



## Effectiveness of Exercise Protocols in Treatment of Patellofemoral Pain Syndrome: A Prospective Comparative Study

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### Authors' contributions

*This work was carried out in collaboration between all authors. Author AHAG designed the study and wrote the protocol. Author NBNA did the statistical analysis and wrote the first draft of the manuscript.*

*Author FQA did the literature review and managed the analyses of the study. All authors read and approved the final manuscript.*

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### ABSTRACT

**Background:** Patellofemoral pain syndrome (PFPS) refers to anterior or retropatellar pain in knees. It is amongst the widespread and commonly known knee disorders seen in orthopaedic clinics, especially in young adult. The majority of patients who have are initially treated non operatively and many non operative imitative are successful wherein physical exercise remains the basic approach to deal with the ailment. Amongst various physical therapies used; open kinetic chain exercises (OKCE) and closed kinetic chain exercises (CKCE) have gained prominence.

**Aim:** The purpose of this study was to investigate the efficacy of closed versus open kinetic chain exercises in Saudi patients with PFPS, and to determine whether any of two programs offer any advantages over the other one.

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**Methodology:** Forty male subjects with PFPS, were randomly assigned into two equal groups, each one consisted of 20 subjects, their age ranged between (20-40) years. Group 1; (28.20 ± 5.39) years, performed only closed kinetic chain exercises (CKCE). Group 2; (28.55 ± 8.00) years, performed only open kinetic chain exercises (OKCE). Pain intensity, patellofemoral scoring scale, isometric knee muscle strength, and patellar tendon muscle torque were measured before and after 6-weeks of treatment program.

**Results:** Statistical analysis showed that both CKCE and OKCE have a significant effect in reduction of pain intensity, increased isometric knee muscle force, and the patellar tendon muscle torque. Results also showed that CKCE has more effective results than OKCE.

**Conclusion:** This study indicates that both CKCE and OKCE could be used in treatment of patients with PFPS.

*Keywords: Closed kinetic chain; hand-held dynamometer; patellofemoral pain syndrome; open kinetic chain.*

## 1. INTRODUCTION

Patellofemoral pain syndrome (PFPS) is a particular form of musculoskeletal syndrome characterized by discomfort and pain in patellofemoral joint. The pain seems to be originating from the Patellofemoral Joint. While the real and precise pathogenesis of Patellofemoral pain syndrome remains unidentified, several predisposing factors have been proposed. Studies showed that 10 percent of active adults experience PFPS during their life time [1,2]. These factors include acute trauma, instability, overweight, knee ligament injury/surgery, genetic predisposition, joint infection, increased quadriceps angle (Q-angle), repetitive intra-articular corticosteroids injections, knee extensor mechanism dysfunction, malalignment, prolonged synovitis, and recurrent joint hemorrhage [3-4]. The syndrome is common in young adults and athletes.

PFPS is a particular form of musculoskeletal syndrome characterized by anterior knee pain and discomfort during Physical Activity.

Crepitus (crackling noise from joints) and giving away of knees are also observed [5]. These occur specially after long-drawn-out knee flexion while an individual is sitting, squatting, or climbing stairs. PFPS result in decreased functionality and strength. Based on the above symptoms, PFPS (*comma removed*) is diagnosed and (combined the sentence by and) the diagnosis is confirmed usually after all other causes of knee pain (like plica syndrome, patellar tendonitis and intra articular disorders) are excluded.

*(This is repetition of the last sentence of the previous paragraph)* The treatment options of PFPS are highly debated. There are several surgical and conservative measures to treat the

syndrome. Nevertheless, preference is given to non-operative method initially over the surgical measures [6].

Non-operative treatment measures remain the significant most-used options, despite of the controversies and differences of opinions surrounding them. Physical therapies are frequently integrated in rehabilitative programs to treat PFP. The idea behind using physical therapy to treat PFPS is restoring patellar alignment through passive and active interventions which includes stretching, corrective foot orthoses, patellar taping and quadriceps muscle strengthening [7].

Even though therapeutic exercise takes its place as one of the key elements that lies in the center of the program to improve or restore the activity limitations and participation restrictions, there is no consensus on which is better between the closed kinetic chain exercises (CKCE) and open kinetic chain exercises (OKCE). Since the goal of most therapeutic exercise includes specific VMO and general quadriceps strengthening exercises [8]. [9], this study was conducted to evaluate the efficacy of closed versus open kinetic chain exercises in the treatment of patients with PFPS, and specifically, to determine whether any of the two programs offer any advantages over the other one on rehabilitation protocol.

