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The effects of two different closed kinetic chain exercises on muscle strength and proprioception in patients with patellofemoral pain syndrome

Patellofemoral ağrı sendromunda farklı kapalı kinetik zincir egzersizlerinin kuvvet ve propriyosepsiyon üzerine etkileri

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Amaç: Patellofemoral ağrı sendromu (PFAS) olan hastalarda iki farklı kapalı kinetik zincir egzersiz programının etkileri karşılaştırıldı.

Çalışma planı: Tek taraflı PFAS tanısı olan 40 kadın hastanın rastgele seçimle 20'sine (ort. yaş 39.1±8.0) kalçadan iç rotasyon, 20'sine ise (ort. yaş 36.1±8.7) kalçadan dış rotasyon pozisyonunda Monitörize Fonksiyonel Diz Bükme Sistemi ile dört hafta süreyle (20 seans) egzersiz uygulandı. Tedavi öncesinde, dört haftalık tedavi sonrasında ve altı haftalık ev egzersiz programı sonrasında, iki grupta da Monitörize Fonksiyonel Diz Bükme Sistemi ile kas kuvveti ve propriyosepsiyon değerlendirmeleri, görsel analog skala ile ağrı ölçümleri yapıldı ve fonksiyonel durum Kujala anketi ile değerlendirildi.

Sonuçlar: Başlangıç özellikleri bakımından iki grup, sadece boy uzunluk ortalamaları açısından anlamlı farklılık gösterdi ($p<0.05$). Tedavi sonrası ve kontrol değerlendirmelerinde iki grubun ağrı şikayetlerindeki azalma anlamlı bulundu ($p<0.05$). Tedavi sonrasında her iki grubun konsentrik ve eksentrik zirve kuvvet ve konsentrik propriyoseptif defisit ve Kujala skorlarında anlamlı iyileşme görülürken ($p<0.05$), kontrol sonuçları ile tedavi sonrası sonuçlar arasında bu açıdan anlamlı farklılık görülmedi ($p>0.05$). Eksentrik propriyoseptif defisitte ise iki grup için de hem tedavi sonrasında hem de kontrolde anlamlı değişim kaydedilmedi ($p>0.05$). Tedavi boyunca iki grup arasında anlamlı farklılık gösteren parametreye rastlanmadı ($p>0.05$).

Çıkarımlar: Bulgularımız, PFAS'li hastalarda kalçadan iç ve dış rotasyon pozisyonlarında uygulanan fonksiyonel diz bükme egzersizleriyle kas kuvveti ve propriyosepsiyonda sağlanan iyileşmelerin benzer olduğunu göstermektedir.

Anahtar sözcükler: Egzersiz tedavisi; diz eklemi; kas kuvveti; patellofemoral ağrı sendromu/rehabilitasyon; propriyosepsiyon.

Objectives: The effects of two different closed kinetic chain exercises were compared in patients with patellofemoral pain syndrome (PFPS).

Methods: Forty female patients with unilateral PFPS were randomly divided into two groups to receive exercises with the hip internally rotated (n=20, mean age 39.1±8.0 years) or externally rotated (n=20, mean age 36.1±8.7 years) with the use of the Monitored Rehab Functional Squat (MRFS) System. The duration of exercises was four weeks with a total of 20 sessions. Both groups were evaluated before therapy, after four weeks of exercises, and after six weeks of home exercise program with the MRFS System for muscle strength and proprioception, with a visual analog scale for pain, and with the Kujala questionnaire for functional assessment.

Results: Among baseline features, the only significant difference between the two groups was in the mean height ($p<0.05$). Pain severity decreased significantly in both groups after treatment and home exercises ($p<0.05$). Concentric and eccentric peak forces, concentric proprioceptive deficit, and Kujala scores improved significantly in both groups after treatment ($p<0.05$), whereas improvements after home exercises were not significant in this respect ($p>0.05$). Eccentric proprioceptive deficit, however, did not change significantly both after treatment and home exercises ($p>0.05$). No significant differences were observed between the two groups during the study period with respect to the parameters assessed ($p>0.05$).

Conclusion: Our results show that functional knee squat exercises with internally and externally rotated hip positions provide similar improvements in muscle strength and proprioception in patients with PFPS.

Key words: Exercise therapy; knee joint; muscle strength; patellofemoral pain syndrome/rehabilitation; proprioception.

