

**The effectiveness of open versus closed kinetic chain exercises
In accelerated rehabilitation after anterior cruciate ligament
Reconstructive surgery: A Systemic Review**

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Abstract

Background and Purpose:

Anterior Cruciate Ligament (ACL) injuries are commonly seen in orthopedic physical therapy clinics. Currently, there are many different approaches for the rehabilitation of ACL injuries after surgical reconstruction. Two of these programs are open kinetic chain (OKC) and closed kinetic chain (CKC) exercises. In 1993, a new school supported the use of CKC after ACL reconstruction, and it drew the attention to the harm which could happen to ACL graft by applying the OKC programs. The purpose of this systemic review is to investigate the effectiveness of OKC versus CKC in accelerating the rehabilitation phases following ACL reconstructive surgery, and to find out which program is the most beneficial following ACL reconstructive surgery.

Methods:

A computerized search of the literature was performed using the following data bases: MEDLINE, CINHALL, COCHRANE and PEDro. The key words for the search were: ACL reconstruction, ACL rehabilitation, open kinetic chain, closed kinetic chain, and exercises. Studies meeting the following criteria were selected for review: (1) studies were related to open versus closed kinetic chain exercises and their effect in accelerated rehabilitation after anterior cruciate ligament reconstructive surgery. (2) meta- analysis and randomized controlled trials; and, (3) published in a peer reviewed source.

Results:

The data base search concluded 855 citations, specific to the search terms used. The inclusive criteria were (1) the literature in English, (2) RCTs, (3) the participants were adults with a clinical diagnosis of ACL reconstruction, (4) the outcome measures contained pain or strength, and (5) OKC or CKC exercises were used in the rehabilitation of ACLR. Based on these inclusive criteria, we screened these citations from each data base through reading the title, and abstract. We excluded the studies that did not meet the inclusive criteria based on our determination, if it was clear in the title, and abstract, plus all the studies were in full text to ensure that these articles meet the inclusive criteria in this systemic review. Twenty four trials were in full text, and screened for inclusion. After more review, more trials were excluded due to the following criteria; groups were not randomly assigned (n= 4), participants of control group did not have the same injury (n= 5), not related to our topic or our review (n=3). Finally, twelve studies were selected according to the mentioned criteria. Five studies investigated the effect of open kinetic chain and closed kinetic chain exercises on knee, function, laxity and level of pain in the early stage after ACL reconstruction and found that no differences between both programs. Two studies compared different types of CKC exercises in their effect during ACL rehabilitation; it was found that CKC exercises decrease the anterior shear force, so it can be safely used after ACLR. Four studies reflect the effect of CKC exercises in accelerated rehabilitation after ACLR and the functional outcome. It was found that CKC exercises have a very important role in strengthening the quadriceps muscle, and they may be protecting the ACL grafts. One study investigated the biomechanics of the knee during OKC and CKC exercise. It found that OKC exercises play an important role in

strengthening rectus femoris, while as CKCE plays an important role in strengthening vasti muscles.

Conclusion:

The review supports that there are no differences between OKC and CKC exercises in their effect on accelerated rehabilitation after ACLR. It can be concluded that a combination of OKC and CKC exercises could be more effective in accelerated rehabilitation.

Introduction:

Anterior cruciate ligament (ACL) injuries are common in athletes. The mechanism of injury usually occurs with deceleration of the planted limb's tibia in relation to the femur combined with turning around, pivoting, twisting, or changing of direction suddenly (valgus stress at knee joint combined with sudden rotation).¹ The ACL plays a very important part in establishing the functional stability of the knee and is considered a primary restraint to the anterior translation of the tibia on the femur.²

During the last 10 years there was a move toward favoring closed kinetic chain (CKC) exercises over the open kinetic chain exercises (OKC) in the rehabilitation of the ACL for the following reasons:

- 1- Decreases the anterior shear forces between tibia and femur;
- 2- Decrease the compression forces of the tibiofemoral joint;
- 3- Increase the hamstrings co contraction;
- 4- CKC exercises are involved in most of our daily living activities than OKC exercises;

and, 5- Decrease the complication of patellofemoral joint as chondromalacia, patella maltracking, patella tendinosis, and pre patellar bursitis .³

