ORIGINAL ARTICLE

Could Hip and Knee Muscle Strengthening Alter the Pain Intensity in Patellofemoral Pain Syndrome?

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Abstract

Background: In patellofemoral pain syndrome (PFPS) as a common cause of knee pain in athletes, muscle weakness is proposed to contribute to its pain and dysfunction. This study was conducted to determine whether hip and knee muscles strengthening can accordingly reduce pain.

Methods: In a single blinded, randomized clinical trial, 32 females (52 knees) with PFPS were randomly divided into a case and a control group. All the hip muscles and knee extensor in the case group and only the knee extensor in the control group were tested. In the case of recognizing weakness, they underwent a 4-week strengthening exercise program, after which a retest was taken. Pain as indicated on a visual analogue scale was recorded before and after the intervention.

Results: Both groups revealed pain reduction, although the amount of reduction was significantly greater in the cases compared to the subjects in the control group. Among the muscles selected for strengthening, only the hip flexors, abductors, and external rotators were found related to successful treatment as defined by at least 15% pain reduction on a pain visual analogue scale.

Conclusions: Despite the current concept of focusing on quadriceps strengthening exercise in PFPS in the attempt to reduce pain and dysfunction, the results of this study did not support this idea. More attention should be shifted toward the hip muscles, if a long term and more efficient treatment is targeted.

Keywords: Muscle weakness; Muscle strengthening; Patellofemoral pain syndrome

Introduction

Patellofemoral pain syndrome (PFPS), as a common source of diffused anterior knee pain in young and active individuals, accounts for 25% of all the knee problems in sports medicine clinic.[1,2] Despite its prevalence, the etiology and treatment of this syndrome remain vague and controversial.[3] It has been suggested that factors like abnormal lower limb biomechanics, soft tissue tightness, muscle weakness, overuse and overload may result in increased cartilage and subchondral bone stress and subsequent patellofemoral pain.[2,4] Abnormal muscular factors (weakness and tightness) that alter tracking of the patella in the femoral trochlear notch can contribute to increased patellofemoral contact pressure and result in pain and dysfunction.[5-7] As early as 1976, Nicholas *et al*. emphasized the importance of hip flexor muscle strength in this condition.[8] The hip musculature (especially external rotator and abductor) contributes to pelvic stability and leg alignment during weight bearing activities.[5-7] Thus, it has been theorized that weakness of these muscles may be a contributing factor to this syndrome.

Many non-operative approaches have been developed to treat this syndrome, but no single intervention has been demonstrated as the most effective.[9] Exercise therapy to strengthen quadriceps is often prescribed. Despite the longevity of such treatment, with reported experiments as early as 1922 advocating quadriceps strengthening exercise, its efficacy is still debated.[10,11] The purpose of this study was to evaluate whether a non-operative treatment program emphasizing hip and

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knee strengthening exercise results in decreased patellofemoral pain.

Materials and Methods

The study was carried out in the Physiotherapy Clinic affiliated to the Rehabilitation Faculty of Shiraz University of Medical Sciences, Shiraz, Southern Iran.

After a broad screening test involving all female students residing in Shiraz University of Medical Sciences dormitories, 32 subjects (52 knees) at the age range of 18-30 years (22.62±2.67 years), with PFPS in one or both lower extremities volunteered to participate in the study by signing an informed consent form approved by the university Ethics Ccommittee. They were divided into a case (16 patients, 24 knees) and a control (16 patients, 28 knees) group based on a systemic random allocation strategy (Table 1).

