The Role of Hip Muscle Function in the Treatment of Patellofemoral Pain Syndrome

Timothy F. Tyler, MS, PT, ATC, Stephen J. Nicholas, MD, Michael J. Mullaney, MPT, and Malachy P. McHugh, PhD
From the Nicholas Institute of Sports Medicine and Athletic Trauma, New York, New York

Background: Previous literature has associated hip weakness with patellofemoral pain syndrome.

Hypothesis: Improvements in hip strength and flexibility are associated with a decrease in patellofemoral pain.

Study Design: Cohort study; Level of evidence, 2.

Methods: Thirty-five patients with patellofemoral pain syndrome, aged 33 ± 16 years (29 women, 6 men; 43 knees), were evaluated and placed on a 6-week treatment program. Hip flexion, abduction, and adduction strengths, Thomas and Ober test results, and visual analog scale scores for pain with activities of daily living as well as with exercise were documented on initial evaluation and again 6 weeks later. Treatment consisted of strength and flexibility exercises primarily focusing on the hip.

Results: Hip flexion strength improved by 35% ± 8.4% in 26 lower extremities treated successfully, compared with –1.8% ± 3.5% in 17 lower extremities with an unsuccessful outcome ($P < .001$). Before treatment, there were positive Ober test results in 39 of 43 lower extremities; positive Thomas test results were seen in 31 of 43 lower extremities. A successful outcome with a concurrent normalized Ober test result was seen in 83% (20/24) of lower extremities, and successful outcomes with normalized Thomas test results were seen in 80% (16/20) of lower extremities. A combination of improved hip flexion strength (> 20%) as well as normal Ober and Thomas test results was seen in 93% of successfully treated cases (14/15 lower extremities), compared with 0% success (0/5 lower extremities) if there was no change in hip flexion strength (< 20%) and if Ober and Thomas test result remained positive.

Conclusions: Improvements in hip flexion strength combined with increased iliotibial band and iliopsoas flexibility were associated with excellent results in patients with patellofemoral pain syndrome.

Keywords: patellofemoral pain syndrome (PFPS); hip strength and flexibility; rehabilitation

Patellofemoral pain syndrome (PFPS) is one of the most common disabilities of the knee joint in sports medicine.[9,21] Many nonoperative approaches have been developed to treat this pain syndrome, but no single intervention has been demonstrated to be the most effective.[3] For many years, the nonoperative treatment approach has been to address abnormal patellar tracking and/or malalignment; this method typically includes quadriceps strengthening, patellar bracing and taping, soft tissue mobilization, and stretching. Unfortunately, the results of this treatment approach have been mixed.[3,11,25]

As early as 1976, Nicholas et al[22] recognized the importance of hip strength in this injury condition. Patients with patellofemoral pain demonstrated significant weakness in their hip flexors during seated hip flexion strength testing. Such findings suggest a possible inability of the hip musculature to control femoral rotation during activities resulting in PFPS. Hip flexor weakness may not adequately provide a stable pelvis during gait to prevent the pelvis from going into an anterior pelvic tilt and concomitant femoral internal rotation. In addition, the iliopsoas muscle is a secondary femoral external rotator, and weakness may allow the femur to be positioned in relative internal rotation, misaligning the trochlear groove with the patella. It has recently been suggested that patellar subluxation during weightbearing activities may be the result of the femur rotating underneath the patella in the transverse plane.[27,30]

The purpose of this study was to objectively evaluate if a nonoperative treatment program emphasizing open and closed kinetic chain hip strength and flexibility exercises resulted in decreased patellofemoral pain. Specifically, the study sought to identify if changes in hip strength and flexibility were related to treatment outcome.

*Address correspondence to Timothy F. Tyler, MS, PT, ATC, Nicholas Institute of Sports Medicine and Athletic Trauma, Lenox Hill Hospital, 130 East 77th Street, New York, NY 10021 (e-mail: shoulderpt@yahoo.com).