One of the very important decisions the clinician has to make is to choose which program is more effective in accelerating the rehabilitation process after an ACL injury. Because of the above reasons we are trying to investigate the effectiveness of CKC versus OKC exercises after ACL reconstruction. CKC exercises replicate most of our daily living activities.²

A strong quadriceps muscle plays an important role in preventing ACL injury and in accelerating the rehabilitation following ACL reconstruction by preventing the anterior translation of the tibia. Due to the confusion regarding which program is more effective following the anterior cruciate ligament reconstruction (ACLR), it is important to understand the role of quadriceps and hamstring muscles during daily living activities. During the OKC activities (kicking, swimming, wrestling), the hamstrings are considered an ACL protector or agonists, and the quadriceps as antagonists. While as during CKC activities (running, standing, walking, jumping, skiing), the quadriceps plays the role of ACL supporter or main protagonists of ACL.⁴

It was found that the quadriceps muscle activation especially over 70⁰ of knee flexion will result in a great effect on ACL strain;⁵ on the other hand, the contraction of hamstring muscle will lead to lowering anterior tibial translation and the internal rotation of the tibia and decrease the ACL tension at range 15-45⁰ knee flexion.⁵

The hamstrings muscle can be contracted independently from quadriceps and help in knee stabilization. If the person has severe quadriceps muscle weakness without good

hamstrings strength, he will have an ACL injury. Any deficiency between eccentric hamstrings strength compared to eccentric quadriceps will result in ACL injuries.⁵

During our different daily activities such as walking, running, hopping, and walking up or down a hill, there are different muscle actions. These different muscle actions could contribute in preventing any knee injuries like the ACL injury. In female athletes with ACLD, ACLR the VMO, VL, and lateral gastrocnemius could develop and create a carefully designed plan of unique actions to protect the knee joint. The contraction time, and the strength of hamstrings in relation to quadriceps` contraction time, and strength are essential factors in preventing a knee injury, and decreasing any stress on ACL.⁶

Knee ligament injury treatment has been improved very quickly, specifically the arthroscopic reconstruction of the ACL.⁷ It is very important for the physical therapist to understand the biomechanics of the knee during exercises to guide creation of the rehabilitation program.⁸

Due to the confusion regarding the advantages and disadvantages of OKC and CKC programs, which program is more effective in accelerated the rehabilitation of ACL, and because of the believe that OKC exercises could harm the ACL graft. The purpose of this systemic review is to investigate the effectiveness of OKC versus CKC in accelerating the rehabilitation phases following ACL reconstructive surgery, and to find out which program is the most beneficial following ACL reconstructive surgery.

Methods:

A computerized search of the literature was performed using the following data bases: MEDLINE, CINHALL, COCHRANE and PEDro. The key words for the search were: ACL reconstruction, ACL rehabilitation, open kinetic chain, closed kinetic chain, and exercises. Studies meeting the following criteria were selected for review: (1) studies were related to open versus closed kinetic chain exercises and their effect in accelerated rehabilitation after anterior cruciate ligament reconstructive surgery. (2) meta- analysis and randomized controlled trials; and, (3) published in a peer reviewed source. The inclusive criteria were (1) the literature in English, (2) the participants were adults with a clinical diagnosis of ACL reconstruction, (3) the outcome measures contained pain or strength, and (4) OKC or CKC exercises were used in the rehabilitation of ACLR. Based on these inclusive criteria, we screened these citations from each data base through reading the title, and abstract. We excluded the studies that didn't meet the inclusive criteria based on our determination, if it was clear in the title, and abstract, plus all the studies were in full text to ensure that these articles meet the inclusive criteria in this systemic review. The trials were evaluated for validity by using the PEDro scale, some of the studies got score between 4 to 5/10, and some articles were not rated. We considered the quality of the articles by examining the level of evidence. We extracted, and recorded specific data from the articles which included pain, knee laxity, and strength outcomes; characteristics of the treatment were performed at the same time with OKC, and CKC exercises; the level of physical activities permitted during rehabilitation stage; and the variables in the exercise protocol.

