A Comparison of Closed Versus Open Kinetic Chain Exercises in Treatment of Patients with Patellofemoral Pain

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ABSTRACT

Background and Purpose: *Patellofemoral pain is a common cause of knee pain and one of the most prevalent musculoskeletal injuries seen by physiotherapy. The purpose of this study was to compare between closed versus open kinetic chain exercises in treatment of patients with patellofemoral pain.* ***Subjects:*** *Forty male patients with patellofemoral pain (mean age 28.37± 6.74 years, mean weight 73.12±7.95 Kg, and mean height 171.95± 5.86 cm) participated in the study.* ***Methods:*** *Subjects were randomly assigned into two equal groups; group A that performed closed kinetic chain exercises and group B that performed open kinetic chain exercises. The treatment program consists of three sessions per week for 6 weeks. Pain intensity, functional knee activities and quadriceps muscle force were measured using visual analog scale, patellofemoral scoring scale and electromechanical dynamometer, prior and at the end of the treatment program.* ***Results:*** *Statistical analysis in the post treatment data, demonstrated significant improvement in all measured parameters in both groups. However, Comparison of these data revealed no clinically significant differences between closed or open kinetic chain exercises.* ***Conclusion:*** *On the basis of these results, supported by the previous studies, both closed and open kinetic chain exercises can be used to reduce pain, improve functional knee activities and increase quadriceps strengthening in patients with patellofemoral pain.*

Key Words: *patellofemoral pain, kinetic chain, dynamometer, Quadriceps force.*

INTRODUCTION

Patellofemoral pain (PFP) is a musculoskeletal complains that is common in active and general populations[4]. It is characterized by diffuse retropatellar pain which is aggravated by activities that repetitively load the patellofemoral joint, like weight bearing, activities that involve knee flexion, ascending and descending stairs and activities requiring high level of quadriceps activity like running or squatting[8]. Other symptoms may include patellar crepitus, giving way, and catching on extension[14].

It is generally established that PFP should managed initially by nonoperative rather than by operative means[27]. Nonoperative treatments have been implemented for patients with PFP, the goals are to maximize quadriceps strength and increase functional activities. There is a similar debate concerning the use of closed kinetic chain exercises (CKCE) and open kinetic chain exercises (OKCE) in lower limb rehabilitation. Differences of opinion excite as to which method would result in optimal activities gains[1,5,26].

Kinetic chain terminology has been used to describe various strengthening exercises for the lower limb that are used during rehabilitation of the knee[15]. During CKCE, the foot is fixed and motion at the knee joint is accompanied by motion at the hip and ankle joints such as during the squat and the leg-press, which strengthen the quadriceps and

hamstrings. In contrast, during OKCE the foot is mobile and motion at the knee joint occur independent of motion at the hip and ankle joints such as leg extension which strengthens the quadriceps by extending the knee against resistance[6].

Over the past decade there has been a shift in clinical practice toward the use of closed kinetic chain rather than open kinetic chain exercises in quadriceps strengthening exercises. One of the reasons these exercises have received increased attention is that they simulate and replicate many functional movements. In addition, it has been suggested that CKCE are safer than OKCE because it place minimal stress of the PFJ in the functional range of motion[9]. There for, patients with PFP may tolerate CKCE better and consequently may exhibit better functional results after such rehabilitation program[22]. However, few studies have compared the ability of both closed and open chain exercises in increasing functional performance[, 16,20,22].

The purpose of this study was to compare between closed versus open kinetic chain exercises in treatment of patients with patellofemoral pain.

SUBJECTS, MATERIALS AND METHODS

Subjects

Forty male patients with PFP were participated in the study. Their mean age, weight, and height were 28.37±6.74 years, 73.12±7.95 Kg, and 171.95± 5.86 cm, respectively. The study was conducted at the out-patient clinic of physiotherapy, King Khalid University Hospital, Saudi Arabia, after confirmed diagnosis by orthopedic surgeon.

Inclusion criteria

Subjects were included if they had, anterior or retropatellar knee pain for at least 3 months duration associated with activities including prolonged sitting, climbing stairs, squatting and/kneeling. Objective signs were also consistent with PFP including pain with compression of the patella into femoral condyles or palpation of the posterior surface of the patella.

Exclusion criteria

Subjects were excluded if they had signs or symptoms of other knee injury or pathology including concurrent ligament instability, meninscal lesion, knee surgery or patellar tendon pathology and aged older than 40 years to reduce the possibility of degenerative knee diseases.

Prior to participation in the study, all subjects signed an institutionally approved informed consent statement revised by the Human Research and Ethics Committee of College of Applied Medical Sciences, King Saud University.