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Patellofemoral pain syndrome (PFPS) is defined as one of the most common joint disorders observed in physiotherapy clinics.[1] Although the etiology of PFPS is not exactly understood, repetitive loading of patellofemoral joint causes damage in retropatellar cartilage and subchondral bone [2, 3] . Strength imbalance in extensor mechanism results in patellofemoral pain by stimulating nociceptive fibers in synovium and retinaculum.[4] Patellofemoral joint reaction forces increase on conditions like running, stair-climbing and descending, slope-climbing and descending, crouching or sitting at flexion angles at 90° or more, and impose too much pressure on patellofemoral joint, therefore cause an increase in pain complaints in patients.[3, 5, 6, 7]

PFPS constitutes 17% and 33% of knee pathologies in men and women, respectively.[7] The force acting on the joint is 20% more in women due to the mechanic disadvantage caused by the short moment arm of the femur. The lower contact area between surfaces due to the smaller dimensions of bone structures in women increases the pressure in unit area. Therefore, PFPS incidence is observed to be 20% in women and 7.4% in men. Patellofemoral malalignment in PFPS leads to damage in joint capsule and external soft tissues, and thus the misperception of proprioceptive input from these structures. In PFPS rehabilitation, it is important to determine the factors and functional limitations causing disorder.[3]

This study was designed to compare the effects of different closed kinetic chain (CKC) exercise programs on strength, proprioception and functional performance in patients with PFPS.

Patients and method

The study included 40 female patients between 20-45 years of age diagnosed with unilateral PFPS by the same orthopedist. Female patients with patellofemoral pain for at least two months and between at least two activities like longtime sitting, stair/slope climbing and descending, crouching, running, bouncing and jumping were included in the study while patients with a history of meniscus and ligament lesions, patellofemoral osteoarthritis, patellofemoral dislocation and/or subluxation history, bone anomaly and surgical knee history were excluded from the study. Pre-treatment age, height, weight, body mass index (BMI), pain duration and training status of patients were recorded.

Patients who gave informed consent were divided into two groups by method of random selection. Patients were treated with two different CKC functional squat exercise programs by using "Monitored Rehab Systems – Functional Squat System, MRS-E0203) (MFSS). Exercise program in hip internal rotation position on "Functional Squat System" was applied to patients in group I (n=20), while the patients in group II (n=20) were given functional rehabilitation program in hip external rotation position on "Functional Squat System". At the end of 20 sessions lasting four weeks, patients were given a 6-weeks home exercise program and asked to come to the clinic for control..

Evaluation parameters

Same evaluations were repeated in both groups prior to the treatment, at the end of the 4 weeks treatment period and at the end of the 6-weeks home exercise program.

Pain and functional capacity. Knee pain experienced during rest and physical activities (stair and slope climbing and descending) was evaluated by both visual analogue scale (VAS) and Kujala patellofemoral scoring system. During VAS evaluation, patients were asked to score their pain severity on a 10 cm horizontal line with a scale between 0 and 10 (0: no pain, 10: maximum, unbearable pain).[8] Pain and functional performances of patients were assessed under the supervision of an observer by using Kujala patellofemoral scoring system including parameters of limping, loading on both lower extremities, walking, stair-climbing and descending, crouching, running, bouncing, long time sitting with bent knees, pain, swelling, abnormal and painful patella movement, femoral atrophy and flexion limitation.[9]

MFSS is a system that allows the evaluation of lower extremity in concentric and eccentric phase during the functional squat movement (Figure 1). Relative position of the patient is represented on the computer screen. In the course of the 'video game' displayed on the computer screen, it allows joint to be able to exercise and make its evaluation in the desired joint mobility. The patient gains points by displaying right positions during exercise and testing, and loses points by displaying wrong positions. MFSS is mentioned in literature as a valid and reliable method used in the evaluation of strength and proprioception.[10]

Figure 1. Monitorized Rehabilitation systems- Functional Squat System. Hip **(a,b)** internal rotation and **(c,d)** external rotation

Evaluation of strength. The strength was evaluated by MFSS. Peak strength was measured in a total of 5 sets in 50%, 70%, 80%, 90% and 100% of the weight, respectively, which patients can lift with 1 maximum repetition in supine position on a horizontal system with a 40°curve. Patients in Group I completed the test by concentric and eccentric movements at 0-45° flexion interval of the knee when they were in 45° internal rotation position of the hip whereas patients in Group II completed the test by concentric and eccentric movements at 0-45° flexion interval of the knee when they were in 45° external rotation position of the hip.

Evaluation of Proprioception. Proprioception of patients was evaluated with 25% of the weight they could lift with 1 maximum repetition. Patients in Group I completed the test at 0-45° flexion interval of the knee when they were in 45° internal rotation position of the hip, while patients in Group II completed the test at 0-45° flexion interval of the knee when they were in 45° external rotation position of the hip. During the test, the blue line appearing on the screen with a red + sign was asked to follow for 1 minute with 4 repetitions by performing 45° eccentric and concentric movements of knee. The difference between the deviation recorded with visual input in concentric and eccentric movement phases at the end of the test and the deviation recorded without visual input was included in the evaluation.