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MATERIALS AND METHODS

Participants were included if they exhibited signs and symptoms of patellofemoral pain with no evidence of any other specific injury condition. The diagnosis of patellofemoral pain was made on the basis of the clinical presentation. The inclusion criteria were (1) anterior or retropatellar knee pain from at least 2 of the following activities: prolonged sitting, stair climbing, squatting, running, kneeling, and hopping/jumping[5]; and/or (2) insidious onset of symptoms unrelated to a traumatic incident and persistent for at least 4 weeks. Participants were excluded if they had (1) signs or symptoms of meniscal or other intra-articular injury conditions; (2) cruciate or collateral ligament involvement; (3) tenderness over the patellar tendon, iliotibial band, or pes anserinus tendons; (4) patellar apprehension sign; (5) Osgood-Schlatter or Sinding-Larsen-Johansson syndromes; (6) evidence of a knee joint effusion; (7) hip or lumbar referred pain; (8) a history of patellar dislocation; (9) previous surgery on the patellofemoral joint; or (10) evidence of degenerative joint disease on radiographs. Patients taking nonsteroidal anti-inflammatory or corticosteroid medication were also excluded.[16]

Thirty-five consecutive patients (29 women, 6 men; age, 33 ± 16 years) who were diagnosed with PFPS and who met the selection criteria were evaluated and placed on a 6-week treatment program. Eight patients had bilateral symptoms; therefore, 43 knees were treated. All subjects gave informed consent to be tested at initial evaluation and at 6 weeks, regardless of how many physical therapy visits they attended. The protocol was approved by the institutional review board. The same investigator performed all strength, flexibility, and clinical tests.

Strength Testing

Hip flexion, abduction, and adduction strengths were measured with a hand-held dynamometer (Nicholas manual muscle tester, Lafayette Instruments, Lafayette, Ind). Hip flexion was tested with the subject in the sitting position. The subject was asked to raise the thigh 8 inches from the table and to maintain the position. A force was manually applied with the hand-held dynamometer to break the muscle contraction[19]; the force to break the muscle contraction was then recorded in newtons. The average of 3 maximum effort test result for each action was taken on both legs for each patient. The same instrumented-break test technique was used for hip abduction and adduction. Hip abduction strength was tested in the side-lying position. The patient was asked to abduct the leg above horizontal; a breaking force was applied distally, 1 inch above the lateral malleolus. The side-lying position was also used for testing adduction strength. The patient was asked to straighten the leg and then lift the straight leg 12 inches off the table; a breaking force was applied 1 inch above the medial malleolus. Bohannon[4] demonstrated test-retest correlation coefficients of 0.84 to 0.99 for hip strength measurements, indicating good to high reproducibility.

Flexibility Testing

The Thomas test[32] position was used to measure hip flexor flexibility. The subject was asked to lie supine on the table with the gluteal folds at the edge of the table. The contralateral limb was held by the subject in a knee-to-chest position. Subjects were instructed to push their low back into the table. The tester then lowered the subject's leg to the point where motion ceased or there was external rotation of the femur. At this point, hip flexibility was determined. The range of motion was quantified as tight if the measurement was above horizontal and loose if below horizontal. Horizontal was considered normal hip flexor flexibility.[10]

The Ober test[24] was used to measure iliotibial band (ITB) flexibility. The patient was positioned in the side-lying position with the uninvolved lower extremity (lower leg) against the table with the knee and hip flexed to 90°. The patient reached behind the lower knee and grabbed the edge of the table to stabilize the pelvis. The examiner passively abducted and extended the contralateral hip (upper leg). The tested knee was flexed and maintained at 90°. The tester then lowered the subject's leg to the point where motion ceased or there was rotation of the femur. At this point, ITB flexibility was determined. The range of motion was quantified as tight if the measurement was above horizontal and loose if below horizontal. Horizontal was considered normal ITB flexibility.[10] The intrarater reliability of the Ober test has been shown to have an intraclass correlation coefficient of 0.90.[31]

Physical Examination

Clarke Sign (Patellar Grind Test). The examiner pressed down slightly proximal to the superior pole or base of the patella with the web of the hand as the patient lay relaxed with the knee extended. The patient was then asked to contract the quadriceps muscles while the examiner pushed down. If the patient could complete and maintain the contraction without pain, the test result was considered negative. If the examination caused retropatellar pain and the patient could not hold a contraction, the test result was considered positive.