Experimental Design

This study was prospective, randomized clinical trial with a 6-week follow-up.

Instrumentation

1- Visual Analogue Scale (VAS) was used to measure pain intensity.
2- Patellofemoral joint Scoring Scale was used to evaluate subjective symptoms and functional patellofemoral joint activities.
3- Electromechanical dynamometer (HUR, Kokkola, FINLAND) was used to measure the isometric quadriceps muscle force.

Procedures

Prior to assignment to group, all subjects who met the criteria for participating in the study were evaluated for pain intensity,

subjective symptoms and functional patellofemoral joint activities and isometric quadriceps muscle force. All subjects were tested prior and after 6-weeks of treatment period. Subjects were instructed and acquainted with the evaluation and treatment procedures orally and in writing prior to initial testing. In case of unilateral knee pain, measurements were recorded from the symptomatic knee and in cases of bilateral knee pain; measurements were recorded from the most symptomatic knee.

Evaluation procedures

1- Pain and discomfort during rest and various activities were recorded on a 10cm VAS[4], where 0 indicated no pain and 10 indicated extremely intense pain. The subject was asked to mark the scale at a point where he believed it represent his pain experienced.

2- Subjective symptoms and functional limitations in patellofemoral joint were recorded using patellofemoral joint Scoring Scale. It consists of many different items that deal with tasks performed daily by most patients and can lead to patellofemoral symptoms. These items evaluate the pain and functional limitation in PFJ during stair climbing, squatting, running, jumping, prolonged sitting, the presence of a limp, swelling, and amount of muscle atrophy, flexion deficiency and need of support during walking[13]. The subject completed the scale independently. The highest possible best score is 100, while the lowest worst score is 0.

3- The maximal isometric quadriceps muscle force was tasted using electromechanical dynamometer connected to leg extension machine through sensor attachments which provides a digital display of measured force. Prior to testing, the axis of the tested knee joint was positioned at the axis of the lever arm of the leg extension machine. During testing subjects were seated in the leg extension chair keeping their hands resting in their chest and stabilized using straps secured around the pelvis and over the proximal and distal aspect of the tested thigh. The trunk-thigh angle was about 95º and the knee was at 90º of flexion with the leg hanging free. The end of the lever arm was adjusted proximal to the ankle on the front lower leg. Subjects were asked to take 1-2 seconds to come to maximum effort and, then, applied maximum knee extension force as hard as possible against stationary resistance of the lever arm for 5 seconds. The average of three trials was performed after a 1-minute rest period between each trial.

Treatment procedure

After the baseline measurement, subjects were randomly assigned into two equal groups: group A performed CKCE and group B performed OKCE. The treatment program include three sessions per week and continue for 6 weeks, each session consists of 3 set of 10 repetition of each exercise which take approximately 30-45 minutes.

The CKCE program consisted of

- One-third knee bends (squat) on the affected leg using his body weight.
- Seated leg press in leg press machine
- Step-up and step-down exercises in which the patient tried to step-up by the affected leg and step down by the sound leg.

Each exercise in CKCE was performed dynamically with a 5-seconds rest between repetitions

The OKCE program consists of

- Maximal isometric (static) quadriceps setting exercises for the affected leg with the knee in full extension
- Straight-leg raises with the patient supine
- Short arc extension movements of the affected knee from 15 degrees of knee flexion to terminal extension

Each exercise was held isometrically for a count of 6 seconds with a 5 second rest between repetitions.

Data Analysis

The Mean and standard deviations of the pretest and posttest variables in both groups were calculated. Student *t*- test was used to compare the values in both groups before and after treatment. Significance for all statistical tests was accepted at 0.05 level of probability.

RESULTS

This study involved 40 subjects with patellofemoral pain classified randomly into two equal groups: group A performed CKCE and group B performed OKCE. At initial assessment, statistical analysis did not reveal any significant differences between the two groups regarding the demographic characteristics of the subjects (P>0.05) as shown in table 1.

Table (1): Description of subjects

	Group A (CKCE) (Mean ± SD)	Group B (OKCE) (Mean ± SD)	P.Value	Group A (CKCE) (Mean ± SD)
Age (year)	28.20 ± 5.39	28.55 ± 8.0	N.S	Age (year)
Weight (Kg)	72.70 ± 9.69	73.55 ± 5.9	N.S	Weight (Kg)
Height (cm)	171.55 ± 5.55	172.35 ± 6.27	N.S	Height (cm)

CKCE: closed kinetic chain exercises OKCE: open kinetic chain exercises N.S: Non significant

The improvement in pain intensity, Patellofemoral scoring scale and quadriceps muscle force in both groups were described as the mean difference between the values obtained before and after treatment program.

