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The effect of hip and knee exercises on pain, function, and strength in patients with patellofemoral pain syndrome: a randomized controlled trial

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Background/aim: The role of hip muscles in the rehabilitation of patellofemoral pain syndrome has recently received interest. The aim of this study was to compare the efficiencies of hip exercises alongside knee exercises versus only knee exercises on pain, function, and isokinetic muscle strength in patients with this syndrome.

Materials and methods: Fifty-five young female patients (mean age: 34.1 ± 6.2 years; mean BMI: 25.9 ± 3.9 kg/m^2) with patellofemoral pain syndrome were included. The patients were randomized into groups of hip-and-knee exercises and knee-only exercise programs for 6 weeks with a total of 30 sessions at the clinic. Both groups were evaluated before therapy, after 6 weeks of a supervised exercise program, and after 6 weeks of an at-home exercise program. The outcome measures were muscle strength, pain, and both subjective and objective function.

Results: The improvements of the patients in the hip-and-knee exercise group were better than in patients of the knee-only exercise group in terms of scores of pain relief ($P < 0.001$) and functional gain ($P = 0.002$) after 12 weeks.

Conclusion: We suggest additional hip-strengthening exercises to patients with patellofemoral pain syndrome in order to decrease pain and increase functional status.

Key words: Patellofemoral pain syndrome, exercise, knee, hip, pain, function, muscle strength

1. Introduction

Patellofemoral pain syndrome (PFPS) is often used as an umbrella term for anterior or retropatellar pain. It is a common source of knee pain, especially in the physically active female population (1–6).

Treatment methods, such as vastus medialis oblique retraining, open kinetic chain exercises, and isokinetic muscle strengthening, were the most effective over a short period of time; however, they were not more effective than home-based exercise programs (7). Quadriceps-strengthening exercise therapy is commonly recommended for patients suffering from PFPS (7). However, PFPS is associated with decreased hip strength, specifically in the abductors and external rotators (1,2,8–16). Since the hip abductors can affect knee valgus by controlling the frontal plane position of the femur, increasing hip abduction strength may help these patients (17).

The importance of hip abductors, external rotator muscles, and extensor-strengthening programs for PFPS has received increased attention in recent years (7). Biomechanically, weakness in the hip musculature could lead to increased femoral adduction and medial rotation during dynamic weight-bearing activities, which would increase the lateral patellofemoral joint vector, leading to patellar facet overload (1,2,5,14).

However, there are limited numbers of controlled studies on additional hip-strengthening exercises in PFPS (3,4,18–22). Sex bias (18,19) and small sample size (3,4,16,19,21) were common problems in most of these studies. Interestingly, specific causes for differential diagnosis of knee pathologies or coexistence of different knee problems confirmed by knee radiographs or magnetic resonance imaging (MRI) were not investigated in the previous studies. Intraarticular lesions, such as meniscus and ligament injuries, were not evaluated in these studies and only clinical PFPS cases were included in these previous reports.

This study aimed to indicate the hip exercises in addition to knee exercises with regard to pain, function, and isokinetic muscle strength in young sedentary women with PFPS.

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2. Materials and methods

2.1. Flow chart diagram

A flow chart diagram of this study is shown in Figure 1. Group A (N = 27) consisted of patients receiving only knee exercises. Group B (N = 28) consisted of patients receiving both hip and knee exercises.

2.2. Inclusion and exclusion criteria

Inclusion criteria (19,23) were: 1) sedentary female patients ranging from age 20 to 45; 2) patients with a full range of motion of the knee joints; 3) presence of anterior or retropatellar knee pain during at least 3 of the following activities: ascending/descending stairs, squatting, hopping/running, and prolonged sitting; 4) insidious onset of symptoms unrelated to a traumatic incident and persistence of symptoms for at least 4 weeks; 5) a score of at least 3 on the visual analog scale (VAS); 6) presence of pain on palpation of the patellar facets; and 7) presence of pain on stepping down from a 25-cm step or double-legged squat.

The exclusion criteria (19,23) were: 1) current significant injury affecting lower limb joints; 2) surgery of the knee joint; 3) signs or symptoms or MRI findings of intraarticular pathologic conditions such as effusion, meniscal, or cruciate or collateral ligament involvement; 4) tenderness of the patellar tendon or iliotibial band or pes anserinus tendon; 5) patellar subluxation or dislocation; 6) signs of patellar apprehension; 7) referred pain with hip pain, or back pain, or sacroiliac joint pain; 8) acute strain or sprain; and 9) current use of nonsteroid antiinflammatory drugs or corticosteroids.

2.3. The setting

The study was planned and exercise sessions were performed in the orthopedic rehabilitation and isokinetic test units of the Department of Physical Medicine and Rehabilitation. This investigation was approved by the committee on research ethics at the institution (ethic approval number: 0449/18.01.2012) in accordance with the Declaration of the World Medical Association and informed consent was obtained as required.

2.4. Patients

Prior to participation, written informed consent was obtained from all of the patients. In total, 73 females were screened for participation. Fifty-five of the 73 patients screened met the study inclusion criteria and agreed to participate and were randomly assigned to a knee-only exercise or knee-and-hip exercise group. Fifty-five young sedentary female patients (mean age: 34.1 ± 6.2 years; mean BMI: 25.9 ± 3.9 kg/m^2) with PFPS were included after detailed clinical and radiological evaluations.