## 2. METHODS

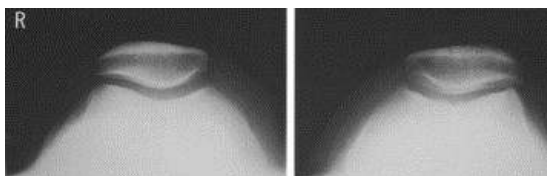
### 2.1 Study Population

The sample size consisted of 40 male individuals and were randomly assigned into two equal treatment groups. All subjects who met the inclusion criteria of the study were evaluated for pain, functional assessments and muscle strength assessments, and were confirmed to

have PFPS from outpatient orthopedic clinics in Dallah Hospital and Prince Faisal bin Fahad Hospital for Sports Medicine in Riyadh. Female was not included in the study because of the cultural restrictions on Saudi females. All patients were diagnosed radiographically by skyline view and clinically by knee Grind test (as shown in Figs. 1-2). This study was approved by the ethical committee of Rehabilitation Department, College of Applied Medical Sciences at the King Saud University, Riyadh, KSA. The ages of sample ranged between 18-40 years. Criteria of age were selected to avoid the possibility of knee osteoarthritis. Informed consent was taken from every participant before including them as subjects if they matched the inclusion criteria.

The inclusion criteria included patients reporting to have retropatellar knee pain for at least 6 weeks and exhibited two of the following criteria on initial assessment: a) patellofemoral pain reported during any of the following: squatting, prolonged sitting, climbing stairs, running, kneeling and/or hopping or jumping; b) pain on direct compression of the patella against the femoral condyles with the knee in full extension; c) pain on resisted knee extension, and/or pain with isometric quadriceps muscle contraction against suprapatellar resistance with the knee in 15° of flexion; d) presence of pain on palpation of patellar facets; e) ages between 18-40 years old.

Exclusion criteria included: a) Severe knee osteoarthritis; b) knee operation history; c) injuries as meniscal lesion, ligamentous instability, and patellar tendon pathology; d) nonsteroidal anti-inflammatory or corticosteroid medication should be stopped within 15 days before treatment program begins.



**Fig. 1. Skyline view**



**Fig 2. Knee grind test**

## 2.2 Group Division

Prior to assignment to group, all subjects who met the criteria for participating in the study were evaluated for pain assessment, combined subjective and functional assessment, and knee muscle strength assessment. All patients were tested prior and after 6-weeks of the treatment program. Patients were randomized into two equal treatment groups:

- Group A: Participated in CKCE only.
- Group B: Participated in OKCE only.

## 2.3 Assessment Procedure

During treatment program, patients were restricted to participate in sports or activities that aggravate the problem such as playing football or running.

## 2.4 Pain Intensity

Knee pain during rest and various activities were recorded on a 10 cm Visual Analogue Scale (V.A.S). Subjects were required to mark the horizontal line on scale where the “high pain” was felt. The distance from the point “No pain” to the point marked by patients was measured and recorded [8].

## 2.5 The Combined Subjective and Functional Evaluation

The Anterior Knee Pain Scale KUJALA Scoring Questionnaire for patellofemoral disorders were used to assess functional limitations and subjective symptoms in PFPS. Participants were asked to fill questionnaires that indicated tasks they do on regular basis and helped in selecting out the items related to those tasks. The tasks were the ones in which they faced difficulty due to PFPS. These items evaluated the pain and functional limitation in patellofemoral Joint during tasks like during climbing, squatting, kneeling, running, jumping, sitting and prolonged stationary positions with the knee flexed the presence of limping, swelling, muscle atrophy of thigh level, abnormal painful kneecap (patellar) movement, flexion deficiency, or need of support during walking. The best score is 100 (a normal, painless fully functioning knee), and the lowest worst score is 0 (severe knee pain and dysfunction) [9].

