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The effect of postural stabilization exercises on pain and function in females with patellofemoral pain syndrome

Gül Deniz YILMAZ YELVAR[1], Gül BALTACI[2], Volga BAYRAKCI TUNAY[2], Ahmet Özgür ATAY[3]

[1]*Turgut Özal University, School of Physical Therapy and Rehabilitation, Ankara, Turkey;*
[2]*Hacettepe University, Faculty of Health Science, Physiotherapy and Rehabilitation Department, Ankara, Turkey;*
[3]*Hacettepe University, Faculty of Medicine, Orthopaedics and Traumatology Department Ankara, Turkey*

Objective: This study aimed to investigate the effect of postural stabilization exercises on pain, muscle strength and function in females with patellofemoral pain.

Methods: Forty-two volunteers with patellofemoral pain syndrome (PFPS) were included in this study. The subjects were randomly divided into two groups: Group 1 performed therapeutic knee and postural stabilization exercises (n=22); Group 2 performed therapeutic knee exercises only (n=20). All patients were evaluated for pain, hamstring flexibility, function, lower extremity strength and postural control before and after treatment and at the 12th week. A two-way ANOVA was done within each group before and after treatment and at the 12th week. The level of significance was set at $p<0.05$, and when this was observed, the Tukey test was used to determine which group had caused the significance.

Results: The results were statistically significant between the groups in terms of pain, flexibility, function, strength, endurance, postural control and the parameters of the Kujala patellofemoral pain scale ($p<0.05$). For all parameters, Group 1 achieved the greater success after treatment ($p<0.05$).

Conclusion: The implementation of physiotherapy and rehabilitation programs including postural stabilization exercises may improve strength and function and reduce pain in patients with PFPS.

Keywords: Function; pain; patellofemoral pain syndrome; physiotherapy; postural stabilization; strengthening.

Patellofemoral pain syndrome (PFPS) is observed during daily activities such as squatting, long-term knee flexion or stair climbing and descending, and is characterized by pain that limits participation in sports. However, its etiology remains vague and controversial.[1] Basal degeneration of deeper layers of patellofemoral joint cartilage, mediolateral patellar mobility, changes in patellofemoral contact points and force due to patellar sacral and lumbar malalignment, decreased flexibility of the quadriceps muscle, vastus medialis obliquus (VMO) muscle reflex response time, overuse and overload are all considered important factors in its etiology.[2-5] Powes explained additional etiology as weak proximal neuromuscular control and/or weakness of muscles around the hip.[6] Previous studies indicate a relationship between hip muscle function and lower extremity injuries.[7,8] This was highlighted by a recent systematic review, which found strong evidence for deficits in hip muscle strength including ab-

Correspondence: Gül Deniz Yılmaz Yelvar, PT, PhD, Asist Prof. Turgut Özal Üniversitesi, Fizik Tedavi ve Rehabilitasyon Yüksekokulu, Ankara, Turkey.
Tel: +90 312 – 397 74 00 / 7203 e-mail: guldenizy@yahoo.com

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duction, external rotation and extension, and moderate evidence for deficits in hip adduction and internal rotation muscle strength, and thereby patellar alignment in women with PFPS.[9]

Both daily and sports activities are in the form of kinetic chains. Trunk dynamic control enables production, transfer and control of force and motion of the distal segments in the chain. Bouisset advocated that stabilization of trunk and pelvis is necessary for all movements of extremities. The transversus abdominis and multifidus muscles work in the form of co-contraction, and also control excessive anterior pelvic tilt, which is believed to be associated with femoral internal rotation and adduction. Excessive femoral internal rotation creates relative external rotation in the tibia. This condition causes a larger quadriceps angle and may significantly increase lateral retropatellar contact pressure. Repetitive activities may lead to retropatellar articular cartilage damage. Therefore, inability to control the trunk and pelvis affects movements of the lower limb and patellofemoral complex.[8,10,11]

Management can be challenging, yet a well-designed and non-operative treatment program usually allows patients to return to recreational and competitive activities.[12] Therefore, physical therapy is the first line of treatment for PFPS. While studies have been done on the clinical efficiency of several different treatment regimens, a recent systematic review revealed a lack of high-quality clinical trials in this area.[4,13]

There is only one study and one case report in the literature regarding the effectiveness of postural stabilization in patients with PFPS. However, the study lacked a control group.[14,15] Therefore, the aim of the current randomized controlled study was twofold: to analyze the role of postural stabilization exercises in increasing patients' quality of life and functionality by reducing the load on the knee joint, and to determine the effectiveness of physiotherapy and rehabilitation programs which include postural stabilization exercises on pain, strength and function in PFPS patients. We hypothesized that adding postural stabilization exercises to a rehabilitation program improves clinical outcomes.