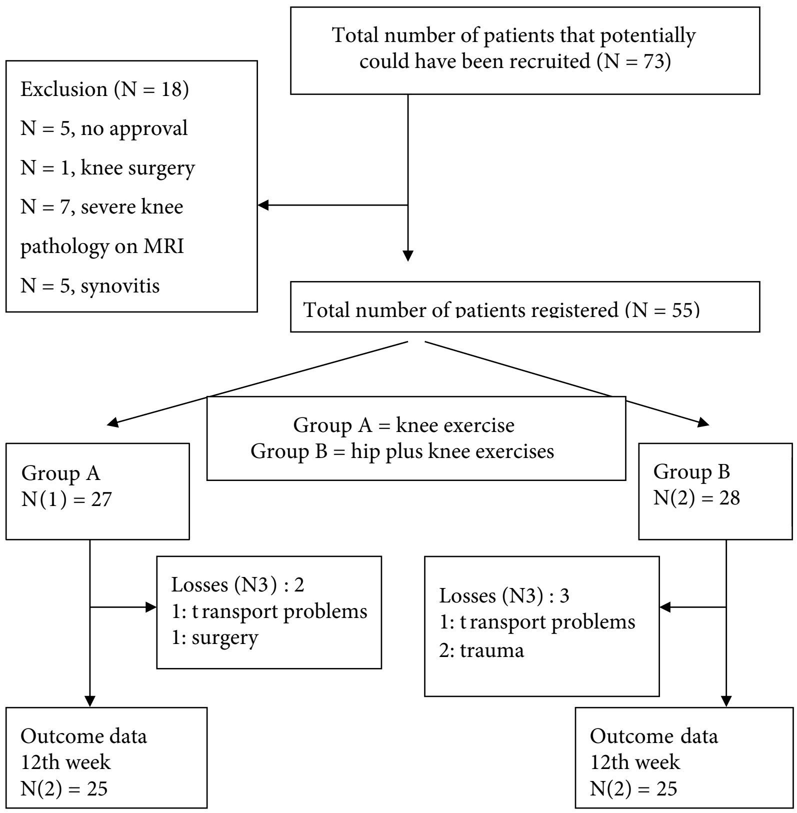

Figure 1. Flow diagram of the study.

2.5. Randomization

At the beginning of the program, a nurse prepared 56 small pieces of opaque paper numbered as 1 or 2, which were folded with the treatment on the inside, and patients picked these small papers from the box. The randomization was performed by this system and patients were divided into 2 groups: knee-only exercise and hip-and-knee exercise groups.

This study was planned as a 12-week prospective, randomized controlled study. Thirty sessions of exercise were supervised by the physical therapist at the clinic. The physician performing the baseline, week 6, and week 12 evaluations and collecting data was masked. Group allocation was hidden from observers using empty patient files prepared by a nurse. The success of masking was checked by asking verbal questions about group allocation. Patients were not blind to the treatment group because of the nature of the exercise programs. Five patients dropped out, meaning a total of 50 patients were entered for the final statistical analysis. A minimum of a 1-cm reduction in the VAS score was considered clinically significant (24). At least 23 subjects needed to be included to the study according to the power analysis at alpha level of 0.05 and beta level of 0.1 (90% power) for a 1-cm reduction in pain on each 10-cm VAS.

2.6. Patient characteristics

The baseline characteristics of the patient groups are summarized in Table 1.

Table 1. Baseline data: mean (SD), median (IQR), or n (%).

Group	Knee group	Hip-and-knee group	P-value
Item	(n = 25)	(n = 25)	
Age	35.0 (5.9)	33.3 (6.5)	0.323
Body mass index (kg/m^2)	26.4 (3.5)	25.5 (4.4)	0.449
Education level			0.771
Primary	18 (72%)	16 (64%)	
High school	4 (16%)	6 (24%)	
University	3 (12%)	3 (12%)	
Job			0.758
Housewife	18 (72%)	17 (68%)	
Office work	7 (28%)	8 (32%)	
Symptoms (months ago)	6 (4–24)	8 (4–24)	0.258
Affected knee, right/left	15/10	12/13	0.395
Pain – resting (/10)	3 (3–4)	3 (3–4)	0.756
Pain – standing (/10)	5 (4–6)	4 (3–5)	0.523
Pain – walking (/10)	5 (4–6)	5 (4–5.5)	0.721
Pain – running (/10)	6 (5–7)	6 (5–7)	0.632
Pain – prolonged sitting (/10)	5 (4–7)	5 (4–6.5)	0.453
Pain – kneeling (/10)	6 (5–8)	6 (6–7)	0.335
Pain – squatting (/10)	6 (4.5–7)	6 (5–7)	0.643
Pain – stairs (/10)	6 (5.5–7)	7 (5.5–7)	0.423
Pain – ramp (/10)	6 (5.5–7)	7 (6–7)	0.256
3-limb hop (cm)	249.9 (53.4)	244.2 (59.8)	0.823
One-leg squat (N/30 s)	11 (10–13)	12 (9–13)	0.634
Step-down (N/30 s)	9 (8–11.5)	10 (8.5–11.0)	0.623
Kujala function score (/100)	72.4 (8.5)	71.4 (5.5)	0.214
Hip abductor peak torque (Nm)	39.2 (18.6)	37.0 (16.5)	0.453
Hip external rotator peak torque (Nm)	27.3 (12.9)	28.6 (10.3)	0.421

2.7. Treatment program

2.7.1. Patient education of both groups

Patient education consisted of recommendations to both groups, such as avoiding prolonged sitting, low-chair sitting, cross-legged sitting, kneeling, stair-climbing, and squatting. Only a cold pack was prescribed for pain control. Other pain medications were restricted.

2.7.2. Exercise program for both groups

A therapist-supervised exercise program of thirty sessions (5 days a week for 6 weeks) was given to both groups. Each session started with a 5-min warm-up, continued with 20 min of lower extremity stretching and strengthening exercises, and concluded with a 5-min cool-down. Elastic resistance exercises were performed using green TheraBand latex exercise bands (TheraBand, USA). Exercises utilizing elastic resistance were standardized to the maximum resistance at which each patient was able to perform 10 repetitions of the exercise. The maximum load and resistance for all strengthening exercises were evaluated during the first treatment session (20).