## 2.6 Measurement of Muscle-strength

The improvements in the quadriceps and hamstring muscle strength due to rehabilitation

protocols were measured using the hand-held dynamometer (HHD) in assessment. The isometric quadriceps strength testing were obtained from subjects by making them sit on chair, bed or table with their legs at 90° angle (perpendicular) to the to the base (floor). To prevent knee joint from sudden movement, it was stabilized using a joint strap [10-11]. At this test positions, dynamometer was placed at 90° angle to tibial crest, just above the malleoli [12].

## 2.7 The Patellar Tendon Muscle Torque

The patellar tendon muscle torque was measured using electromechanical dynamometer connected to leg press machine (3540 leg press HUR, Kokkola, Finland) through sensor attachments on the foot plate. Subjects were sitting on the machine with back in upright position, knee at 60° of flexion and the foot supported in neutral position on the foot plate. Fixation was ensured by grasping the hand supports on both sides. Patient applied force onto the foot plate with the affected leg by pushing the lever arm away. Electromechanical dynamometer measured the force of maximum torque of quadriceps muscle which was applied in the patella by maximum pushing of the lever arm (Fig. 3).



**Fig. 3. Testing of patellar-tendon muscle torque electromechanical dynamometer connected to leg-press machine (3540 Leg-press machine - HUR)**

## 2.8 Treatment Procedure

Participants were randomly assigned into OKCE and CKCE groups for a six week rehabilitation program. Training was given to patients thrice a week for 30 to 45 minutes each. They were instructed to do three sets of exercises with ten repetition rounds. All subjects experienced similar knee extension and knee flexion rates during exercise thereby negating any possible inertial influence because of cadence [13,14].

## 2.9 CKCE Exercise Intervention

CKCE exercise intervention included a) semi squat exercise where in Patient started in standing position, and dropped to half-squat 45° on his affected leg using his weight as weight resistance, with holding started with 6 seconds, which was increased gradually depend on the patient tolerance. b) seated leg-press exercise where in patient sit in the leg press machine with knee flexion angle in 60° and tried to push the lever arm by affected leg with holding started from 10 seconds which was increased gradually with resistance depend on the patient tolerated c) Step-up and Step-down Exercise wherein patient tried to step-up by affected leg and down-step by sound leg. Repeated this exercise and increased it gradually as tolerated by the patient

## 2.10 OKCE Exercise Intervention

OKCE exercise intervention included: a) quadriceps setting exercise wherein participants were made to take supine positions). The ipsilateral quadriceps is contracted and the foot dorsiflexed. Patient tried to contract the quadriceps muscle as he could as possible with holding starting from 5 seconds, which was increased gradually with sessions; b) straight leg-raises wherein The ipsilateral leg was extended with contracted quadriceps and the foot dorsiflexed. The extended leg was raised until a hip flexion angle of 75° was reached. Holding the raised leg starting with 5 seconds and weight free. This allowed the leg to come back to the bed and the quadriceps becomes relaxed; c) terminal (short) arc extension wherein a rolled towel or a padded object is placed approximately six inches in diameter under affected knee, Patient was made to bring his knee from its resting position to full extension. Holding starting from 5 seconds and weight free. Patient brought the leg back to its started position. Increased the holding and weight resistance gradually by the

time of the sessions of treatment as tolerated by the patient.

## 2.11 Data Analysis

The Mean and Standard Deviations of the pre test and post test variables in both groups were calculated. Student *t*-test was calculated on the pretest to posttest changes for each variable to determine and analyze the difference between the pre and post tests results in both groups. If there were a significant difference between the pre-test and post-test in both groups. 0.05 level of probability were set.

## 3. RESULTS

### 3.1 Comparison of Pain Assessment

As shown in (Table 1), there were a significant reduction in pain intensity on both groups after treatment by either CKC or OKC exercises. The mean values of VAS in the CKCE were significantly decreased from ( $6.54 \pm 1.54$ ) pretreatment to ( $1.83 \pm 0.91$ ) post treatment with mean differences ( $4.71 \pm 1.71$ ) which was significant  $P < 0.001$ . While the mean values of VAS in the OKCE were significantly decreased from ( $6.04 \pm 1.66$ ) pretreatment to ( $2.02 \pm 0.95$ ) post treatment with a mean difference ( $4.02 \pm 2.00$ ) which was significantly  $P < 0.001$ .