Patients and methods

This randomized controlled clinical study was conducted to evaluate the effectiveness of exercise programs including stabilization and therapeutic exercises applied to two different groups with PFPS (Table 1).

Fifty-two female patients with unilateral patellofemoral pain syndrome were included. Ten participants discontinued because of personal issues (Fig. 1). Therefore, this study was conducted with forty-two (mean age 45.45±4.95 yrs) patients (Table 2). Subjects were included if they had retropatellar pain of more than 6 months duration brought on by two (or more) of the following symptoms without traumatic onset: prolonged sitting, stair climbing and descending, running, kneeling, hopping/jumping, pain on palpation of patellar facets, a step down. Subjects clinically diagnosed with PFPS by physician had received physical therapy for the first time. Exclusion criteria were: *a)* a current or previous record of knee pain, trauma, surgery and other joint disease, *b)* in-

Table 1. Exercise programs.

Postural stabilization program	Therapeutic knee exercise program
• Stretching hip flexors, hamstrings, iliotibial band and lumbal extensors	• Stretching hip flexors, hamstrings, iliotibial band and lumbal extensors
• Curl-ups	• Curl-ups
• Marching	• Bridge exercise
• Toe taps	• Straight leg raising on supine
• Bridge exercise	• Isometric quadriceps strengthening (250 times/day)
• Supine straight leg raising	• Isometric adductor strengthening (50 times/day)
• Side lying straight leg raising	• Strengthening hip muscles
• Prone knee flexion	• Weight bearing on one leg
• Draw foot circles in the supine position	• Heel and toe walking on the soft ground
• Draw foot circles lying sideways	
• Prone cobra	
• Hip and knee extension in the crawling position	
• Weight bearing on one leg	
• Hip flexion sitting on the ball	
• Weight bearing forward and backward sitting on the ball	
• Stairs-up on swissball	

Table 2. Comparison of demographic characteristics in patients.

	Group 1 (n=22) Mean±SD	Group 2 (n=20) Mean±SD	F	p
Age (year)	45.41±4.39	45.50±5.52	0.025	0.976
Height (cm)	160.32±6.08	158.65±4.80	0.493	0.613
Weight (kg)	68.80±9.70	73.05±12.89	0.882	0.419
Pain duration (month)	12.45±7.77	15.30±9.32	2.373	0.131

$p<0.05$; F: T-test.

jury or dysfunction in the knee ligament, bursae, menisci and synovial plicae, *c)* involvement in competitive sports, *d)* radiographic evidence of osteoarthritis of the knee joint, *e)* a neurological problem affecting walking, *f)* pregnancy. Subjects were instructed to avoid taking analgesics or anti-inflammatory medications during the study.

Since previous studies showed that there are some differences between the genders in terms of force and kinematics,[16,17] only women were included in the study. The University's Human Investigation Committee approved the study, and all participants read and signed the informed consent form prior to enrollment in the study.

Before treatment, patients were assigned sequentially into 2 groups by the second author, who was blinded for the evaluation. The first group, as the study group, performed therapeutic knee exercises with additional stabilization exercises, and the second group, as the control group, performed only therapeutic knee exercises under the supervision of a physiotherapist and did therapeutic knee exercises as a home program.

Before treatment, each patient was informed about patellofemoral pain syndrome and the factors that needed attention during daily activities and the home program. Each patient was asked to perform cold press applications to the knee for 15 minutes, 3 times a day for 6 weeks.

