACL recovery utilizing patellar tendon autograft, arthroscopy, and fixation with a 9mm interference screw.

Each study (1, 2, 3, 4, and 5) received an identical intervention consisting of OKC and CKC exercises. However, despite using the same intervention, there were many variations in the training provided. For instance, in study 1, OKC interventions included isometric and isotonic quadriceps exercises, flexor-extensor bench, knee stretching exercises, on-off isometric long-hold, while CKC interventions comprised standing weight shifts, squatting lunge exercises, lateral stepping, wall sits, and single-legged quadriceps positions. Similar interventions were used in studies 2, 3, and 4. OKC exercises involved equipment-based activities for hip and knee extension, as well as ankle weight exercises. Resistance exercises using a leg press machine on single knee and hip extensor muscles were also available in CKC. Study 5 employed OKC exercises like leg lifts, isotonic quadriceps exercises with minimal weights, and backward and forward jogging on a treadmill. In CKC, they used knee flexing and tightening exercises, seated leg presses, stationary cycling, and running exercises.

All these studies arrived at the same conclusion regarding the differences in the effectiveness of OKC and CKC exercises. Despite similar outcomes, each study used various additional metrics to enhance results beyond the Lysholm knee function score and the Hughston clinic questionnaire. For example, (1) examined thigh circumference and knee flexion. (2) Measured thigh circumference, used a visual analog scale, and assessed knee bending. (3) Utilized metrics such as total cycling duration, pain location frequency, therapy sessions for patients with pain/swelling or balance/non-optimal position issues, maximum isometric knee extensor torque point, and perceived discomfort during maximum isometric knee extensor torque. (4) Considered factors like modified Tegner activity assessment scale, graft failure side effects, patellofemoral pain, patient overall ranking or sequence, extension movement reduction, and flexion movement reduction using KT-1000 (20 lb and max).

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*Email: j120200062@student.ums.ac.id

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Table 3. Forest Plot of the Open Versus Closed Kinetic Chain Exercise Following an Anterior Cruciate Ligament Reconstruction

Study/Sub Grup	OKC Mean	OKC SD	OKC Total	CKC Mean	CKC SD	CKC Total	Weight	Mean Difference IV, Random, 95% CI	Year
Bynum, Barrack, & Alexander, 1995	20	29.63	41	20	30.93	44	30.2%	0.00 [-12.00, 12.88]	1995
Hooper, Morrissey, Drechsler, Morrissey, & King, 2001	14	29.04	19	16	32.17	18	12.8%	-200 [-21.78.17.78]	2001
Morrissey, Drechsler, Morrissey, Knight, Armstrong, & McAuliffe, 2002	11.47	24.44	19	14.9	24.83	21	21.5%	-3.43 [-18.71, 11.85]	2002
Perry, Morrissey, King, Morrissey, & Earnshaw, 2005	9	21.31	24	10	24.22	25	30..8%	-1.00 [-13.76,11.76]	2005
Uçar, Koca, Eroglu, Eroglu, Sarp, Arik, & Yetisgin, 2014	20.1	51.59	28	27.8	74.1	30	4.7%	-7.70 [-40.38, 24.98]	2014
Total (95% CI)			**131**			**138**	**100.0%**	**-1.66 [-8.74, 5.42]**	

Heterogeneity: Tau² = 0.00;Chi² =0.26, df= 4 (P=0.99); I²=0%
Test for overall effect: Z = 0.46 (P=0.65)

The results of the meta-analysis with a forest plot from five studies, combined with assessments using the Lysholm knee score and Hughes Clinic questionnaire in the aforementioned estimate, indicated that the heterogeneity value, known as the institutional index (I2), was less than 50%, precisely at 0%. The forest plot above demonstrated that both OKC and CKC exercises had a statistically significant effect on the reconstructed ACL, as indicated by a p-value greater than 0.05 (MD=-1.66; 95% CI=-18.71 to 5.42; P=0.65). Furthermore, the difference in exercise benefits between OKC and CKC exercises was not notably significant. The funnel plot also illustrated how researchers assessed the potential bias in this study.

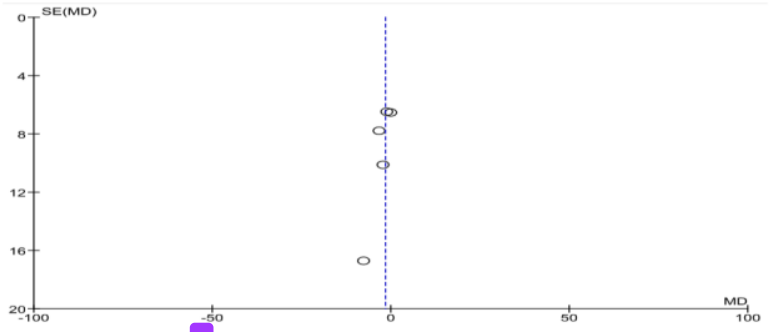

Figure 2. Funnel plot of the Open Versus Closed Kinetik Chain Exercise Following An Anterior Cruciate Ligament Reconstruction