Results:

The data base search concluded 855 citations specific to the search terms used.

Twenty four trials were in full text and screened for inclusion. After more review, more trials were excluded due to the following criteria; groups were not randomly assigned (n=4), participants of control group didn't have the same injury (n= 5), and not related to our topic or our review (n=3).

Twelve studies were selected according to the mentioned criteria. Five studies investigated the effect of open kinetic chain and closed kinetic chain exercises on knee, function, laxity and level of pain in the early stage after ACL reconstruction and found that no differences between both programs. Two studies compared different types of CKC exercises in their effect during ACL rehabilitation; it was found that CKC exercises decrease the anterior shear force so it can be safely used after ACLR. Four studies reflect the effect of CKC exercises in accelerated rehabilitation after ACLR and the functional outcome. It was found that CKC exercises have a very important role in strengthening the quadriceps muscle, and they may be protecting the ACL grafts. One study investigated the biomechanics of the knee during OKC and CKC exercises, and found that OKC exercises play an important role in strengthening rectus femoris while as CKCE plays an important role in strengthening vasti muscles.

Table 1 summarizes the literature that indicates the effectiveness of OKC versus CKC exercises in accelerated rehabilitation after ACL reconstructive surgery.

Citation	Purpose	Subjects	Interventions	Results
Perry et al., 2005 ⁹	The purpose of this study is to compare the effects of closed and open knee exercises on knee laxity and functions in patients with ACLD knees.	64 participants had been diagnosed with knee anterior Cruciate ligament deficiency, and their diagnosis was based on arthroscopy, MRI, or clinical tests. Their age was between 18-60 (49 males and 15 females). Were randomized to two groups CKC group (n=32); OKC group (n=32).	The CKC group subjects received unilateral CKC strengthening exercises for the hip and knee extension using leg press machine. The OKC group subjects received unilateral OKC knee strengthening exercises by using ankle weights or knee extension/ham curl machine for the hip and knee extensor. strengthening exercises were performed: 3 sets of 20 each session until week 4, then 3 sets of 6 at week 6. Also both Groups received other very common exercises and treatment.	The results of this study showed that OKC and CKC knee extensors exercises have no significant differences in their effect on knee laxity and functions with patients with ACLD knees. The only thing was different that the total hamstring load was increased in the CKC group which showed positive relation with the horizontal jump which indicates that these subjects were able to perform the test better.
Morrissey et al., 2002 ¹⁰	The purpose of this study is to compare the effect of CKC and OKC on the level of knee pain in the early stage after ACL reconstruction.	43 subjects participated in this study had ACL reconstruction surgery, Their age was between 16-54 (9 females and 34 males) were assigned randomly to two treatments groups. Group C (CKC training) (n=21); and Group O (OKC training) (n= 22)	Group C received unilateral CKC resistance exercises for hip and knee extensors muscles by using the leg press machine. Group O received resistance for hip and muscle extensors group by using ankle weights or using the hip and knee extension machine: all participants received 3 sessions per week for 4 weeks. Resistance exercises were 3 sets of 20 RM in each session with no additional resistance exercises.	The results showed that there were no differences between the two groups in muscle performance; also there was no significant change in pain reduction between the groups who used the leg extensor strengthening exercise with the lower extremity distally fixated (CKC) and the group who used none distally fixated exercises (OKC).