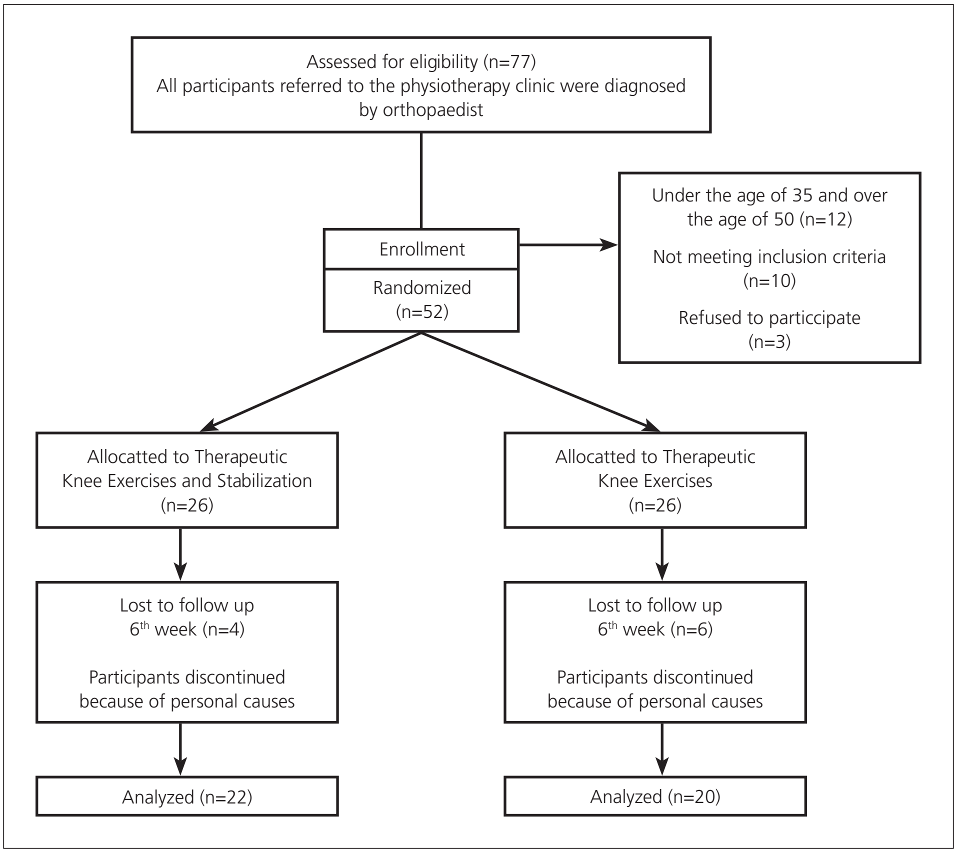

Fig. 1. Flow chart for enrollment and testing procedure.

Table 3. Results in pre-treatment (0 weeks), after six week of treatment (6 weeks) and at the final evaluation at 12th week in both groups.

	Group 1			Group 2				
	0 Week	6 Week	12 Week	0 Week	6 Week	12 Week	F	p
Pain	7.54±1.68	3.02±1.54	2.00±1.71	7.65±1.69	5.50±1.76	4.55±1.60	77.216	0.000*
QUAD								
60°/s	0.85±0.31	1.04±0.32	1.07±0.33	0.85±0.46	0.99±0.47	1.04±0.44	3.181	0.045*
180°/s	0.69±0.29	0.83±0.27	0.84±0.25	0.64±0.25	0.79±0.28	0.81±0.29	4.333	0.015*
HAMS								
60°/s	0.70±0.22	0.88±0.19	0.89±0.19	0.62±0.27	0.69±0.26	0.74±0.31	4.904	0.009*
180°/s	0.64±0.25	0.83±0.14	0.81±0.16	0.51±0.21	0.66±0.18	0.68±0.22	10.546	0.000*
One leg hop	54.38±22.53	75.61±20.09	78.68±22.74	48.65±24.75	64.30±23.52	70.10±24.54	11.633	0.000*
TUG	3.86±0.79	3.37±0.55	3.30±0.48	4.33±0.78	3.89±0.50	3.76±0.39	10.301	0.000*
Kujala	48.00±12.54	82.45±13.02	87.64±8.39	49.35±11.23	66.75±16.19	74.85±14.71	75.121	0.000*
Flexibility	23.45±12.50	8.27±7.21	7.22±4.83	30.10±14.13	17.85±10.89	17.15±8.93	27.080	0.000*
Sorenson	30.29±16.42	66.31±26.61	78.24±31.49	23.33±14.70	36.18±17.48	49.46±12.61	32.852	0.000*
Sit-up	22.66±10.73	57.97±24.22	60.67±30.77	19.88±12.59	33.71±15.74	41.51±15.61	27.127	0.000*