2.7.3. Exercise program for the knee-only exercise group

2.7.3.1. Lower extremity stretches

Patients were asked to perform 3 repetitions of supine hamstring stretching and standing quadriceps, iliotibial band, and gastrocnemius stretching exercises twice a day (Figure 2). Patients were asked to hold the muscle in contraction for 10 s in each exercise.

2.7.3.2. Isometric quadriceps-strengthening exercise

A towel was placed under the knees in the supine position. Patients were asked to repeat the exercise twice a day with 20 initial repetitions, after which 5 repetitions were added every following week (Figure 3). Patients were asked to hold the muscle in contraction for 10 s in each exercise.

2.7.3.3. Straight leg raise exercise

Patients were instructed to perform the exercise twice a day with 10 repetitions (Figure 4). Patients were asked to hold the muscle in contraction and work up to holding the contraction for 3.5 s in each exercise.

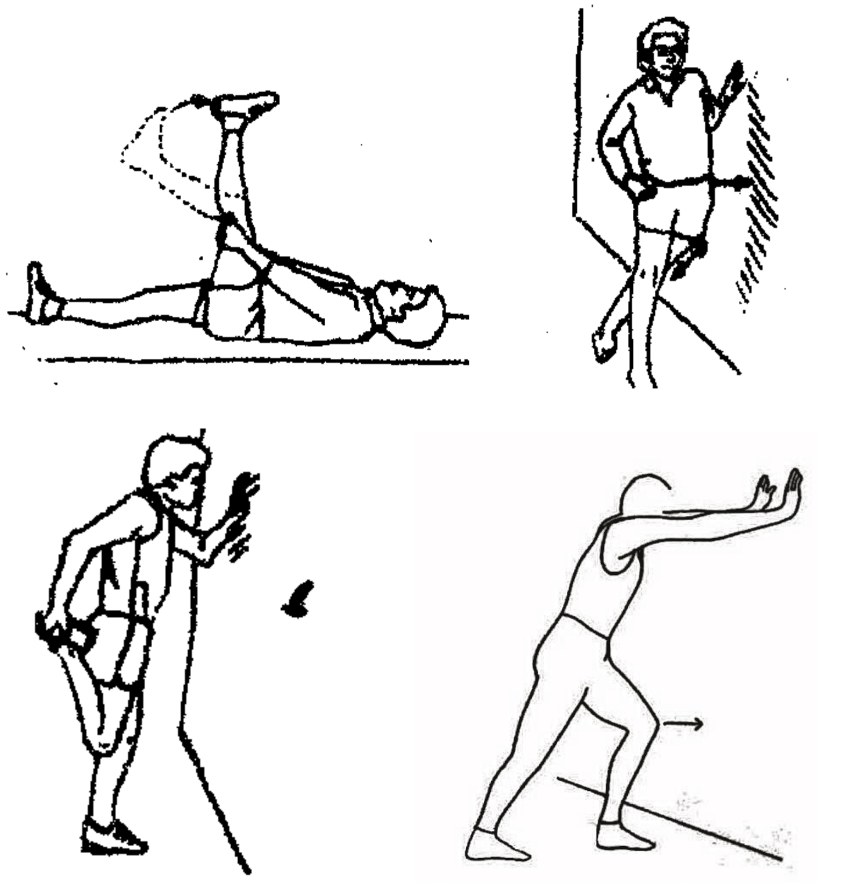

Figure 2. Hamstring, iliotibial band, quadriceps, and gastrocnemius stretching exercises for both groups (exercise booklet).

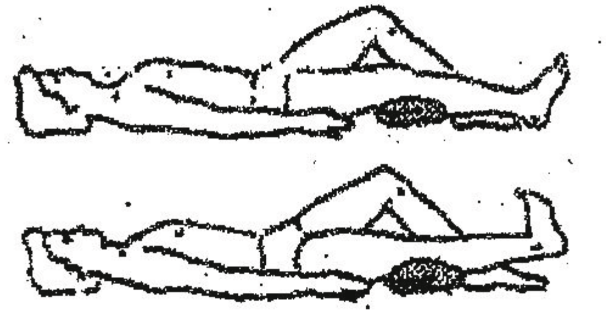

Figure 3. Isometric quadriceps exercise for both groups (exercise booklet).

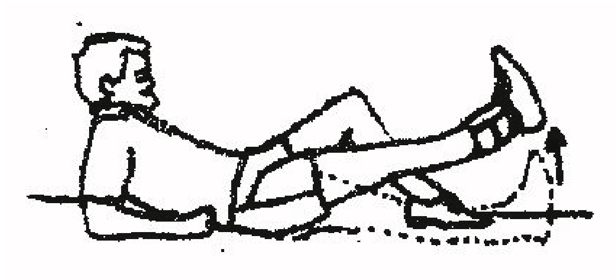

Figure 4. Straight leg raise exercise for both groups (exercise booklet).

2.7.3.4. Minisquatting exercise

Patients were asked to repeat 10 repetitions of 30°–45° (20) knee flexion and extension while the patient's back and arms were supported by a wall twice a day (Figure 5). Patients were asked to hold the muscle in contraction for 10 s in each exercise.

2.7.3.5. Knee extensor-strengthening exercise

Patients were asked to repeat this exercise twice a day with an initial 5 repetitions; 5 repetitions were added every following week (Figure 6). Patients were asked to hold the muscle in contraction for 3.5 s in each exercise.

2.7.4. Exercise program for the hip-and-knee exercise group

The following exercises were added to the knee exercises as described above.

2.7.4.1. Hip abductor-strengthening exercises

Patients were instructed to perform 5 repetitions of 30°–35° standing hip abductions with an elastic resistance exercise twice a day (Figure 7); 5 repetitions were added every following week. Patients were asked to hold the muscle in contraction for 3.5 s in each exercise.