Treatment protocol

All patients were given concentric and eccentric strengthening and proprioception training on MFSS under the supervision of the same physiotherapist for 4 weeks. After the treatment, patients were given home exercise program and followed up for 6 weeks.

Exercise program on MFSS. Functional squat exercise in the rehabilitation mode of the system was given to patients in Group I at 45° internal rotation of the hip and 0-45° flexion interval of knee (Figure 1.a-b) and to patients in Group II at 45° external rotation of the hip and 0-45° flexion interval of knee (Figure 2.a-b). Patients were asked to follow the small square inside the red box moving at a speed of 4cm/sec with their sick and healthy extremity respectively in line with the visual directions received from the screen, and move the square inside the green box at the same speed. Exercise was started with approximately 20-25% of the weight that patients could lift with 1 maximum repetition. At the end of every 5

Table 1. Initial characteristics of two groups.

	Group I	Group II		
	X ±SD	X ±SD	U	*p*
Age (year)	39.1±8.0	36.1±8.7	148.5	0.15
Height (cm)	161.4±6.7	166.9±4.2	103.5	**0.009**
Body weight (kg)	68.8±10.3	68.8±11.1	198.5	0.96
Pain duration (month)	35.8±29.3	27.8±31.7	183.0	0.65
Body mass index (kg/m2)	26.6±5.3	24.3±3.9		

days, the target was to reach 50% of 1 maximum repetition at the end of 20 sessions by increasing the weight 10-12% of 1 maximum repetition.

Home exercise program. Patients in both groups were given straight leg raising exercise in supine position, strengthening exercise of hip adductor muscles in side-lying position and multiple angle isometric exercises in sitting position with 10 repetitions 3 times a day for 6 weeks.

Statistical analysis

Data of patients in both groups obtained from the controls in the pre-treatment period, at the end of 4-weeks CKC treatment and at the end of 6-weeks home exercise program were evaluated by using the statistical method of two-way variance analysis in repeated measurements with SPSS 13.0 statistical packet program. Statistical significance level was determined as p<0.05.

Findings

Demographic findings of patients, such as age, height, weight, pain duration and BMI are given in Table 1. When the physical characteristics and pain durations of both groups were compared by Mann-Whitney U test, no statistically significant difference was found between the two groups in terms of the mean weight values, age and pain duration (p>0.05), while a statistically significant difference was observed between the mean height values of patients (p<0.05).

It was determined that 70% of patients were university graduates, 12.5% were high school graduates, 5% were secondary school graduates and 12.5% were primary school graduates. 14 of the patients were housewives, 9 worked as standing all day, and 17 worked at a desk job.

Table 2. Assessment results of the groups (Means in pre-treatment, post-treatment and control times)

	Pre-Treatment		Post-Treatment		Control		A		B	
	Group I (n=20) *Mean±SD*	Group II (n=20) Mean±SD	Group I (n=20) Mean±SD	Group II (n=20) Mean±SD	Group I (n=17) Mean±SD	Group II (n=17) Mean±SD	F	*p*	F	*p*
Pain (cm)										
Rest	1.9±2.4	2.8±2.5	0.6±1.4	0.8±1.4	0.2±1.0	0.2±0.5	0.63	0.43	24.67	**0.00**
Activity	6.2±1.9	7.2±2.3	4.2±2.1	4.5±1.6	2.3±2.3	3.0±1.7	1.27	0.27	103.4	**0.00**
Concentric										
Weight (kg)	27.6±8.7	30.0±8.7	38.5±9.1	41.5±8.8	39.7±8.6	41.2±7.2	0.70	0.41	87.62	**0.00**
Force (N)	474.3±109.3	443.5±99.5	650.5±33.8	633.5±101.3	669.3±123.9	656.5±101.6	0.34	0.56	110.64	**0.00**
Eksentrik										
Weight (kg)	27.6±8.6	30.0±8.6	38.5±9.1	41.4±8.8	39.7±8.5	41.1±7.9	0.70	0.41	87.62	**0.00**
Force (N)	405.0±92.1	389.9±99.2	553.1±101.0	553.1±103.1	578.2±98.6	559.8±87.6	0.15	0.70	90.48	**0.00**
Proprioception										
Concentric (cm)	60.8±39.4	59.7±69.8	44.4±37.8	26.9±36.3	50.1±46.7	2.6±49.1	0.37	0.55	3.36	**0.04**
Eksentrik (cm)	65.5±57.0	37.2±63.4	51.2±37.4	36.5±61.5	60.9±46.7	40.4±38.6	1.91	0.18	0.31	0.74
Kujala Score	60.5±14.6	56.4±8.9	72.9±7.2	66.7±11.4	76.8±12.9	72.4±12.0	2.83	0.10	26.67	**0.00**

A: Difference between groups; B: Difference between pre-treatment, post-treatment and control times.