F: One way ANOVA; QUAD: Quadriceps strength; HAMS: Hamstring strength; TUG: Timed up and go test, $p<0.05$.

Group 1– The stabilization exercises were performed 3 days a week for 6 weeks under supervision of a physiotherapist. The principles of postural stabilization were explained before the treatment and patients were asked to comply with these during the exercise. These principles included:

**Core activation*– Transversus abdominis, pelvic floor, multifidus and diaphragm muscles work together for stabilization of the lumbopelvic region defined core. Since this activation constitutes the foundation of movement, the patients were instructed on this principle first. For this, patients were asked to lie down in the supine position, with hips and knees flexed. They were asked to put their fingers just medially to the crista iliaca, told to contract the transversus abdominus with posterior pelvic tilt and feel the contraction on the fingertip. The physiotherapist helped the patients to learn about this position through close supervision.

**Neutral spine*– The patients were asked to imagine putting the spine in a straight line, and correct their posture in supine, prone and standing position. They were also asked to perform posterior pelvic tilt, and scapular stabilization and chin retraction, which enabled the spine to remain in neutral position.

**Stabilization exercises* were done with diaphragmatic breathing to increase the efficiency of activation in the core, facilitate movement, enhance mobility, improve lung capacity and enhance focusing. After instruction on the principles, the exercise program was started. Exercises were done 5 times in the order shown in the table and using the patients' own body weight for the first 2 weeks. During the next 4 weeks, in order to increase force, an appropriate elastic resistance band was chosen for each patient and exercises were done with it. The therapeutic knee exercise program was prepared and every patient was instructed on the home regimen. The patients were asked to do the home exercise program 3 times a day, and 10 times for each exercise (Table 1) (Fig. 2).

Group 2– Patients were prescribed only the therapeutic knee exercise program at home and asked to write an exercise diary for completed exercises. They were encouraged to do these exercises correctly and consistently by being invited to the clinic every week and contacted by telephone 3 times a week. They were asked to do the home exercise program 3 times a day and 10 times for each exercise using their own body weight for the first 2 weeks. During the next 4 weeks, in order to increase force, an appropriate elastic resistance band for the patient was chosen and exercises were done with it (Table 1).

Before evaluation, subjects warmed up on a stationary bicycle ergometer in pain-free range of motion for 5 minutes. They were then evaluated by tests, including pain scale, flexibility, function, strength and postural stabilization in the morning by a first examiner who was blinded for randomization.

The visual analogue scale (VAS) (0-10 cm), which has been shown to be valid, reliable, and sensitive to patients in PFPS, was used for pain assessment.[18] Average pain was recorded during ascending and descending 10-step stairs. Zero point indicated no pain and 10 points worst pain. Activity pain was also evaluated using the Kujala Patellofemoral Pain Scale, defined by Kujala et al.[19] and adapted for the Turkish population by Kuru et al.[20]