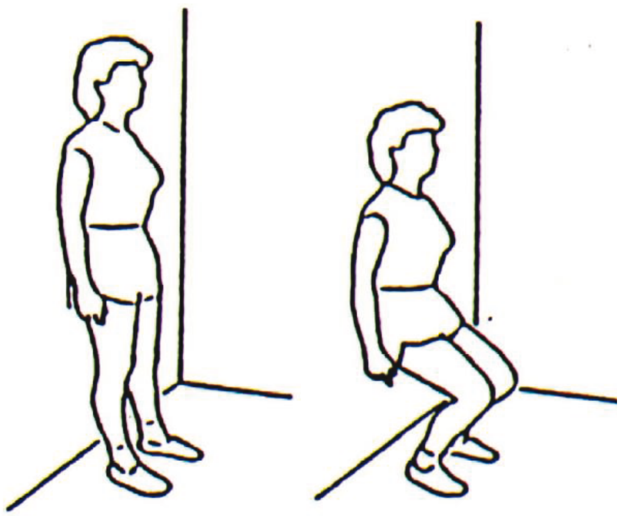

Figure 5. Closed kinetic chain (minisquat) exercise for both groups (exercise booklet).

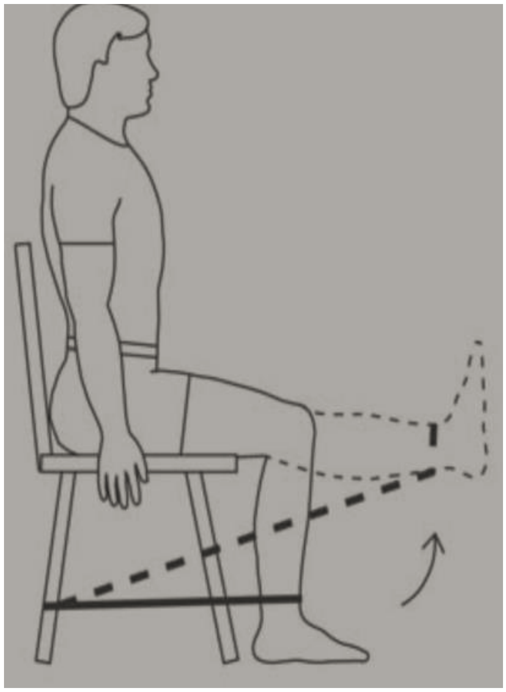

Figure 6. Elastic resistance quadriceps-strengthening exercise for both groups (exercise booklet).

2.7.4.2. Hip external rotator-strengthening exercises

A towel was placed between the thighs. Patients were instructed to externally rotate the hip to approximately 30° and then hold the contraction for 3.5 s (Figure 7). Patients were instructed to perform this exercise twice a day with an initial 5 repetitions; 5 repetitions were added every following week. After five sessions a week for 6 weeks (30 sessions) with the supervised exercise program at the clinic, patients were instructed to continue with 6 weeks of an at-home exercise program and follow-up visits.

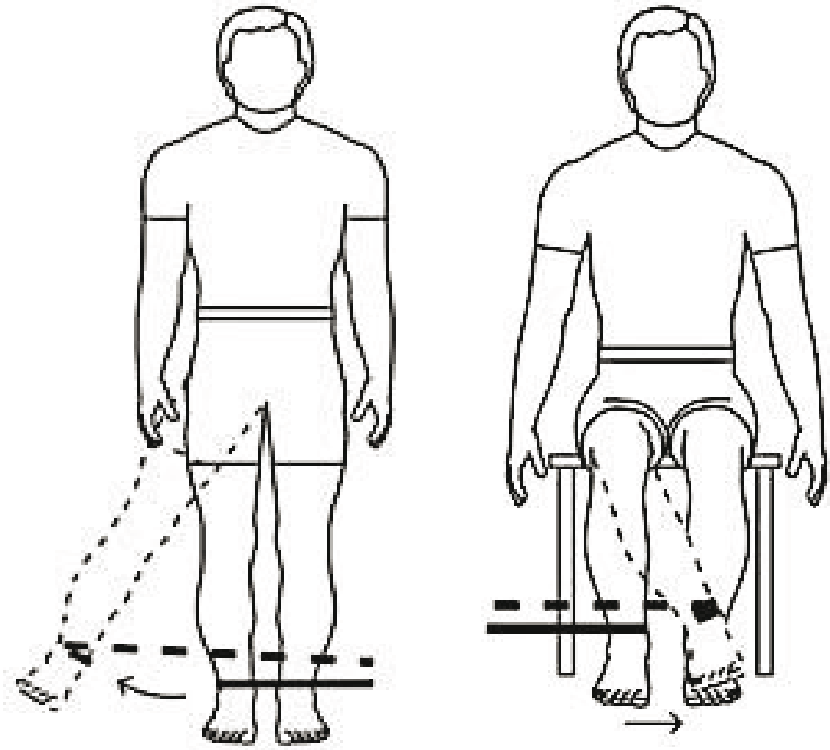

Figure 7. Elastic resistance strengthening exercises for the hip-and-knee exercise group (exercise booklet).

2.8. Measurement of outcome

2.8.1. Primary outcome measures

The three-limb hop test, one-leg squat test, and step-down test were used to assess objective patellofemoral function at follow-up visits (25–28).

The Kujala Anterior Knee Pain Scale questionnaire was selected for self-reported functional activity level of the patients (29,30). The composite score ranges from 0 to 100, with 100 indicating no functional limitation.

Pain in 9 different activities (resting, standing, walking, running, prolonged sitting, kneeling, squatting, stairs, and ramp) was measured using a VAS, in which 0 indicated no pain and 10 indicated the most pain imaginable (31).