No statistically significant difference was found between the groups in terms of pain, concentric and eccentric peak strength, proprioception and Kujala scores evaluated at rest and during physical activity ($p>0.05$, Table 2). The reduction in pain values in both groups between pre-treatment – post-treatment ($p=00$), post-treatment – control ($p=0.01$) and pre-treatment – control ($p=0.00$) assessed by VAS at rest and during physical activity were found to be statistically significant ($p>0.05$, Table 2).

In the analysis of strength values evaluated in concentric and eccentric phases, the increase in peak strength values of both groups between pre-treatment – post-treatment ($p=00$) and pre-treatment – control ($p=0.00$) was found to be statistically significant ($p<0.05$, Table 3). The change in peak strength values of both groups between pre-treatment – post-treatment and post-treatment control (concentric phase, $p=0.1$; eccentric phase, $p=0.5$) was observed to be statistically insignificant ($p>0.05$, Table 2).

A statistically significant reduction was found in the pre-treatment – post-treatment ($p=0.01$) concentric phase proprioceptive deficits of patients in both groups ($p<0.05$, Table 2). On the other hand, the change between post-treatment control ($p=0.75$) and pre-treatment – control ($p=0.64$) was found to be statistically insignificant ($p>0.05$, Table 2). The change observed in the eccentric phase proprioceptive deficits evaluated in pre-treatment, post-treatment and control periods in both groups was not statistically significant ($p>0.05$, Table 2). Kujala test score analysis revealed a statistically significant difference between pre-treatment – post-treatment ($p=0.00$) and pre-treatment – control ($p=0.00$) periods in both groups ($p<0.05$, Table 2). The change between pre-treatment – post-treatment and post-treatment-control periods ($p=0.2$) was found to be statistically insignificant ($p>0.05$, Table 2).

Discussion

Different CKC exercise programs in patients with PFPS are effective on strength, proprioception and functional performance. In order to prepare the patients to daily life activities in an early period, it is important that the assigned exercises are functional. Stabilization of knee, hip and ankle joints is provided by the eccentric control of gluteus maximus, gastrocnemius and quadriceps muscle during activities like stair and slope climbing and crouching. There should be full motor control and coordination during these activities. Many activities performed in daily life consist of CKC movements.[10] No difference was found between the demographic characteristics of two groups. Therefore, it was considered that the treatment result was not affected by demographic characteristics. Although there are no available studies in literature investigating the effect of exercise program performed with "Functional Squat System" on pain, muscle strength, proprioception and functional condition; it was demonstrated in some studies that leg press and mini squat exercises similar to functional squat exercise are effective in reducing pain.[11, 12] Witvrouw et al. [13] followed PFPS patients by CKC exercises, hamstring and stretching exercises in gastrocnemius muscles for 5 weeks, Thomee et al. [14] followed them by isometric strengthening and eccentric strengthening training programs for 12 weeks, Fehr et al. [12] followed them by multiple angle isometric exercises, leg press, mini squat exercises at 50° for 8 weeks, and they all recorded a decrease in patients' pain complaints at the end of the treatment.

CKC exercise programs assigned in this study focus on concentric and eccentric muscle control. Patellofemoral pain was reduced by CKC exercises, so that patients could do their OKC exercises at home without feeling pain. It was thought that the exercise program given in MFSS prepared the patients for physical activities like crouching and stair climbing and descending. Although patients did not feel pain at rest at the end of week 10, they still felt some pain during physical activities. This demonstrates the necessity of applying a longer exercise program in order to remove pain symptoms completely during functional activities.