Pain intensity

There were significant reductions in pain intensity on both groups after treatment. The mean values of VAS in the CKCE were significantly decreased from (6.54±1.54) to (1.83 ±.92) with a mean difference 4.71±1.71 which was significant (P<0.001). In the OKCE group, the mean values of VAS were significantly decreased from (6.04 ±1.66) to (2.02± 0.95) with a mean difference 4.02±2.0 which was significant (P<0.001), as shown in table (2) and figure (1).

Table (2): The means and standard deviations values for pain intensity pre and post treatment in both groups.

	Closed kinetic chain group		Closed kinetic chain group	
	Pretest	Posttest	Pretest	Posttest
Mean ± SD	6.54±1.54	1.83 ± 0.92	6.54 ± 1.54	1.83 ± 0.92
Mean difference	4.71±1.71		4.02 ± 2.0	
T.Value	12.28		8.99	
P .Value	p<0.001*		p<0.001*	

Significant at P<0.05

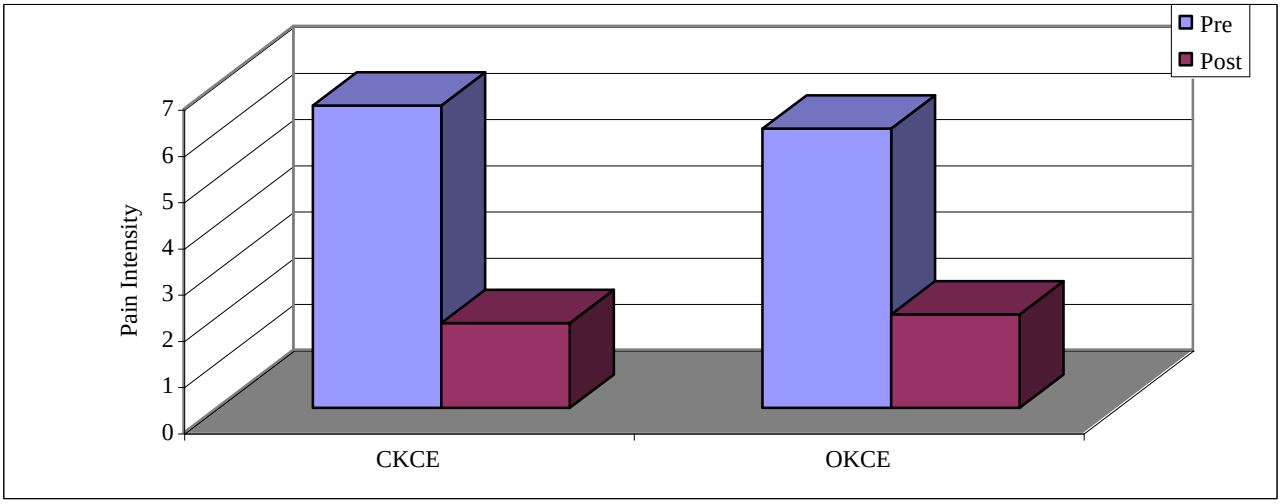

Fig. (1): Pain intensity values (mean ± standard deviation) pre and post treatment in both groups.

Patellofemoral scoring scale

There were significant improvements in patellofemoral scoring scale on both groups after treatment. The mean values of patellofemoral scoring scale in the CKCE were significantly increased from (57.30±22.71) to (83.80±16.91) with a mean difference 26.50±18.85 which was significant (P<0.001). In the OKCE group, the mean values of knee scoring scale were significantly increased from (57.00±14.13) to (81.45±17.63) with a mean difference 24.45±17.88 which was significant (P<0.001), as shown in table (3) and figure (2).

Table (3): The means and standard deviations values for patellofemoral scoring scale pre and post treatment in both groups.

	Closed kinetic chain group		Open kinetic chain group	
	Pretest	Posttest	Pretest	Posttest
Mean±SD	57.30±22.71	83.80±16.91	57.30±22.71	81.45±17.63
Mean difference	26.50±18.85		24.45±17.88	
T.Value	6.28		6.11	
p. value	p<0.001*		p<0.001*	