The values of the isokinetic muscle strength test (19) for knee extension (60°/s and 180°/s), hip flexion (60°/s and 120°/s), hip abduction (60°/s and 120°/s), and hip external rotation (30°/s and 60°/s) were calculated using an isokinetic dynamometer (System 4 Pro; Biodex, USA). Maximal isokinetic tests were applied to the patients for five repetitions of combined concentric–concentric contractions after 3 trials by the same physician.

2.8.2. Secondary outcome measures

Trendelenburg and muscle tightness tests (Thomas test, Ober test, Ely test, Silfverskiöld test, and hamstring tightness test) were compared before and after the therapy as positive or negative test results (25,28).

The scores of patellar tilt, patellar grind, and patellar compression tests were also compared. Quadriceps atrophy (cm), Q-angle (degrees), and number of tender points (superior and inferior medial and lateral of the patella) were also evaluated (25).

2.9. Baseline radiologic evaluation

Images with a standard knee anterior–posterior, lateral view with 30° knee flexion and a Merchant view with 45° knee flexion were obtained. The angle of the sulcus and the lateral patellofemoral angle (32) were calculated by the same physician using Merchant views of the patellofemoral joints. A Goldseal Signa Excite HD 1.5T MRI device (GE, USA) was used for the evaluation of the knee joint.

2.10. Statistics

NCSS/PASS 2000 statistical package programs were used for power analysis and SPSS 11.5 for Windows was used for the remaining statistics. The significance of intergroup differences for the means and medians were evaluated using Student's t-test for parametric variables and the Mann–Whitney U test for nonparametric variables. Pearson's chi-square test and Fisher's exact result chi-square test were used for categorical variables. Bonferroni adjustments for multiple comparisons or a Wilcoxon signed-rank test were applied to find the follow-up time for statistically significant differences. $P < 0.05$ was accepted for statistically significant results within the 95% confidence interval.

3. Results

3.1. Patient characteristics

Fifty of the fifty-five patients completed the study (drop-out rate was 9.1%). There were no differences between the baseline characteristics of groups (P > 0.05).

3.2. Frequency of malalignments

The frequencies of malalignments (22 versus 23 patients) and generalized ligamentous laxity (2 versus 2 patients) were also not different between groups (P > 0.05).

3.3. Radiologic results

There were no statistically significant differences in the radiographic sulcus angle [138.8° ± 5° (128°–148°) versus 138.2° ± 6° (128°–154°)] or radiographic lateral patellofemoral angle [medial or parallel in 3 versus 2 patients] between groups (P > 0.05). Meniscus lesions of lower stages (16 versus 15 patients) were common MRI findings in both groups (P > 0.05).

3.4. Pain scores

The hip-and-knee exercise group showed higher scores of improvement than the knee-only exercise group in regard to pain relief scores of resting, standing, walking, running, squatting, stairs, and ramp at weeks 6 and 12, and pain relief scores of prolonged sitting and kneeling at week 12 (P < 0.017). The comparisons of pain relief scores and the mean values of the VAS scores at follow-up are also shown in Table 2 and Figure 8.

Table 2. Outcome data at 6 and 12 weeks: median (IQR). The comparisons of pain scores in both groups at follow-up.

Group Item	Knee group	Hip-and-knee group	Knee group	Hip-and-knee group
	At 6 weeks (n = 25)		At 12 weeks (n= 25)	
Pain (/10)				
Resting change	2 (1.5–3) [a] –1 (–2 to 0)	1 (0–2) [a] 3 (–3 to –2)	2 (1.5–3) [b] –1 (–2 to 0)	1 (0–2) [b] 3 (–3 to –2)
P-value [c]	<0.001		<0.001	
Standing change	3 (2–4) [a] –1 (–2 to –1)	1 (1–2) [a] 3 (–3 to –2)	3 (2–4) [b] –2 (–2.5 to –1)	1 (0.5–2) [b] –3 (–3 to –2)
P-value [c]	<0.001		0.002	
Walking change	4 (3–5) [a] –2 (–2 to 0)	2 (2–3) [a] –3 (–3 to –2)	4 (3–5) [b] –1 (–2 to 0)	2 (2–3) [b] –3 (–3 to –2)
P-value [c]	<0.001		<0.001	
Running change	5 (4–6) [a] –1 (–2 to 0)	3 (3–5) [a] –3 (–4 to –1)	5 (4–6) [b] –1 (–1.5 to 0)	3 (3–5.5) [b] –3 (–3.5 to –1)
P-value [c]	0.003		<0.001	
Prolonged sitting change	4 (3–5) [a] –1 (–2 to –1)	3 (2–4) [a] –3 (–3 to –1.5)	4 (3.5–5) [b] –1 (–2 to 0)	3 (2–4.5) [b] –2 (–3 to –1.5)
P-value [c]	0.021		0.005	
Kneeling change	4 (3–5.5) [a] –2 (–3 to –0.5)	4 (2–5.5) [a] –3 (–3 to –1.5)	5 (3.5–6) [b] –1 (–2.5 to 0)	3 (2–5) [b] –3 (–4 to –1.5)
P-value [c]	0.035		0.004	
Squatting change	4 (3–5) [a] –2 (–2 to 0)	3 (2–4) [a] –3 (–4 to –2)	4 (4–5.5) [b] –1 (–2 to 0)	3 (2–4.5) [b] –3 (–4 to –1)
P-value [c]	0.003		<0.001	
Stairs change	5 (3–6) [a] –2 (–2 to –1)	3 (3–4) [a] –3 (–4 to –2)	5 (3.5–6) [b] –1 (–2 to –0.5)	3 (3–5) [b] –3 (–4 to –1.5)
P-value [c]	<0.001			
Ramp change	4 (3–6) [a] –2 (–3 to –0.5)	4 (3–4.5) [a] –3 (–3.5 to –2)	5 (4–6) [b] –2 (–2 to 0)	4 (3–4.5) [b] –2 (–4 to –2)
P-value [c]	0.007		0.005	

a: Statistically significant intragroup differences between baseline and week 6 (P < 0.001), b: statistically significant intragroup differences between baseline and week 12 (P < 0.001), c: Bonferroni adjustment. P < 0.017 accepted as statistically significant for intergroup comparison.