There are several studies in literature which investigate the effect of different hip and tibia positions on VMO/VL muscle activation.[7, 15, 16] However, there is still no consensus on this issue. Some studies focus on exercises of varying hip positions, while some studies compare the effects of OKC and CKC exercises. It is commonly reported that all these exercises provide an increase in muscle strength.[17, 18, 19]. Miller et al. (1997) found no significant difference in VMO/VL muscle activation rate during physical activities in women with PFPS at the end of the evaluation they made during stair climbing and descending at neutral

45° internal rotation and external rotation positions of the hip, and 75° wall squat activities.[16]

Grossi et al. (2005) recorded the activations of VMO, VLL and VLO muscles by EMG in the eccentric phase during isometric squat exercise at an angle of 45° in standing position and 60° knee flexion angle. They found no difference between VMO, VLL and VLO muscle activations in both exercise positions in patients with PFPS.[15] Lam and Ng (2001) performed measurements in standing position, crouching position at 20° and 40°, neutral position at 30° medial rotation of the hip in 60% of the maximum voluntary contraction (MVC) and 45° lateral rotation position. They observed no difference between the activation rates of VMO/VL muscles recorded by EMG at 3 different hip rotation positions at 20° knee flexion position; whereas they found that VMO/VL muscle activation at medial hip rotation was higher compared to lateral hip rotation evaluated at 40° knee flexion position.[20]

In literature, the effect of various CKC exercises on muscle strength was investigated on specific muscles. In this study, functional muscle strength measurements assessed in lower extremity concentric and eccentric phases were taken into consideration. It was concluded that the same exercise and test position used in our study had a positive effect on measurement results. In this study, an increase was recorded in peak strength values at the end of the exercise programs assigned at different hip rotation positions. Increases in strength evaluated after the exercises in home program were not found to be significant. It can be stated that CKC exercises performed under the supervision of a physiotherapist provide more increase in strength compared to home exercise program.

While the studies in literature discuss the effect of exercise on muscle strength in patients with PFPS, its effect on proprioceptive senses has not been investigated. Baker et al. suggested that CKC exercises stimulate more muscle fibers and proprioceptive senses, and leg press exercises given in sitting and supine positions as CKC impose less load on the joint.[18, 21]

Hazneci et al. (2005) recorded improvement in passive proprioceptive test evaluated during 40° knee flexion and 50° knee extension in patients with PFPS at the end of the isokinetic treatment of 6 weeks.[22] . In this study, improvement was observed in concentric phase proprioceptive senses of patients in both groups at the end of the active proprioception evaluation at 0-45° knee flexion angle. The improvement in proprioceptive senses provided by CKC exercise programs may be associated with the increase in muscle strength and the decrease in patellofemoral joint reaction strengths. Selfe et al. (2006) carried out active and passive proprioception evaluations at 20° and 40° knee flexion angles in 32 patients with PFPS. No difference was found between flexion angles, whereas a significant difference was observed between active and passive tests. It was also determined that performing the active test with 4-5 repetitions and passive test with 5-6 repetitions was sufficient for the stabilization of proprioceptive data.[23] In our study, proprioception senses of patients were evaluated by an active test with 4 repetitions. The use of active tests supports the result obtained in this study. More afferent nerve fibers are stimulated during the active test compared to the passive test, and a better proprioceptive performance was achieved. Exercise training given in this study aimed at both proprioceptive improvement and increase in muscle strength.. The objective of the treatment was to improve proprioceptive senses during functional activities by integrating exercise and proprioceptive training. At the end of the treatment applied in our study, improvement was observed in proprioceptive senses evaluated throughout the concentric phase of patients, while there was no significant change in proprioceptive senses evaluated throughout the excentric phase. Yet, it was concluded that proprioceptive improvement results obtained in the excentric phase of knee should be monitored for a longer period of time.

Physical activity levels of individuals are affected by the functional limitations occurring due to pain and reduced muscle strength in patients with PFPS. In Kujala questionnaire, unlike in other questionnaires, we can examine the description of pain and walking and running distance numerically, rather than the severity of pain experienced during functional movements like standing, running, jumping and sitting with bent knees. Bennel et al. (2000) investigated the validity and safety of the pain measurement of 5 questionnaires applied to 53 women with PFPS under 40 years of age in the last week of Kujala, Functional Index Questionnaire (FIQ), Flandery and VAS evaluations and on the day of VAS evaluation. Kujala, FIQ and Flandery were found to be the most reliable questionnaires.[9] Witvrouw et al. (2002) applied a 5 weeks treatment with CKC exercises on 30 patients (20 women, 10 men) of approximately 21 years of age with front knee pain. Improvement was observed in Kujala scores at the end of five weeks and in the 3rd month [13] . In our study, Kujala scores of patients improved following the 4-weeks CKC functional exercise program. The improvement in Kujala scores is the indication of the increase in patients' functional performances. Consequently, different CKC exercise programs may be recommended for patients with PFPS diagnosis in order to reduce pain and increase functional muscle strength, proprioception and performance.

This study demonstrated that the exercise program to be assigned in CKC position with the right proprioceptive input would be effective in improving functional activities, reducing pain and increasing the independence of the individual.

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