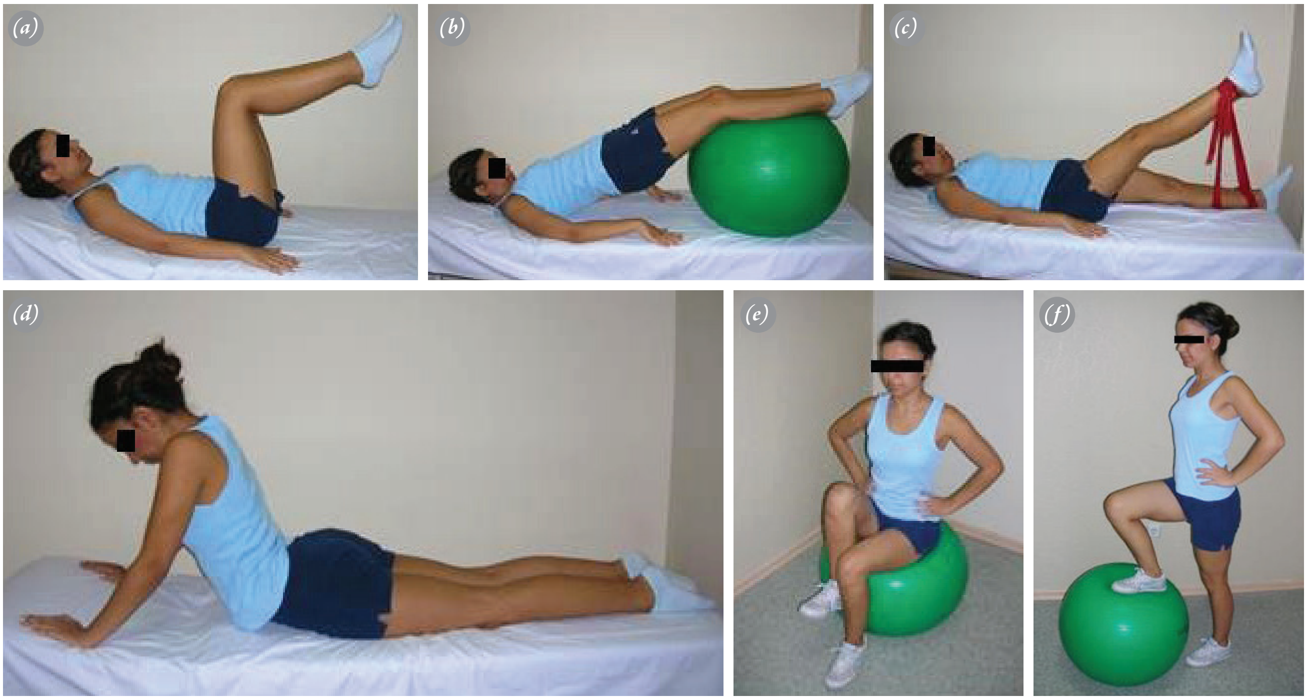

Fig. 2. Stabilization exercises. **(a)** Marching. **(b)** Bridge exercise. **(c)** Draw foot circles in the supine position. **(d)** Prone Cobra. **(e)** hip flexion sitting on the ball. **(f)** Stairs-up on Swiss ball sitting on the ball. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

The 90/90 passive test method was used to evaluate hamstring muscle flexibility.[21] Hamstring flexibility was measured using a double-armed goniometer. Patients were in supine position with hip and knee flexed to 90°. The goniometer was centered over the lateral condyle of the femur, its arms aligned with the lateral malleolus of the tibia and the greater trochanter of the femur. While one researcher passively moved the leg toward knee extension, the other held the goniometer, and read and recorded the results.

The one-leg-hop test was used for evaluating knee functions.[22,23] Patients were asked to stand on the affected leg and jump as far forward as possible. This method was repeated three times for each leg and the average result recorded. Also used was the timed get up & go (TUG) test, which contains multiple tasks in a series of getting up from sitting, walking, turning, stopping and sitting.[24] At the beginning of the test the patient was sitting, with her back against the back of the chair. When the researcher said 'go', she sat upright, walked 3 meters, turned around, returned to the chair and sat down. This series of actions was repeated three times and the average result in seconds recorded.

Quadriceps and hamstring muscle strengths were assessed at 60 °/s, and muscle endurance was assessed at 180 °/s using an isokinetic dynamometer (IsoMed® 2000 D&R GmbH, Germany). Subjects performed reciprocal quadriceps and hamstring concentric contraction with five repetitions at angular velocities of 60 °/s and ten repetitions at angular velocities of 180 °/s. Average peak torque to body weight was recorded for each speed.