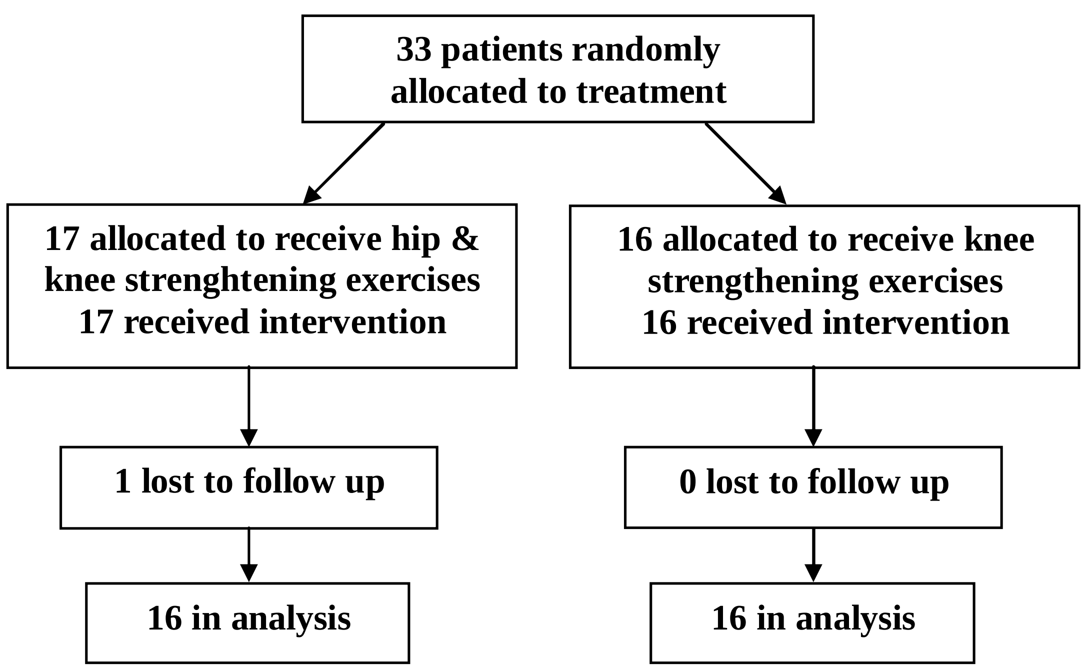
The inclusion criteria were 1. Retro- or peripatellar pain from at least two of the following activities: squatting, prolonged sitting, stair climbing, running, kneeling; 2. Insidious onset of pain without a history of trauma persisting for at least 4 weeks; 3. Pain during patellar compression test, patellar grind test or medial/lateral patellar facet tenderness and 4. No professional sports activity by the subjects.

Subjects were excluded if any of the following conditions was present. 1. Meniscal injury, 2. Cruciate or collateral ligament involvement, 3. Tenderness over iliotibial band, patellar or pes anserinous tendon, 4. A positive history of patellar dislocation, 5. A positive patellar apprehension sign, 6. Knee surgery in the past 2 years, 7. Diagnosis of peri-patellar bursitis, sinding-larsen-johansson and osgood-schlatter disease, 8. Referral pain from the lumbar or hip region, 9. Pes planus or cavus, 10. Leg length discrepancy, 11. Lower limb malignancy, 12. Pregnancy and 13. A positive history of being on a steroidal or non-steroidal medication during the previous 6 months.

By employing a digital myometer (Medical Research ltd, Leeds, UK), muscle strength testing was performed. A good repeatability as indicated by ICC of 0.76 to 0.85 has been reported for this technique with the same device.[12] Pain intensity was marked on a 10 cm visual analogue scale (VAS) for both groups. The subjects followed a 4-week treatment program. At the end of the 4th week, the muscle strength and pain intensity tests were repeated.

During the test procedure, the subjects applied a maximum isometric muscle contraction against the strap of the myometer. After a set of practice trials, 3 consecutive successful trials were recorded. The muscle contraction was held for 5 seconds with 60 sec-

Table 1: Subject allocation chart showing the number of subjects in each group



onds of rest between the trials. The average of the peak force from 3 trials was used for data analysis. The hip flexor, extensor, abductor, adductor, internal and external rotator and knee extensor in the case group and the knee extensor in the control group underwent assessment.