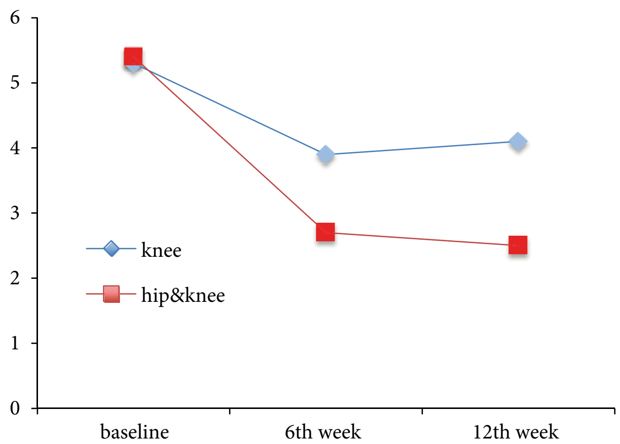

Figure 8. Mean pain scores in both groups at follow-up.

3.5. Function scores

The hip-and-knee exercise group performed a higher number of repetitions than the knee-only exercise group in the one-leg squat test at week 6 and step-down tests at weeks 6 and 12 ($P < 0.017$). The comparisons of these tests are summarized in Table 3.

Patellar grind and compression test scores, Q-angle, quadriceps atrophy, and the number of tender points were not significantly different between the groups at follow-up ($P > 0.025$). These test results are shown in Table 4.

The hip-and-knee exercise group had higher scores in functional gains on the Kujala scale than the knee-only exercise group at follow-up ($P < 0.017$). Kujala score comparisons are shown in Table 5 and Figure 9.

3.6. Isokinetic peak torque values

The hip-and-knee exercise group also had higher peak torque in isokinetic strength values of 60°/s hip abduction and 60°/s hip external rotation than the knee-only exercise group in intergroup comparisons after 6 weeks ($P < 0.017$). The comparisons of isokinetic test values are shown in Table 6. Isokinetic peak torque values of hip abduction (60°/s) and external rotation (60°/s) are illustrated in Figures 10 and 11.

4. Discussion

The results of this randomized controlled study demonstrated that the 6-week intervention of knee-only or hip-and-knee exercises both led to improved function, increased isokinetic muscle strength, and reduced pain in sedentary females with PFPS. For most outcome measures, including pain, objective functional tests, self-reported function of Kujala index, and isokinetic peak torque values of hip abductor and external rotator strength, statistically significant improvements were noted in the hip-and-knee exercise group over the knee-only exercise group.

In the literature, there are limited numbers of controlled studies about additional hip-strengthening exercises in PFPS (3,4,18–22). Interestingly, conventional radiographs and MRI were not investigated in all of these studies. Therefore, one of the advantages of this study was the presence of radiologic investigation, including knee radiographs and MRI, compared to other studies (3,4,18–22). This study included knee problems as confirmed by radiologic evaluations. Another advantage of the present study was the highly comprehensive

Table 3. Outcome data at 6 and 12 weeks: mean (SD) or median (IQR). The intragroup and intergroup comparisons of objective functional tests in both groups at follow-up.

Group Item	Knee group	Hip-and-knee group	Knee group	Hip-and-knee group
	At 6 weeks (n = 25)		At 12 weeks (n = 25)	
Test				
3-limb hop change (cm)	301.9 (58.8) [a] [52.0 (35.3)]	311.9 (61.9.8) [a,c] [67.7 (32.2)]	315.2 (57.1) [b] [65.3 (34.3)]	328.7 (71.4) [b] [84.4 (46.6)]
P-value	0.109		0.104	
One-leg squat change (N)	15 (13–18) [a] [4 (2–5)]	16 (14.5–19.5) [a] [6 (4.5–7.5)]	15 (13–17) [b] [4 (2.5–5)]	17 (15–19.5) [b] [5 (3–8)]
P-value [c]	0.007		0.027	
Step-down change (N)	14 (12–15.5) [a] [4 (2.5–5.5)]	15 (14–16.5) [a] [6 (4.5–6.5)]	14 (13–15.5) [b] [4 (1.5–6.5)]	16 (13.5–17) [b] [6 (4–7)]
P-value [c]	0.008		0.012	

a: Intragroup comparisons before and after therapy and Bonferroni adjustment, $P < 0.025$ accepted as statistically significant; b: intergroup comparisons of improvement percentages, $P < 0.025$ accepted as statistically significant; c: Bonferroni adjustment. $P < 0.017$ accepted as statistically significant for intergroup comparison.

Table 4. Outcome data after treatment: mean (SD). The intragroup and intergroup comparisons of clinical tests in both groups at follow-up.

Group Item	Knee group after treatment (n = 25)	Hip-and-knee group after treatment (n = 25)	P-value [b]
Test			
Patellar tilt change	6 (24%) 8 (32%)	6 (24%) 8 (32%)	0.109 0.039
P-value [a]	–		
Patellar grind change	6 (24%) 7 (28%)	6 (24%) 9 (36%)	0.016 0.021
P-value [a]	0.544		
Patellar compression change	7 (28%) 5 (20%)	6 (24%) 10 (40%)	0.063 0.002
P-value [a]	0.123		
Quadriceps atrophy (cm) change	0 (0–0.75) 0 (–0.5 to 0)	0 (0–0.75) 0 (–0.25 to 0)	0.667
P-value [a]	0.038	0.020	
Q-angle (°) change	18.5 (4.3) –2.0 (1.2)	20.2 (3.2) –2.2 (1.3)	0.577
P-value [a]	<0.001	<0.001	
Tender point count change	0 (0–1) 0(–0.5 to 0)	0 (0–0) 0(–0.6 to 0.8)	0.135
P-value [a]	0.058	0.005	

a: Statistically significant differences between baseline and week 6 (P < 0.001), b: statistically significant differences between baseline and week 12 (P < 0.001), c: Bonferroni adjustment. P < 0.017 accepted as statistically significant for intergroup comparison.