For evaluation of postural stabilization, the modified Beiring Sorenson test for muscle capacity of posterior core and sit-up test for anterior core were used. For the modified Beiring Sorenson test, the subject was positioned in prone position with pelvis at the edge of the table and strapped to the table for her security. The subject was asked to maintain the body in a horizontal position for as long as possible, and total time was recorded.[8] For the sit-up test, the subject was positioned on the test bench and her upper body placed against a support at an angle of 60° from the test bed, with hips and knees flexed at 90°. Arms were folded across the chest with hands placed on the opposite shoulder. The subject was asked to maintain the body position while the supporting wedge was pulled back 10 cm to begin the test. The test ended when the upper body fell below the 60° angle and total time was recorded.[25]

Evaluation of all subjects after treatment and at the 12th week was performed as described above.

Independent t-test was used for comparison between groups for age, BMI, pain and duration of symptoms. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk's test) to determine distribution. Two way ANOVA was done within each group before and after the treatment, and at the 12th week after treatment. When differences were observed, the Tukey test was used to find out the group or before and after the treatment and at the 12th week that caused the differences with SPSS 16.0 for Windows (SPSS, Inc., Chicago, IL, USA). The level of significance was set at $p<0.05$.

The sample-size estimation calculations were based on detecting a 13-point difference in the Kujala anterior knee pain scale, which was based on a previously reported minimal clinically important difference of 9 points assuming a standard deviation of 11 points, 2 tailed, an alpha level of .05, and 80% power. A sample size of 20 women per group was determined.[27]

Results

There was no significant difference in any of the demographic characteristics between the groups, as shown in Table 2 ($p>0.05$).

Pain was decreased in each group. There were significant differences between the groups in activity pain in favor of Group 1 ($p<0.05$), and among the evaluations of pre- and post-rehabilitation and at 12th week. The reduction in post-rehabilitation pain continued until 12th week evaluation (Table 3).

Hamstring flexibility was increased after rehabilitation, and at 12th week evaluation. There was significant difference in hamstring flexibility in favor of Group 1 ($p<0.05$) (Table 3).

Function was increased in post-rehabilitation, and at 12th week evaluation. There was a significant difference in favor of Group 1 for TUG and one-leg-hop test (Table 3) ($p<0.05$) (Fig. 3). There was also a significant difference in Kujala Scores in pre- and post-rehabilitation and at 12th week evaluation for Group 1 ($p=0.00$) (Fig. 4).

There was a significant difference in favor of Group 1 for peak torque/body weight in 60 °/s and 180 °/s for quadriceps and hamstring muscles ($p<0.05$). All scores were improved in the groups, with the best result found at 12th week (Table 3). Assessment of postural stabilization, showed a significant difference in favor of Group 1 in all evaluations of pre- and post-rehabilitation and at 12th week ($p=0.00$) (Fig. 5).

Discussion

This study showed the effectiveness of postural stabilization exercises on pain and function in patellofemoral pain syndrome. It was concluded that stabilization exercises improve pain relief, muscle strength, flexibility and function, and that this improvement continues until the 12th week.

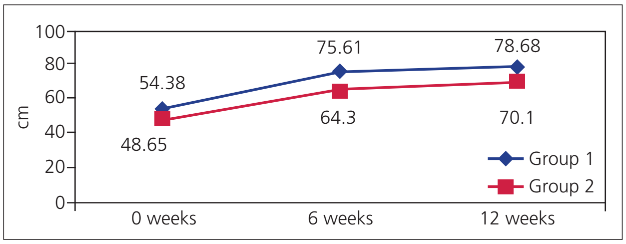

Fig. 3. Function (One leg hop test) assessment in pre-treatment (0 weeks), after six weeks of treatment (6 weeks) and at 12th week evaluation in both groups. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

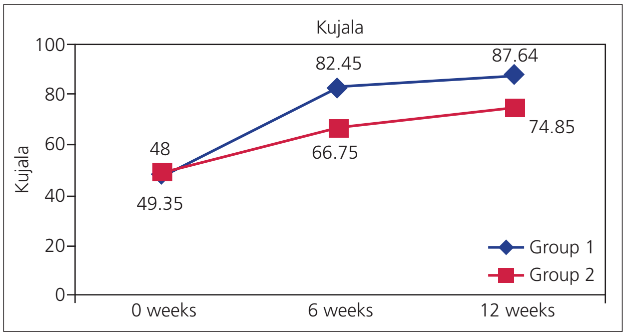

Fig. 4. Subjective function assessment in pre-treatment (0 weeks), after six weeks of treatment (6 weeks) and at 12th week evaluation in both groups. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