Citation	Purpose	Subjects	Intervention	Results
Morrissey et al., 2000 ¹¹	The purpose of this study was trying to compare the effect of OKC versus CKC on knee laxity in the early period stage following ACLR.	Thirty six participants with ACL reconstructive surgery, with a mean age of 30(29 males and 7 females) were assigned randomly to two treatment groups CKC (18 with 6 F and 12 M) OKC (18 with 1 F and 17 M).	CKC group received unilateral closed kinetic chain resistive exercises for the knee and hip extensor on a horizontal leg press machine. The OKC group received resistive exercises for the hip and knee extensor either with using weights or special machines; giving resistive exercises to these groups of muscles. Both groups received physical therapy three times a week for 4 weeks and with three sets of 20 repetitions in each session.	The results in this study showed no statistically significant differences between OKC and CKC training exercises of knee and hip extensor in the knee laxity or anterior tibial displacements (ATD) in the early period following ACLR. The only difference in the study is the OKC group showed increases in their knee laxity in the post training examination test.(OKC group was more looser by 9% than CKC)
Mikkelsen et al., 2000 ¹²	The purpose of this study was to investigate and compare CKC program alone versus a combined program of CKC and OKC for quadriceps hamstring strength, knee laxity, and return to pre injury activity after ACLR.	Forty four participants (all patients except one were athletes in different sports) with a unilateral ACL reconstruction with age between 18 and 40 years assigned randomly into two groups (22 patients in each group). CKC group (17 men and 5 women) and CKC combined with OKC group (17 men and 5 women).	1 st group received only CKC quadriceps exercises. The 2 nd group received the same quadriceps CKC exercise as in the 1 st group, but from the 6 th week after the reconstruction surgery OKC quadriceps training exercises were added. The rehabilitation period was for 6 months.	There were no significant differences in between both groups in the knee laxity at 6 month after the surgery. OKC combined with CKC showed a significant improvement in the concentric and eccentric strength of quadriceps at the 6 month following surgery, and no difference in concentric or eccentric strength of hamstring at 6 month of the surgery. For return to sports, 12 subjects out of 22 patients OKC and CKC returned to the same level of sport and earlier by 2 months than the CKC group, while only 5 out of 22 patients in the CKC returned to the same level of sports.

Citation	Purpose	Subjects	Intervention	Results
Graham et al., 1993 ¹³	The purpose of this study is to compare the electromyographic activity of quadriceps and hamstrings during six different exercises: one quarter squats, extension of the leg, lateral step ups, movements on fitter, movements on stair master 4000, and movements on sideboard.	The participants in the study were 10 athlete female students with average age of 21 years. The participants were included in the study if they did not have any pathological knee condition, their availability for the study, and if they were able to exercise.	Each participant went individually under 2 experiments in the same laboratory. One session was to practice all the various exercises, and the 2 nd session included EMG and video data. Electrodes of EMG were placed on biceps femoris and rectus femoris muscles. All participants did 6 repetitions of all the following exercises: one quarter squats, extension of the leg, lateral step ups, movements on fitter, movements on stair master 4000, and movements on sideboard. EMG data was analyzed after three cycles for each exercise to calculate the maximum EMG activity for both quadriceps and hamstrings.	The study showed that the five CKC exercises (Fitter, quarter squat, Stairmaster, slide board, and lateral step ups) have the lowest anteroposterior A/P shearing forces on the knee joint than the only OKC exercise (leg extension). The study showed significant differences among all the six exercises in all the next variables: ROM of knee joint contraction, co contraction time of quadriceps and hamstrings, maximum angular velocity, maximum voluntary contraction percentage of quadriceps and hamstrings, and the sum of EMG data.

Discussion:

This review summarizes the results of twelve studies that investigate the effect of OKC and CKC exercises on knee function, laxity, and level of pain in the early stage after ACLR, different types of CKC exercises in their effect during ACL rehabilitation, effect of CKC exercises in accelerated rehabilitation after ACLR and the functional outcome, and the biomechanics of the knee during OKC and CKC exercises.

Functional Changes after Rehab:

Four studies reflect the effect of CKC exercises in accelerated rehabilitation after ACLR and the functional outcome. Beutler et al.¹⁴ investigated the muscle activity of the quadriceps during one - legged, CKCE in young athletes. They concluded that one legged squats and set-ups produced maximum level of quadriceps muscle activity and can be very effective in strengthening the muscles. The advantages of these CKCE are that it may be protecting the ACL grafts because these exercises do not involve free weights or exercise equipments, so they are more cost effective than traditional rehabilitation techniques. The second advantage of the one -legged exercise is that it creates lower anterior shear force than OKCE plus it involves increased torso flexion which results in lowering of the tibiofemoral force. Third, in order to practice one -legged exercises, it requires high balance level which may improve the coordination and proprioception in the rehabilitation process.