Rizka Salsabila Putri[1], Suryo Saputra Perdana[1]*, Amalia Nur Azizah[2]

[1]Fakultas Kedokteran, Universitas Muhammadiyah Surakarta, Indonesia.
[2]Departemen Fisioterapi, Komite Pelimpiade Nasional Indonesia
*Email: j120200062@student.ums.ac.id

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The funnel plot to estimate bias risk using MD showed a slight potential for publication bias, evident from a fairly symmetrical distribution with minimal distance between the right and left plots. There were 2 plots positioned towards the center of the vertical line but slightly leaning to the right, 1 plot on the vertical line slightly leaning to the left, and 2 plots leaning slightly to the left. However, this didn't rule out the possibility of bias.

DISCUSSION

The systematic review and meta-analysis titled "Open Kinetic Chain vs Closed Kinetic Chain Exercise following Anterior Cruciate Ligament Reconstruction" compared the effectiveness of OKC and CKC exercises in post-ACL surgery patients. Researchers utilized a Critical Appraisal Checklist to assess journal quality for CRT designs in this meta-analysis. The findings revealed two studies with a total score of 22 (studies 1 and 3). Three studies scored a final score of 21 (2, 4, 5), with 5 papers receiving satisfactory interpretation.

This research involved two variables: independent and dependent. The independent variables included OKC and CKC exercises, while the dependent variable was the recovery process in ACL ligament reconstruction. All five studies utilized an RCT study design originating from three different continents. From Europe, three studies from the same country, the UK, one from the American continent (United States), and one from Asia (Turkey), demonstrated differences in an individual's effect post-ACL reconstruction when subjected to interventions like OKC and CKC exercises. The assessment using forest plots with Revman 5.4 showed that individuals with post - ACL reconstruction conditions, when given OKC and CKC training, had a statistically significant effect on the ACL after reconstruction, indicated by a p-value > 0.05 (MD=-1.66; 95% CI=-18.71 to 5.42; P=0.65).

The exercises performed had a significant impact on improvement (Hooper, Morrissey, Drechsler, Morrissey, & King, 2001). However, there was no significant difference between the two exercises in their effectiveness. Several statements supported the above statistical test results; after receiving OKC and CKC exercises, all outcome measures indicated significant improvement, with OKC exercises being more effective in enhancing isokinetic strength and extensor muscle endurance (Kang, Jung, & Yu, 2012). The function of the knee extensor after ACL reconstruction was a crucial factor in a patient's ability to overcome such an injury. However, some studies stated otherwise; research results suggested that in ACL reconstruction rehabilitation, CKC exercises were more effective than OKC exercises in providing increased mobility and potential for faster return to daily activities and sports (Uçar, Koca, Eroglu, Eroglu, Sarp, Arik, & Yetisgin, 2014).

Subjective knee functional improvement, as determined by the Hughston Clinic Questionnaire and Lysholm Knee Function Score, was analyzed concerning the improvement effects after ACL repair with OKC and CKC exercises (Perry, Morrissey, King, Morrissey, & Earnshaw, 2005). The study found no clinically significant difference in functional improvement when choosing between OKC or CKC exercises in the early postoperative period (Hooper, Morrissey, Drechsler, Morrissey, & King, 2001). OKC and CKC knee extensor exercises had no differential direct effects on anterior knee discomfort after ACL repair surgery (Morrissey, Drechsler, Morrissey, Knight, Armstrong, & McAuliffe, 2002)..

CONCLUSION

OKC and CKC exercises had shown to have an effect in enhancing ACL recovery after reconstruction, yet no discernible difference in effects between OKC and CKC was found.

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Rizka Salsabila Putri[1], Suryo Saputra Perdana[1]*, Amalia Nur Azizah[2]

[1]Fakultas Kedokteran, Universitas Muhammadiyah Surakarta, Indonesia.
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Rizka Salsabila Putri[1], Suryo Saputra Perdana[1]*, Amalia Nur Azizah[2]

[1]Fakultas Kedokteran, Universitas Muhammadiyah Surakarta, Indonesia.
[2]Departemen Fisioterapi, Komite Paralimpiade Nasional Indonesia
*Email: j120200062@student.ums.ac.id

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Rizka Salsabila Putri[1], Suryo Saputra Perdana[1]*, Amalia Nur Azizah[2]

[1]Fakultas Kedokteran, Universitas Muhammadiyah Surakarta, Indonesia.
[2]Departemen Fisioterapi, Komite Paralimpiade Nasional Indonesia
*Email: j120200062@student.ums.ac.id

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