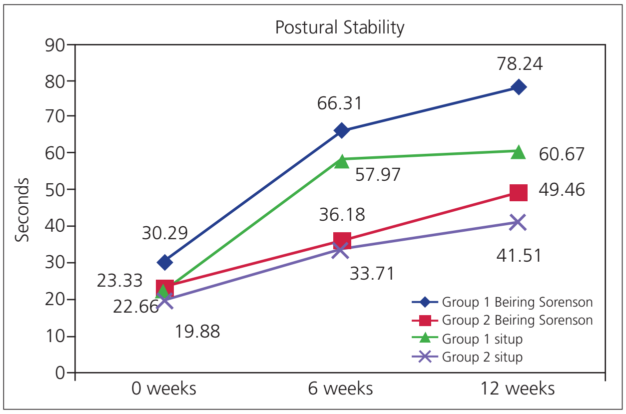

Fig. 5. Postural stability assessment in pre-treatment (0 weeks), after six weeks of treatment (6 weeks) and at 12th week evaluation in both groups. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

In the literature, conservative approaches generally include many methods, such as stretching and strengthening exercises for lower extremity muscles, VMO strengthening, activity modification, biofeedback, neuromuscular electrical stimulation, taping, foot orthoses and appropriate footwear selection.[5,12]

In a case-series study by Lowry et al., they applied a rehabilitation program including lumbopelvic, hip and patellar manipulation and trunk and lumbopelvic stabilization exercises to 5 patients for 6-14 weeks. The pain decreased in 4 of the patients, who had had pain of 8 months duration on average.[28] In their case-study, Mascal et al. reported a decrease in activity pain for 2 patients who followed trunk, pelvis and hip strength exercises.[15] Earl et al. indicated that pain significantly decreased with a 6-8 week postural stabilization exercises program.[14] In our study, pain was reduced in both groups after a 6-week exercise program. The best result was found in the group that did additional stabilization exercises. The results could have been affected by the duration of pain differences between our groups, but in this study there was no relationship between pain and the duration of pain.

Functional tests are simulated activities of daily living or sports-related movements, and are crucial to understanding the effectiveness of treatment. The TUG test contains multiple tasks in a series of getting up from sitting, walking, twisting, and stopping. Sitting is used especially in the evaluation of functional performance in patients with PFPS. In our study, in addition to these tests, the one-leg-hop test was used to evaluate performance in remaining balanced on a single leg. Since pain reduction has a positive effect on muscle inhibition, activity without pain increases function and quality of life as well. Indeed, we found a relationship between activity pain, strength, endurance and functional tests. Alaca et al. reported that muscle strength was related with the 6 m hop test after an isokinetic exercises program in patients with PFSP.[29] In their study, Fukuda et al. showed the knee and hip exercises group as more effective than the knee exercises group. They indicated that strengthening the gluteus maximus improves jump function because this muscle can be a synergistic muscle of the quadriceps during knee extension.[30]

The Kujala PFPS scale assesses the pain, function and limitation of joint motion. Robinson et al. found mean values to be 69.7 in patients, and did not record control groups' values.[31] In their study treating patients with PFPS using biofeedback, patellar taping and therapeutic exercises, Crossley et al. noted that improvement of patients' Kujala scores in the treatment group was more likely than in the placebo group.[32] Earl et al. indicated significantly increased Kujala scores with a postural stabilization exercises program for 6-8 weeks.[14] In the current study, although the score increased in both groups, we found the better Kujala score results in Group 1.