Wawrzyniak et al.¹⁵ investigated the effect of CKC leg press exercise on the torque of quadriceps muscle, and functional performance of lower extremities. They found a significant difference between the control group and the two experimental groups in concentric and eccentric torque. There was a remarkable increase in eccentric muscle

peak torque between the two experimental groups, and the control group. Concentric quadriceps peak torque was higher in the group who performed leg press within ROM 0-90 degrees, while on the other hand the group eccentric quadriceps peak torque was significant in the group performed leg press within ROM 0-60 degrees of knee flexion. The study showed no difference between groups in the functional performance test (Hopping test for distance and, time), which supports the idea of combining CKC and OKC in regaining and improving functional activities which is needed especially after ACLR. So, as the study showed that a six weeks single leg press exercise in ROM from 0- 90 degrees of knee flexion increased quadriceps` concentric and eccentric torque, and the single leg press performed within ROM from 0-60 degrees improves quadriceps` eccentric torque.

Bunton et al.¹⁶ investigated the differences between the OKC and CKC, and investigated the limb torque role, muscle action, and proprioception in rehabilitation process of LE during CKC exercise. They concluded that the CKC exercises` goal is to improve lower extremity proprioception, which will increase LE stability against any unexpected movements (external factors as speed or direction change). On the other hand he concluded that OKC exercises did not have the privilege of proprioception feedback on the LE, and could lead to ATD, increased forces, and stretch on the ACL graft.

One article was trying to compare single leg hop, postural stability, and isokinetic muscle strength in participants with ACLR, to the control group. Carl et al.¹⁷ investigated the muscle strength, postural stability, and functional outcome following ACLR with a mean time after the reconstruction surgery of 18 months. They found that there was no significant difference in postural stability, hopping test of single leg, and muscle strength

in between the ACLR group and the control group, although the study showed that the muscle strength of the quadriceps and the hop test were not as normal when compared with the sound limb or with the controlled group.

Based on these studies, the CKC exercises have a very important role in strengthening the quadriceps muscle, and it may be protecting the ACL grafts.^{14,15,16,17}

Two studies compared different types of CKC exercises in their effect during ACL rehabilitation. Schulthies et al.¹⁸ compared the EMG activity of the vastus medialis oblique (VMO), vastus lateralis (VL), semitendinosus and semimembranosus (ST), and biceps femoris (BF) during four elastic-tubing CKCE (front pull, back pull, crossover, reverse crossover) in patients after ACL reconstruction. They found that all four CKC exercises improve hamstring / quadriceps co contraction, but the front pull and cross over exercises results in significant increase in hamstring / quadriceps ratio, so that may lead to a decrease in the anterior shear force, so it can be safely used in the early stage in ACL rehabilitation.

Hopkins et al.¹⁹ compared the EMG activity of four CKCE. They found that maximum muscle activity level of biceps femoris was obtained during the flexcord front pull and back pull than the quarter squat and set-up. Flexcord front pull exercise results in maximum muscle activity of vastus medialis in knee flexion than the quarter squat, lateral set-up, or flexcord back pull. Due to the increase in the biceps femoris activity during flexcord exercise, the higher co contraction will be produced which means that the flexcord is considered safe to be used after ACL rehabilitation. On the other hand, increased vastus medialis activity during the flexcord exercise will be more effective exercise in the rehabilitation of patellofemoral disorders. They concluded that flexcord

exercise could be the safest exercise for the ACL graft than other exercises because of increased hamstring activity.

Based on these papers, it was found that CKC exercises decrease the anterior shear force so it can be safely used after ACLR.^{18, 19}