Hip flexion and extension was tested in side lying. The strap of the myometer applied resistance on the anterior (for flexion) and posterior (for extension) aspects of the distal tight at 12 cm proximal to the head of the fibula. Figure 1 displays the technique used to measure the left hip extension strength.

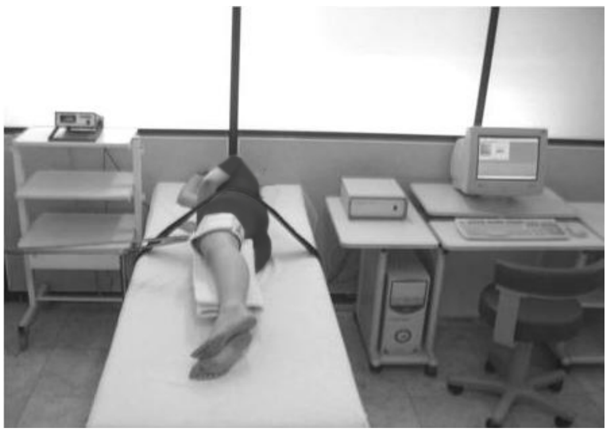


Fig. 1: The technique used to measure left hip extensor strength

Hip abduction and adduction was tested in the supine position. The hip was in neutral position with the knee extended. Resistance was applied on the lateral (for abduction) and medial (for adduction) aspects of the distal tight at 12 cm proximal to the head of the fibula. Figure 2 shows the technique used to measure the right hip adduction strength.

Fig. 2: The technique used to measure right hip adductor strength

Internal and external hip rotations were tested in prone with 90° flexion of the knee. Resistance was applied 15 cm proximal to the lateral malleolus. Figure 3 shows the technique used to measure the right hip internal rotation strength. Knee extension strength was measured in the same position as hip rotation, except that the myometer was placed above the head of the subjects.

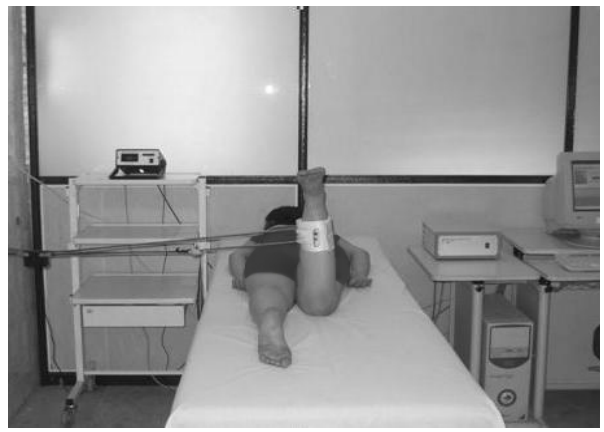


Fig. 3: The technique used to measure right hip internal rotator strength

Exercise was requested to strengthen all the hip muscles and knee extensor in the case group in the subjects suffering from bilateral knee pain and in the presence of any discrepancy in the strength of any muscle group while comparing the affected side with the sound side in unilaterally affected knees. Strengthening exercise in the control group focused only on the quadriceps muscle. The treatment program consisted of progressive resistive exercises for the hip muscles and terminal and 90° to 50° resistive knee extension and mini squat for the quadriceps. The Mc Queen progressive resistive technique was applied to increase exercise resistance.

The data were analyzed, using SPSS software for windows (version 15.0; SPSS Inc, Chicago, Illinois, USA). The non-parametric Wilcoxon and Mann-Whitney U test was used to compare the percentage of the improvement in the muscle strength in the successful and unsuccessful outcomes. Treatment success was defined as a minimum of 1.5 cm reduction in pain on each 10 cm VAS, which has been considered clinically significant.[13] Statistical significance was accepted at the level of $\alpha \leq 0.05$.