Table 5. Outcome data after treatment: mean (SD). The intragroup and intergroup comparisons of Kujala test scores in both groups at follow-up.

Group	Knee group At 6 weeks (n = 25)	Hip-and-knee group At 6 weeks (n = 25)	Knee group At 12 weeks (n = 25)	Hip-and-knee group At 12 weeks (n = 25)
Item				
Kujala test score change	79.1 (7.6) [a] 6.8 (6.1)	85.4 (5.8) [a] 14.0 (6.2)	77.9 (6.6) [b] 5.6 (6.9)	83.0 (6.8) [b] 11.6 (5.8)
P-value [c]	<0.001		0.002	

a: Statistically significant differences between baseline and week 6 (P < 0.025), b: statistically significant differences between baseline and week 12 (P < 0.025), c: Bonferroni adjustment. P < 0.017 accepted as statistically significant for intergroup comparison.

outcome measurements for clinical and laboratory evaluations, including detailed physical examinations, pain assessments, objective and self-reported functional tests, and isokinetic muscle strength measurements at the follow-ups.

The importance of strengthening hip abductors and external rotator muscles in the treatment of PFPS has received increased attention in recent years. This approach, based on systematic reviews, demonstrated the weakness of hip abductors and external rotators in women with PFPS

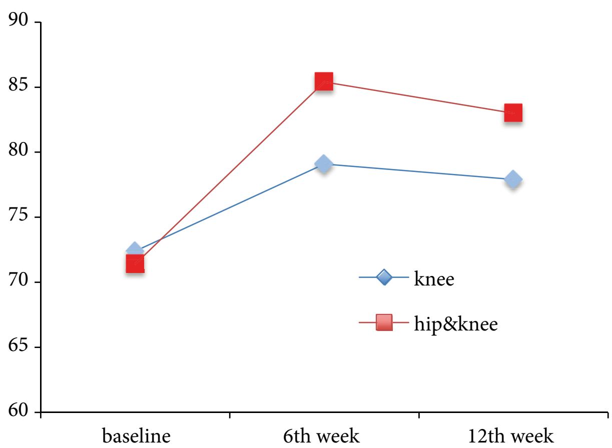

Figure 9. Mean Kujala function scores in both groups at follow-up.

(1,2). Biomechanically, weakness of the hip musculature could lead to increased femoral adduction and medial rotation during dynamic weight-bearing activities, which would increase the lateral patellofemoral joint vector and lead to patellar facet overload (1,2,5,14).

Various randomized controlled studies evaluating hip and knee exercises with different styles and durations have been reported for the rehabilitation of the patients with patellofemoral pain syndrome (3,4,18–21). Although the studies by Nakagawa et al. (19), Fukuda et al. (20), and Dolak et al. (4) provided evidence for supporting hip strengthening for female persons with PFPS, the isolated influence of hip muscle strengthening on PFPS was demonstrated by Khayambashi et al. (21). It is important to emphasize that these previous studies had small sample sizes (3,19,21). There was also a limited number

Table 6. Outcome data after treatment: mean (SD). The intragroup and intergroup comparisons of isokinetic peak torque measurements (Nm) in both groups at follow-up.

Group Item	Knee group At 6 weeks	Hip-and-knee group At 6 weeks	Knee group At 12 weeks	Hip-and-knee group At 6 weeks
Peak torque (Nm)				
Knee extension				
(60°/s) Change	91.1 (29.3) [a] 26.1 (18.3)	87.5 (23.4) [a] 26.8 (21.2)	80.1 (28.2) [b] 15.0 (26.1)	74.2 (23.7) [b] 13.5 (20.6)
P-value [c]	0.890		0.816	
Knee extension (180°/s)				
Change	48.5 (18.6) [a] 15.5 (14.9)	44.2 (18.3) [a] 10.9 (12.1)	46.0 (15.6) [b] 12.9 (16.6)	38.2 (17.1) 4.8 (14.6)
P-value [c]	0.236		0.074	
Hip flexion				
(60°/s) Change	46.9 (12.8) [a] 9.5 (12.2)	43.7 (11.9) [a] 10.2 (11.5)	48.2 (11.3) [b] 10.9 (9.8)	41.5 (13.4) [b] 8.1 (1.6)
P-value [c]	0.845		0.358	
Hip flexion				
(120°/s) Change	34.0 (12.7) [a] 10.3 (11.1)	30.0 (13.7) [a] 7.5 (13.1)	33.4 (11.8) [b] 9.7 (10.6)	27.3 (10.7) 4.8 (10.4)
P-value [c]	0.434		0.110	
Hip abduction (60°/s) change	48.6 (17.5) [a] 9.4 (14.3)	59.0 (15.0) [a] 22.1 (15.7)	49.1 (15.4) [b] 9.9 (16.3)	48.7 (16.1) [b] 11.7 (15.0)
P-value [c]	0.004		*0.674*	
Hip abduction				
(120°/s) Change	21.6 (12.7) [a] 7. 0 (9.7)	30.0 (14.9) [a] 12.0 (8.2)	22.5 (8.3)[b] 8.0 (7.6)	23.5 (15.1) [b] 5.5 (6.7)
P-value [c]	0.058		0.233	
Hip external rotation (30°/s) change	42.4 (13.3) 7.9 (14.7)	48.2 (14.2) [a] 13.3 (11.9)	42.0 (14.4) [b] 7.4 (12.7)	41.9 (9.7) 7.1 (13.4)
P-value [c]	0.156		0.945	
Hip external rotation (60°/s) change	34.2 (8.5) 6.9 (12.2)	45.4 (13.4)[a] 16.8 (9.6)	33.0 (9.7) 5.7 (12.2)	42.1 (15.0) [b] 13.5 (11.9)
P-value [c]	0.003		0.027	