One study investigated the biomechanics of the knee during OKC and CKC exercises. Escamilla et al.²⁰ compare cruciate ligament tensile forces, tibiofemoral forces, patellofemoral forces, and muscle activity of the knee in OKC and CKC exercises. They found that rectus femoris muscle activity was 45% more in OKCE than CKCE, while vastus medialis activity was 20% more, and vastus lateralis was 5% more in CKCE than OKCE. These results suggest that OKCE can be more effective in strengthening rectus femoris while CKCE can be more effective in strengthening vasti muscles. During OKCE, the vastus medialis, vastus lateralis, and rectus femoris all produced similar muscle activity but in comparing the CKCE, the two vasti muscles generated 50% more muscle activity than the rectus femoris. These results are very important for the clinicians in deciding which program to use after ACL reconstruction. So for strengthening quadriceps, OKCE can be superior or equivalent in their effect as CKCE. Both OKCE and CKCE have a similar effect in decreasing ACL tensile force except the last 25⁰ of knee extension in OKCE. So it might be better if we avoid this range of motion when we use OKCE in ACL rehabilitation, but if PCL force is preferred, OKCE will be better than CKCE. Because of the increase of patellofemoral force and stress in CKCE, these patients who have patellofemoral dysfunction should use (0-50⁰ knee range) during CKCE.

Effects on Knee Function, Ligamentous Laxity and Pain:

Five studies investigated the effect of OKC and CKC exercises on knee function, laxity and level of pain in the early stage after ACLR.^{9, 10, 11, 12, 13} Perry et al.⁹ investigated the effects of closed and open knee exercises on knee laxity and functions in patients with ACLD knees. They found that knee extensors OKC and CKC exercises do not differ in their effect on knee laxity and functions with patients with ACLD knees. Three possible reasons could contribute to these results. First, the number of the subjects was low, which could contribute to type II error. Second, may be the both OKC and CKC exercises caused similar strain on the secondary restraints instead of ACL results in the same long term effects on knee laxity. Third, it was noticed that OKC caused an increase in the amount of strain on the secondary restraints to ATD, but that is because of the type of machines and training exercises that were used. This strain did not pass the limitation of the secondary restraints, so it did not affect of the knee laxity. The increase of the total hamstring load in the CKC group, which showed positive relation with the horizontal jump which indicates that these subjects were able to perform the test better, indicates that hamstring training will decrease the strain on the ACL and may improve the knee function after ACL rehabilitation.

Morrissey et al.¹⁰ investigated the effect of CKC and OKC on the level of knee pain in the early stage after ACL reconstruction and concluded that were no differences between the two groups in muscle performance. Also there was no significant change in pain reduction between the group who used the leg extensor strengthening exercise with the lower extremity distally fixated (CKC) and the group who used non distally fixated exercises (OKC). The only explanation of no differences in pain reduction between both groups using different types of knee extensors after ACL reconstruction surgery is that

CKC has no effect on knee pain. That conclusion contradicts the common belief that OKC exercises caused irritation to the extensor mechanism which results in an increase in knee pain in OKC compared to CKC. If the reason of knee pain is related to the strain of the patellar ligament, we will predict no differences between CKC and OKC in knee pain because the strain of the patellar ligament did not change between OKC and CKC exercises, and if there are any differences, they will be more in CKC than in OKC exercises.

Morrissey et al.¹¹ investigated the effects of OKC compared to CKC on the laxity of knee joint in the early period following ACLR. They found out that there is no significant difference between both programs on the ATD, and the only result which could be considered having value is that the OKC program showed an increase in the knee laxity scores by 9% in the after training test. But this result could be as a result of chance. Some reasons could explain the no significant difference result in this study. The first reason could be the differences in the stress placed on knee joint which caused by ADL out of the treatment program. The second reason for the result could be type II error due to number of participants. Another reason for this result could be the intervention given was not enough in frequency or duration to cause significant difference.

Mikkelsen et al.¹² investigated the CKC program versus a combined program of CKC and OKC in the strength of quadriceps muscle, laxity of knee (anterior laxity), and the ability to return to previous level of sports following ACLR. They found no significant differences in both programs on the anterior laxity of the knee after six months of the surgery. On the other hand, he found a significant increase in quadriceps strength in the second group (OKC and CKC) more than the first group (CKC only), and there was no

difference in hamstring strength in both groups. The return to sports level was higher (12 versus 5) and earlier by two months in the second group than first group. So, in other words, the study showed the importance of controlled OKC exercises following ACLR, and it is better to be carried out after six weeks after ACLR. And also, the study clearly stated that only CKC exercises will not regain the quadriceps's strength, but we have to add OKC exercises after six weeks, to be done in a range between 90 and 40 degrees of knee flexion.