### 3.2 Patellofemoral Scoring Scale

As shown in (Fig. 4), there was a significant improvement in patellofemoral scoring scale (PFSS) on both groups after treatment by CKCE or OKCE. The mean values of PFSC in the CKCE was significantly improved from ( $57.30 \pm 22.71$ ) pretreatment to ( $83.80 \pm 16.91$ ) post treatment, with a mean difference ( $26.50 \pm 18.85$ ) which was significant  $P < 0.001$ . While the mean values in the OKCE was significantly improved from ( $57.00 \pm 14.13$ ) pretreatment to ( $81.45 \pm 17.63$ ) post treatment with a mean difference ( $24.45 \pm 17.88$ ) which was significant  $P < 0.001$ .

### 3.3 Maximum Isometric Quadriceps Strength

The mean values of isometric quadriceps strength in the CKCE was significantly improved from ( $84.25 \pm 34.52$ ) pretreatment to ( $125.76 \pm 31.78$ ) post treatment with a mean difference ( $41.51 \pm 25.15$ ) which was significant  $P < 0.001$ .

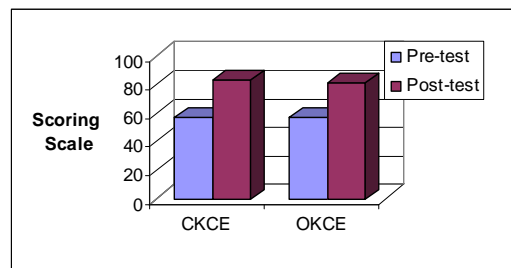
While the mean values of isometric quadriceps strength in the OKCE was significantly improved from ( $82.04 \pm 14.63$ ) pretreatment to ( $106.49 \pm 22.54$ ) post treatment with a mean difference ( $24.44 \pm 20.09$ ) which was significant  $P < 0.001$ .

### 3.4 Maximum Isometric Hamstring Strength

The mean values of isometric hamstring strength in the CKCE was significantly improved from ( $59.03 \pm 27.74$ ) pretreatment to ( $86.63 \pm 28.38$ ) post treatment with a mean difference ( $27.60 \pm 18.12$ ) which was significant  $P < 0.001$ . While the mean values of isometric hamstring strength in the OKCE was significantly improved from ( $58.01 \pm 16.35$ ) pretreatment to ( $83.17 \pm 20.46$ ) post treatment with a mean difference ( $25.15 \pm 14.54$ ) which was significant  $P < 0.001$ .

### 3.5 Patellar Tendon Muscle Torque

The mean values of patellar tendon muscle torque in the CKCE was significantly improved from ( $87.60 \pm 49.38$ ) pretreatment to ( $121.56 \pm 36.67$ ) post treatment with a mean difference ( $33.96 \pm 25.08$ ) which was significant  $P < 0.001$ . While the mean values of patellar tendon muscle force in the OKCE was significantly improved from ( $87.94 \pm 32.31$ ) pretreatment to ( $116.04 \pm 21.79$ ) post treatment with a mean difference ( $28.10 \pm 21.94$ ) which was significant  $P < 0.001$  (Table 2).



**Fig. 4. The means values of patellofemoral scoring scales Pre- and post-treatment in both groups**

### 3.6 Comparison between the Two Groups

A comparison of the two groups in relation to their pre treatment baseline depended variables revealed non-significant differences before starting the treatment programs. Also there were non-significant differences in the post treatments variables between the two groups which revealed that both programs have the same effects.

**Table 1. The mean and standard deviations values for pain intensity Pre- and post-treatment in both groups**

	Closed kinetic chain group		Open kinetic chain group	
	Pre-test	Post-test	Pre-test	Post-test
Mean±SD	6.54±1.54	1.83±0.91	6.04±1.66	2.02±0.95
Mean difference	4.71±1.71		4.02±2.00	
T. value	12.28		8.99	
P. value	P<0.001*		P<0.001*	

\*Significant at P<0.05

**Table 2. The mean and standard deviations values for patellar tendon muscle torque (Newton) pre and post treatment in both groups**

	Closed kinetic chain group		Open kinetic chain group	
	Pre-test	Post-test	Pre-test	Post-test
Mean±SD	87.60±49.38	121.56±36.67	87.94±32.31	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

In summary, the results of this study showed that both CKCE and OKCE had a significant effect in pain reduction, increase the patellofemoral scoring scale, improvement the isometric knee muscle force, and the patellar-tendon muscle torque. Results also showed that CKCE are superior to OKCE in treatment of subjects with PFPS as demonstrated by the more difference in all treated variables.