Results

The VAS pain score decreased significantly after the intervention (6.68±1.62 to 3.37±1.50, p=0.001 in the case group; and 6.31±1.25 to 4.81±1.79, p=0.005 in the control group) as shown in Table 2. Pain reduction was significantly greater in the cases compared to the subjects in the control group (p=0.032) (Table 3). A significantly better level of treatment success was also achieved in the case group compared to that in the control group (66.7% and 33.3%, respectively, $p < 0.05$). Hip flexion strength increased by 32.95% in 16 lower extremities with successful treatment, compared to 4.25% in 8 extremities with unsuccessful treatment ($p < 0.05$). Hip abductor strength showed 34.75% improvement in the lower extremities, showing a successful outcome and 9.87% in the lower extremities, showing an unsuccessful outcome ($p < 0.05$). The hip external rotator strength in the lower extremities with successful outcome improved 24.21% and 3.25% in the extremities of subjects with unsuccessful results ($p < 0.05$) (Table 4). Improvement in the hip extensor, adductor and internal rotator strength was unrelated to the outcome ($p > 0.05$) (Table 5).

No statistically significant changes were found in the knee extensor strength in both the case and the control groups, when lower extremities with successful and unsuccessful results were compared (Table 6). A comparison between patients with successful treatment in the case and control groups revealed no statistically significant difference. The same results were noticed when the subjects with unsuccessful treatment were compared in the two groups (Table 7).

Table 2: Comparison of pain intensity based on VAS mean before and after intervention in both group

Groups	**VAS** (before)	**VAS** (after)	***P* value**
Case	6.68±1.62	3.37±1.50	0.001
Control	6.31±1.25	4.81±1.79	0.005

Table 3: Comparison of pain intensity based on VAS mean before and after intervention between groups

VAS	**Groups**	**Mean±SD**	***P* value**
Before	case	6.68±1.62	0.266
	control	6.31±1.25	
After	case	3.37±1.50	0.032
	control	4.81±1.79	

Table 4: The percentage of improvement in hip flexion, abduction, and external rotation strength in knees treated successfully and unsuccessfully

	Groups	**Mean**	**SD**	**95%, CI**	***P* Value**
Hip Flexion	Unsuccessful treatment	4.25	1.55	5.77	0.004
	Successful treatment	32.95	6.68	36.73	
Hip Abduction	Unsuccessful treatment	9.87	3.47	13.27	0.003
	Successful treatment	34.75	7.60	39.05	
Hip External rotation	Unsuccessful treatment	3.25	1.26	4.48	0.004
	Successful treatment	24.21	19.16	40.87	

Table 5: The percentage of improvement in hip extension, adduction, and internal rotation strength in knees treated successfully and unsuccessfully

	Groups	**Mean**	**SD**	**95%, CI**	***P* Value**
Hip Extension	Unsuccessful treatment	28.63	6.90	35.39	0.163
	Successful treatment	23.33	4.88	26.09	
Hip Adduction	Unsuccessful treatment	47.88	11.12	55.78	0.060
	Successful treatment	36.46	8.21	41.11	
Hip Internal rotation	Unsuccessful treatment	28.50	4.02	32.44	0.202
	Successful treatment	25.17	5.47	28.26	

Table 6: The percentage of improvement in knee extension strength in knees treated successfully and unsuccessfully (in case and control groups)

Groups		Mean	SD	95%, CI	*P* Value
case	Unsuccessful treatment	50.37	7.18	57.41	0.125
	Successful treatment	43.37	9.28	48.62	
control	Unsuccessful treatment	41.7	5.36	45.02	0.142
	Successful treatment	49.66	9.07	56.92	

Table 7: The percentage of improvement in knee extension strength between case and control groups

Groups		Mean	SD	95%, CI	*P* Value
Unsuccessful treatment	case	50.37	7.18	57.41	0.064
	control	41.7	5.36	45.02	
Successful treatment	case	43.37	9.28	48.62	0.071
	control	49.66	9.07	56.92	
Total	case	45.12	9.12	49.59	0.610
	control	46.56	9.31	51.12	