Graham et al.¹³ investigated the EMG activity of quadriceps and hamstrings muscles in five CKC exercises and one OKC exercise (squats, extension of the leg, lateral step ups, movements on fitter, movements on stair master 4000, and movements on sideboard). She found that there are significant differences between these exercises in ROM, contraction time of quadriceps and hamstrings, curve of EMG, percentage of contraction, and the angular velocity. This study showed that five CKC exercise produce less anteroposterior shearing forces on the knee joint than OKC leg extension exercise. These differences were related to ROM and movement speed; also EMG difference was as a result of movement nature. The study showed that lateral step up, stair master, and extension of leg have ROM more than 70 degrees, so therapists should consider if they need to gain ROM. On the other hand, the fitter exercise and slide board have limited ROM but both improve quadriceps, and hamstrings strength. During the slide board exercise, the study showed the maximum hamstring voluntary contraction, with consideration of contraction time, so hamstrings have a valuable role in the knee stability. The study showed that maximum voluntary contraction of quadriceps muscle is low relatively to other four CKC and the only OKC exercise in the study. The study showed

the anteroposterior shearing forces is related to quadriceps/hamstrings ratio which is higher for the leg extension exercise (OKC) when compared to CKC exercises.

While these five CKC exercises are safer after ACLR, the leg extension exercise is more effective to restore the muscle strength of the quadriceps muscle.

Based on these studies, OKC and CKC knee extensors exercises have no significant differences in their effect on knee laxity, or anterior tibial displacements (ATD), muscle performance, pain reduction and functions with patients with ACLD knees.

Many studies have found that anterior tibial translation in the ACL reconstructive surgery was significantly greater in the OKC training exercises compared to CKC exercises. Jonsson et al.²¹ concluded that anterior direct tibial displacement in the ACL reconstructive surgery was increased by 1.9-mm compared to intact ACL knee active knee extension exercise (OKC) during the range (15-10 degree) of knee extension while they found no differences during the setup exercise during extension of the knee (CKC).

Fleming et al.²² measured and investigated the strain which could happen on sound ACL in CKC versus OKC exercises by inserting a gauge to measure the strain on ACL fibers during meniscectomy surgery. Measurements of the strain on ACL have been taken for leg extension, isometric contraction of the quadriceps muscle with resistance given to the distal end of tibia at different angles of knee flexion as OKC exercises, and for squat exercises against resistance from elastic cord, and squatting without resistance as CKC exercises. They found no difference between both exercises programs (OKC and CKC) in the strain on ACL. Also, the study showed no strain with quadriceps isometric contraction exercise against resistance at two angles of knee flexion 60, and 90 degrees. They were trying to give reasons that if the ACL graft was properly fixed by the new

surgical procedures, and techniques we have, the reconstructed ACL will tolerate both OKC and CKC exercises, and probably will act as the intact ACL in the study.

The differences between OKC and CKC training exercises in their effect on knee function, graft healing, and satisfaction of the patients must be compared by using randomized clinical trials. There are two different opinions based on several studies comparing OKC and CKC: one report concluded that OKC training exercises result in increased knee laxity and patellofemoral pain³ while the other studies suggest that there were no differences between both patients groups in the knee function and satisfaction of the patient.^{2, 5, 23}

Hooper et al.²³ investigated the differences in joints kinematics and kinetics in patients after ACL surgery by performing gait analysis. They found no significant differences between the effect of OKC and CKC training exercise on the knee kinetics and kinematics, and they concluded that choosing OKC or CKC training exercises had no significant differences in the improvement of the knee function in the early stage of ACL rehabilitation.

Conclusion:

The review supports that there are no differences between OKC and CKC exercises in their effect on accelerated rehabilitation after ACLR. It can be concluded that combining OKC and CKC exercises could be more effective in accelerated rehabilitation. Further randomized clinical trials are needed to be done to determine the best time to start these exercises and to investigate how and when to combine OKC and CKC exercises to accelerate rehabilitation of ACLR and to provide strong evidence about selective OKC and CKC exercises that could be used in acceleration rehabilitation after ACLR.

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