#### 4. DISCUSSION

Use of Closed Kinetic Chain Exercises (CKCE) and Open Kinetic Chain Exercises (OKCE) are common when it comes to non-operative treatment of PFPS. The use of CKCE has considerably increased in clinical practices during the past decades. The primary reason of increase utilization of exercise is its ability to stimulate and replicate several functional movements. It is known that key alterations due to strength-training are task-specific, hence, it is better to integrate the rehab practices in to task related practices [15].

At present, minimal consensus resides concerning the best non-operative intervention. Open kinetic chain exercises (OKCE) have always been the conventional method of strengthening the quadriceps muscles. Even though, a number of experts claim that these physical exertions aggravate symptoms in different patients with PFPS. Concerning functionality and pain, there were limited differences noted in the study. Both groups

suggest that the CKCE has a little more effect than OKCE in reducing pain, increasing muscle forces, and demonstrating more functional benefits. The results are consistent with study done by Witvrouw et al. found that both CKCE and OKCE programs lead to an improvement in subjective and clinical outcome in patients with anterior knee pain, with a few better functional results were obtained in the CKCE group [16-17].

Furthermore, many experts have advocated that CKCE are much safer compared to OKCE since the former place lesser pressure on the patellofemoral joint in the functional mobility [18]. Thus, patients with PFPS might withstand the effects of CKCE better and hence may demonstrate superior functional results after such a rehabilitation regime.

There exists debate concerning whether or not the exercise sessions should be performed in open or closed chain manner. Lately, clinical application of OKCE and CKCE have become center of attention. Earlier research indicated that there seemed to be a noteworthy betterment in functionality and strength resulting from both CKCE and OKCE methods. According to present literatures, several physiotherapists agree that the CKCE possess an upper hand on PFPS, while some debate that OKCE are better than CKCE. A comprehension of these findings could assist in selecting best suited exercises for therapy and programs. Both CKCE and OKCE alleviated discomfort, and enhanced functionality and muscles strength in adolescent women and



men with patellofemoral discomfort. There is insufficient evidence to determine the best form of exercise therapy and it is unknown whether this result would apply to all people with PFPS [19].

The results of this study showed more significant improvement in pain intensity, muscle strength, and functional performance in CKCE rehabilitation program than OKCE rehabilitation program in patients with PFPS, which supported by the results of Stiene et al. which demonstrated that both groups experienced improvement to significant level in peak torque, however CKCE improvement were more noteworthy. This leads to conclusion that CKCE is more effective than OKCE in restoring functionality in PFDF for 8-weeks training.

The closed kinetic chain system is involved in the majority of activities performed in daily living, such as walking, climbing, and rising to a standing position. The advantages of CKCE are to minimize the shear forces, to reduce pain, and to increase the range of motion. CKCE may be safely performed from early to progressed rehabilitation process virtually for all degrees of knee range of motion. CKCE tries to maximize the area of contact surface. With CKCE, as the angle on the knee decreases, the flexion moment acting on the knee increases. This requires greater quadriceps femoris and patellar tendon tension to counteract the effects of the increased flexion moment arm, resulting in an increased patellofemoral resistive force, distributed over a large patellofemoral contact area, thus minimizing the increase in contact stress per unit area. Therefore, it appears that CKCE may be better tolerated by PFJ than by OKCE [20]. Moreover, this study is consistent with other investigators that showed that the duration of symptoms was significantly decreased gradually as treatment progress, and associated with a good functional outcome in CKCE group more than OKCE group. In this study, patients with knee pathology not involved which need other study to involve them with large sample size.

## 5. CONCLUSION

The results of this study showed that both CKCE and OKCE had a significant effect in reduction of pain intensity, increased isometric knee muscle force, and the patellar tendon muscle torque. It is our opinion that CKCE has more effective results than OKCE, even though the research from this study is inconclusive. It can be concluded that

both CKCE and OKCE are effective in treatment of patients with PFPS.

## CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the authors.

## ETHICAL APPROVAL

As per international standard or university standard, written approval of Ethics committee has been collected and preserved by the authors.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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