Significant at P<0.05

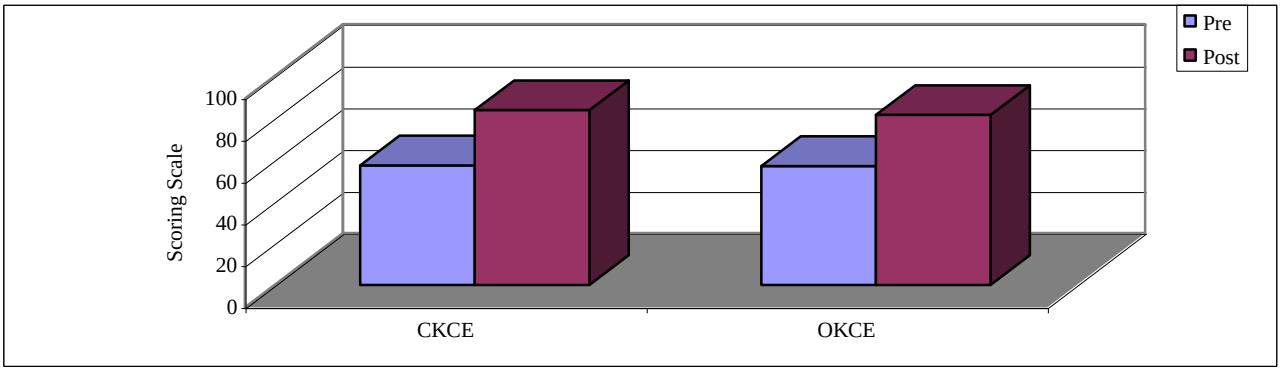

Fig. (2): Patellofemoral scoring scales values (mean ± standard deviation) pre and post treatment in both groups.

The isometric quadriceps muscle force

There were significant improvements in the isometric quadriceps force on both groups after treatment. The mean values of isometric quadriceps force in the CKCE were significantly increased from (87.60 ± 49.38) to (121.56 ± 36.67) with a mean difference (33.95 ± 25.08) which was significant (P<0.001). In the OKCE group, the mean values of isometric knee extensors force were significantly increased from (87.94 ± 32.31) to (116.04 ± 21.79) with a mean difference 28.10±21.94 which was significant (P<0.001), as shown in table (4) and figure (3).

Table (4): The means and standard deviations values for isometric quadriceps force (Newton) pre and post treatment in both groups.

	Closed kinetic chain group		Open kinetic chain group	
	Pretest	Posttest	Pretest	Pretest
Mean±SD	87.60±49.38	121.56±36.67	87.60±49.38	116.04±21.79
Mean difference	33.96±25.08		28.10±21.94	
T.Value	6.05		5.72	
p. value	p<0.001*		p<0.001*	

Significant at P<0.05

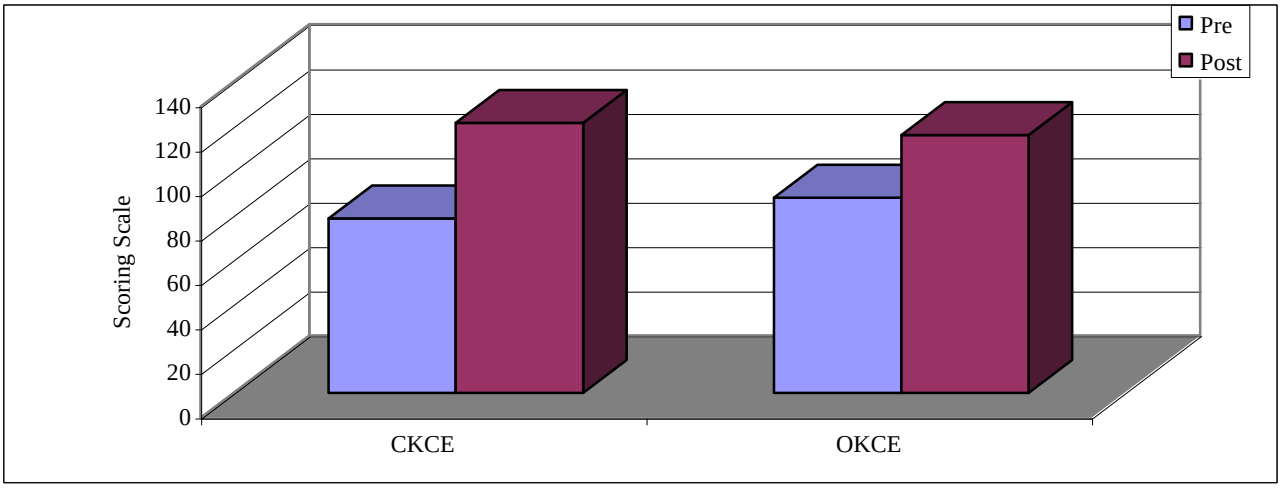

Fig. (3): Isometric quadriceps force values (mean ± standard deviation) pre and post treatment in both groups.

Comparison between the two groups

A Comparison of two groups in relation to their pre treatment baseline dependent variables revealed non significant differences before starting the treatment programs. Also there were non significant differences in the post treatment variables between the two groups.