Discussion

The results of the present study indicated that pain decreased significantly after the intervention in both groups. However, a statistically significant greater reduction was noticed in the case group, which could be attributed to the improvement in the hip muscle strength. Treatment success was found to be related to improvement in the hip flexion strength. Tyler *et al.* reported similar results, suggesting that improvement in the hip flexion strength may provide a stable pelvis during gait and allow it to act eccentrically to prevent the pelvis from going into an anterior pelvic tilt and concomitant femoral internal rotation.[14] Lee demonstrated increased patellofemoral compression force with increasing femoral internal rotation that can result in patellofemoral pain.[15]

Based on the results of this study, improvement in the hip abduction and external rotation can reduce patellofemoral pain. Mascal also showed the positive effect of the hip abductor strength improvement in the treatment of PFPS.[3] The hip external rotator and abductor muscles contribute to pelvic stability and leg alignment by eccentrically controlling femoral internal rotation and influencing the hip adduction during weight bearing activities.[5-7] It is hypothesized that weakness of these muscles may increase the medial femoral rotation and valgus knee movement. These deviations may alter the abduction/adduction moment at the hip or lead to increased Q angle, which may subsequently alter tracking of the patella, increase compressive forces on the patellofemoral joint and ultimately lead to knee pain.[16]

Likewise, Tyler showed that improvement in the hip adductor strength was unrelated to treatment success. Vastus medialis oblique (VMO) has an important role as a medial stabilizer of the patella, assisting normal functioning of the patellofemoral joint.[17,18] It originates from the adductor longus and magnus tendons and the medial intramuscular septum.[19] The purpose of the hip adductor strengthening exercise is usually VMO activation and facilitation. Based on their anatomical finding, Brownstein *et al.*, however, have suggested that simultaneous activation of the knee extensor and hip adductors, not the hip adductor alone, might provide the VMO with a more stable origin and thus facilitate the preferential activity of this component of the quadriceps.[20]

The results of this study were not indicative of the influence of strength improvement of the hip extensor muscles on the knee symptom reduction. This finding is against that of Mascal *et al.*'s study that noticed pain reduction in two PFPS cases going through combined hip extensor and abductor (Gluteous Maximus & Medius) muscle strengthening program. This difference might be due to the fact that the measurement and strengthening techniques we used generally focused on the group as a whole and no attempt was made to separate different muscles.

Treatment success as seen by pain relief was found unrelated to the strength increase in the hip internal rotator muscles. It could be considered relevant to the insignificant effects of these horizontally-oriented, short lever-armed muscles on the factors governing PFPS function. As a key finding of this study, pain reduced in the control group. However, the quadriceps strength improved in the lower extremities with both successful and unsuccessful outcomes, showing that improvement in the quadriceps strength might be unrelated to pain reduction.

A selective hypotrophy of the VMO is usually reported as a common clinical finding in PFPS patients. The VMO is believed to prevent lateral sublaxation by pulling the patella medially during knee extension.[21] Several studies have reported that the EMG VMO/VL ratio in PFPS patients is less than that in healthy subjects with decreased VMO activity.[22,23] Quadriceps strengthening exercises and terminal knee extension are typically administered for PFPS rehabilitation. However, these exercises have not been reported to increase the VMO activity.[24] The only known possible way to selectively strengthen the VMO is, therefore, the use of electrical muscle stimulation. It is also hypothesized that in patients with PFPS, the vastus lateralis (VL) is activated earlier than the VMO, contributing to a laterally directed force on the patella.[25] Therefore, rehabilitation should focus on simultaneous activation of VMO and VL during quadriceps contraction and selective strengthening of VMO.

Treatment success was significantly related to improvement in the hip flexor, abductor and external rotator muscle strength. Improvement in the hip extensor, adductor, internal rotator and knee extensor was found unrelated to successful outcomes.

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Conflict of interest: None declared.

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