Due to closed kinetic activity in sports, researchers include distal and proximal parts of the injured region in their evaluation. Effective proximal stabilization is necessary for all upper and lower limb movement in a closed kinetic chain. In Letuun et al.'s study, the modified Beiring Sorenson test and lateral bridge test were used to measure stability in evaluating the effect of postural stability on lower extremity injury. According to the results of Sorenson test, it was 124.3±46.1 s in healthy women, and 38.0 s for anterior cruciate ligament injury in female athletes. A strong correlation was found between the side bridge test and performance, but poor correlation was observed between the Sorenson test and isometric contraction of hip abduction and external rotation. In addition, reduced lateral bridge endurance, isometric contraction of hip abduction and external rotation were recorded in the injured athletes. Based on these data, they stated that hip and trunk weakness reduces the ability of the females to stabilize their hip and trunk.[8] In a study investigating the relationship between the lower limb and abdominal muscles, electromyography (EMG) was used to measure the transversus abdominis, rectus abdominis, oblique abdominal, multifidus, rectus femoris, gluteus maximus and tensor fascia lata, and the following results were found: Trunk muscle activity occurring prior to activity of the prime mover of the limb was associated with hip movement in each direction. The transversus abdominis muscle was invariably the first muscle that was active during hip stabilization exercises.[10] Based on these studies, we considered that the transversus abdominis muscle should be actively involved in every movement. In the evaluation of postural stabilization, we recorded that the Beiring Sorenson test results were significantly increased after treatment. Although abdominal core muscle weakness has been related to lower extremity injury, among previous studies on hip strengthening and PFPS, only Earl's study has included postural stabilization measurements. Earl stated that lateral endurance was increased but anterior and posterior endurance was not, which was similar to the result of our study.[14] Because we did not use the lateral endurance test in our study.

In the published literature, muscle strength and endurance are usually assessed by isokinetic test to evaluate the effect of open/closed kinetic chain exercises. Increase in strength, endurance, and functional performance, and reduction in subjective complaints of PFSP patients are also recorded, but there are no significant difference between the groups.[12,33,34] Tang reported that the closed kinetic chain exercise in 60°/s was selective for VMO activity.[34] In order to strengthen trunk, hip and leg muscles, nine different exercises were examined using EMG analysis in 30 healthy volunteers by Ekstrom et al. Side step-up and lunge for VMO strengthening, bridge on one leg and raising contralateral arm/leg in crawling position for hamstring, and side bridge and bridge on single leg for the multifidus were recommended based on EMG activity.[35] We used these exercises in our treatment program and recorded an increase in both strength and endurance for quadriceps and hamstring muscles isokinetically. It is difficult to compare these values directly to previously reported results because of different measurement and normalization techniques that have been used. There are many studies determining reduction in the strength of hip muscles on the site of pain in patients with PFPS, and exercises for hip and pelvic muscles should be included in treatment.[7,36] In our study, although we used exercises that included trunk and hip muscles, we did not use an isokinetic system in evaluation. Ott indicated that VMO and vastus lateralis (VL) activation decrease in PFPS patients with elevated knee pain. Abdominal muscles and trunk extensor muscles work in the form of co-contraction and also control anterior pelvic tilt. Anterior pelvic tilt is believed to be associated with femoral internal rotation and adduction, which plays an important role in PFPS by increasing the valgus angle in the knee, thus causing abnormal lateral patellar tracking that brings about pain. With a decrease in pain, strengthening around the knee can improve.[37]

Lowry et al. evaluated the flexibility of the hamstring muscles in 5 patients with PFPS and measured 20° limitation in knee extension. In our study, there was a 23° limitation in the first group, and 30° in the second group. Lowery did not measure the limitation after treatment.[28] Limitation was decreased in both groups after treatment in our study.

Limitations of the study

This study analyzed female patients only to ensure standardization in the treatment, and to achieve successful results. Further studies are needed to determine whether the same results could be obtained for males as well. Flexibility of other muscles that play a role in the etiology of PFPS should be evaluated and results should be compared with quadriceps, tensorfascia lata and gastrocnemius etc. Flexibility of the hamstring muscle group only was evaluated in this study. Given patient' complaints about stair climbing & descending, a stair test could have been used in addition to the TUG, walking and one-leg-hop tests to evaluate function in this study. We examined only extensor and flexor endurance in our study. Lateral endurance should be also considered to improve effectiveness of the study. For more objective results, ultrasound and EMG studies may be utilized to understand if there is an increase in muscle mass or in the number of the muscle fibers involved in the activity.

The addition of postural stabilization exercises to a 6-week knee exercise program was more effective in improving strength and function and reducing pain in females with PFPS.

Conflics of Interest: No conflicts declared.

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