DISCUSSION

This work was a comparative study between the effects of CKC and OKC programs in treatment of patients with PFP. Results showed that both programs are effective in reduction of pain intensity, improve functional patellofemoral joint activities and increase the isometric quadriceps

force. These results are in consistence with strength increases after an CKC or OKC exercises protocols[26,27].

Regarding the strength increase in knee muscle force after CKC are assumed to be as result of the eccentric muscle exercises develops during such exercise, which develop more tension and induce maximal vastus medialis oblique firing and thereby, obtain a greater training effect[23]. It is documented in the literature that the short squat exercises within pain-free range of motion may be more effective in selective strengthening of the vastus medialis obliquis than the maximal isometric quadriceps muscle contraction with the knee fully extended[10].

In CKCE in which motion at the knee joint is accompanied by motion at the hip and ankle joints. It is documented that individual quadriceps muscle strength correlates with gluteus maximus muscle and triceps surae muscle, which result in increasing the strength of the extensor mechanism[2]. As lower extremity function in daily weight-bearing activities involves multiple muscle groups acting in synergy. It can be deduced that rehabilitation in a weight-bearing position may have greater effect to functional activities[7,9].

Studies showed that the patellofemoral joint stresses were greater during knee extension exercises (OKCE) than during leg press exercises (CKCE)[12,22,26]. Such stresses on the compromised tissues around the knee may result in persistent inflammation that affects functional status.

The improvement of the quadriceps muscle has shown to occur during both OKCE and OKCE. Currently, there is a little agreement in the literature as to whether only CKCE or a combination of both kinetic chain exercises should be performed. It is thought that a combination of both exercises protocols can be used to effectively and safely strengthen the quadriceps[21]. It has been concluded that both types of exercise programs lead to an equal long-term good functional outcome[26].

The association between pain reduction and increase in muscle strength and improvement in functional outcome demonstrates the relationship between locomotor function and quadriceps muscle strength. It was concluded that strengthening program could be considered a very useful treatment option for patients with PFP[10]. Study done by Natri et al.,[17], confirmed the strong correlation between restoration of quadriceps muscle strength and the long term outcome in patients with PFP.

Increase in isometric quadriceps force after application of both CKCE and OKCE was the result of positive effects of training program on patellofemoral joint structures[24]. The adaptive changes can be possibly explained by increased diffusion of nutrients to cartilage caused by loading and unloading on PFJ and by improved nutrition of surrounding joint structures and muscles caused by increased blood circulation[11].

Closed chain exercises have been thought to recruit muscles in functional and familiar patterns, this result in less time being spent in the learning phase of strength building and more rapid entry into the muscular building phase of strength training[25]. Additionally, recruiting and activating muscles in such functional patterns may improve proprioception and coordination, leading to decreased rate of injury[3]. A recent study, found that muscle strength and functional performance improved significantly more during CKCE than during OKCE[18]. This conclusion can't be generalized due to the difference in patient selection and the underlying pathology.

Conclusion

The results of this study concluded that both CKCE and OKCE have significant effects in decreasing pain, improve functional activities and increasing muscle strength in patients with patellofemoral pain.

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الملخص العربي

تأثير تمرينات السلسلة الحركية المقفولة والمفتوحة في علاج مرضى الألم الرضفي الفخذي.

يعتبر الألم الرضفي الفخذي من أهم مشاكل مفصل الركبة. تهدف الدراسة الحالية إلى تقييم تأثير تمرينات السلسلة الحركية المقفلة وتمرينات السلسلة الحركية المفتوحة على مرضى الألم الفخذي الرضفي. أشترك في الدراسة أربعون مريضا متوسط أعمارهم 28.37 ±6.74 عاما قسموا عشوائيا إلى مجموعتين: تلقت المجموعة الأولى (أ) تمرينات السلسلة الحركية المقفولة والمجموعة الثانية (ب) تمرينات السلسلة الحركية المفتوحة في برنامج علاجي مدته 6 أسابيع. تم قياس شدة الألم، وميزان الدرجة الوظيفية والموضعية لمفصل الركبة، والقوة الساكنة للعضلة الرباعية قبل بدء وبعد انتهاء البرنامج العلاجي. أظهرت النتائج تحسن ذو دلالة إحصائية بعد تطبيق البرنامج العلاجي في كلتا المجموعتين مع عدم وجود فروق ذو دلالة إحصائية بين البرنامجين. أستخلص من البحث فاعلية تمرينات السلسلة الحركية المقفلة و المفتوحة في علاج مرضى الألم الرضفي الفخذي.