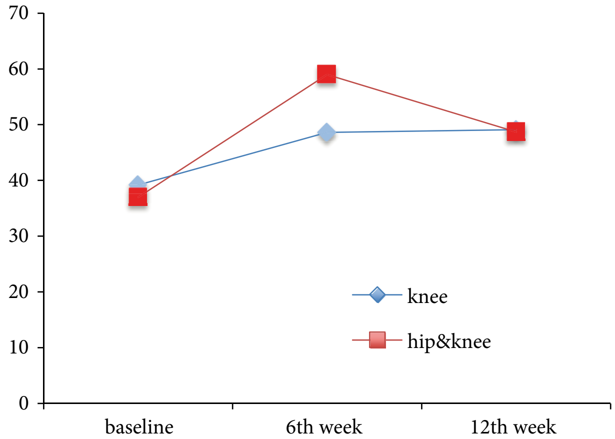

Figure 10. Hip 60°/s abduction–isokinetic peak torque values in both groups at follow-up.

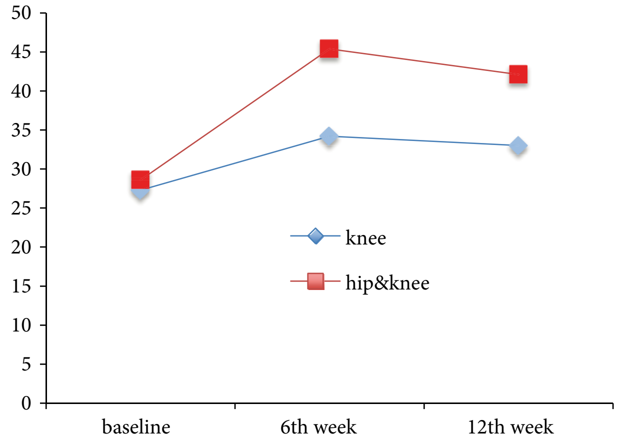

Figure 11. Hip 60°/s external rotation–isokinetic peak torque values in both groups at follow-up.

of randomized controlled studies that had sample size estimation in the literature (20,33).

Fukuda et al. reported similar improvements in patellofemoral pain and function in their 4-week follow-up study, which consisted of 3 groups (12 sessions each for the knee-only and hip-and-knee exercise groups, plus no-exercise controls) (33). Their exercise programs were similar to ours. However, we found higher improvements of pain, function, and hip abduction and external rotation isokinetic strength in the hip-and-knee exercise group than in the knee-only exercise group. It can be explained by the different numbers of sessions (30 sessions versus 12 sessions) or different follow-up durations (12 weeks versus 4 weeks). Unfortunately, strength measurements of the lower extremity muscles were not evaluated in Fukuda et al.'s study. Because of ethical concerns, we did not include a no-exercise control group in our study.

Recently, a long-term study of 54 young sedentary women with a diagnosis of PFPS was performed (20). Twelve sessions of hip and knee exercises were found to be more effective than knee exercises alone in improving long-term function and reducing pain in this 12-month follow-up study.

The present results are also similar to the second study of Fukuda et al. (20). Additionally, this study found that isokinetic muscle strength of the hip abductor and external rotators was improved in the hip-and-knee exercise group compared to the knee-only exercise only group. Fukuda et al. only used the one-limb hop test in their study and found no difference in intergroup comparisons. In contrast, the present study found better scores on the one-leg squat test and step-down test in the hip-and-knee exercise group than in the knee-only exercise group. The greater number of exercise sessions may be responsible for these better and different results. Patients who receive more sessions may develop an exercise habit. This study also evaluated muscle strength using an isokinetic dynamometer. However, a hand dynamometer was used in most of the studies evaluating hip-strengthening exercises in patients with PFPS (2,21,34,35). Most of them showed more improvement in muscle strength after the hip exercise program (2,20,34). Isokinetic peak torque gains of hip abduction and external rotation were more prominent in the hip-and-knee exercise group than in the knee-only exercise group at week 6 of this study. It confirmed effective strengthening for hip abductors and external rotators in the hip-and-knee exercise group.

This study considered that additional hip exercises decreased patellofemoral stress load by inhibiting medial positioning of the patella relative to the tibial tubercle. Therefore, additional hip abductor- and external rotator-strengthening exercises may improve lower extremity biomechanics by decreasing patellofemoral compressive forces; working more muscle mass may cause more pain relief by decreasing nociceptor sensitivity.

There may be some limitations of the present study due to the duration of supervised exercise and home exercise programs. A major limitation of this study may also be the short follow-up duration of 12 weeks. Therefore, long-term recurrences could not be checked. However, education and longer exercise sessions may develop exercise habits in patients. The selection of sedentary females may also be a disadvantage. Some features, including pain perception, functional evaluation, and strength measurements, may be different between males and females. As a result, the findings of this study may not be generalized to the whole population, including males and athletic females. Lastly, the overall findings of this study were derived from an analysis without a control group (group receiving no treatment) because of ethical concerns. Therefore, interpretations should be cautious.

In conclusion, in the rehabilitation of PFPS, strengthening hip abductors and external rotators in addition to knees is more efficient, allowing for muscle training while reducing pain and increasing function and muscle strength. This study strongly recommends hip-strengthening exercises in addition to knee-strengthening exercises in patients with PFPS.

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