Patellar Compression Test. A rolled towel was placed underneath the knee to create 20° of flexion. The patella was pressed downward into the femoral groove and then moved medial and lateral. If the patient felt pain, the patellar compression test result was positive.

Medial/Lateral Retinacular Tenderness. The examiner pushed down on the lateral aspect of the patella to tension the medial retinaculum and then palpated for tenderness. The lateral retinaculum was palpated in a similar fashion, with the examiner pushing down on the medial aspect of the patella.

Medial/Lateral Facet Tenderness. With the quadriceps muscles relaxed, the articular facets of the patella were palpated for tenderness. This palpation was facilitated by

TABLE 1
Patellofemoral Rehabilitation Guidelines[a]

Phase I
- Hip PREs: seated hip flexion, adduction, extension, abduction
- Modalities prescribed as needed
- Stretching: manual and self (hip flexors, quadriceps, iliotibial band)
- HEP: hip PREs, self-stretching
- Manual therapy: medial and lateral retinaculum
- Mini squats
- Balance exercises: unilateral stance, balance board, etc
- Step-ups: varying height of step, repetitions, and speed
- Upper extremity reaches

Clinical milestones:
- Ability to minisquat to 45° without pain
- Improved stability with unilateral stance
- Step-ups from 4-inch platform with no pain and good concentric control
- Minimal to no pain on therapeutic exercises

Phase II
- Continue with hip PREs
- Patient resumes self-stretching, continue manual stretching
- Lower extremity reaches: focus on weakest plane of motion
- Step-downs: varying height of step, repetitions, and speed
- Increase difficulty of balance exercises

Clinical milestones:
- Step-downs from 4-inch platform with no pain and good eccentric control
- Progress reaches: by moving farther from target and increasing speed

Phase III
- Home stretching, discontinue manual stretching if necessary
- Discontinue reaches: perform other activities that focus on same deficit
- Plyometric/agility exercises
- Lunges
- Return to sports activities

Return-to-activity clinical milestones:
- Vertical jump test (< 20% of normative [height] data, adjusted for body size)
- Functional hop test for distance (pain free)
- Pain-free sport-specific test (comparable sign)

[a]PRE, progressive resistive exercise; HEP, home exercise program.

carefully pushing the patella medially to palpate the medial facets and laterally to palpate the lateral facet.

Pain Assessment

Pain and discomfort during activities of daily living and during exercise were documented on a 10-cm visual analog scale (VAS), with 0 indicating no pain and 10 indicating extremely intense pain. Additional yes or no questions were administered for pain during squatting, stair climbing, and prolonged sitting.

Therapeutic Intervention

The treatment consisted of open and closed kinetic chain strength and flexibility exercises for the hip. The hip flexors, abductors, adductors, and extensors were progressively strengthened initially in nonweightbearing positions, then in weightbearing positions. By focusing on the maintenance of a stable pelvis while introducing active hip motions, it was thought that proprioceptive awareness would also be enhanced. If indicated, stretching as per Ober and Thomas tests was prescribed, along with self-performed ITB and hip flexor stretching (Table 1). All patients were given a home exercise program that they were to perform once daily. The home program paralleled the exercises given in the clinic, and each patient was deemed ready to commence a new exercise at home when he/she was able to correctly carry out the movement in the clinic with minimal verbal prompts. As muscle strength and motor control improved, patients progressed to complex, coordinated motor patterns involving functional activities.

Outcome Measures, Sample Size Estimates, and Statistics

Treatment success was defined as a minimum of a 1.5-cm reduction in pain on each 10-cm VAS. A 1.5-cm change has been considered clinically significant.[7] The sample size for this study was based on the ability to detect a significant difference in strength improvements between patients with and without treatment success. The standard deviation of the percentage change in hip flexion strength with repeated measures was estimated to be 20% based on previously published data.[33] Therefore, with a sample of 40 lower extremities, an 18% difference in strength improvement between groups could be detected at an α level of .05 and a β level of .2 (80% power). Independent t tests and χ^2 analyses were used to compare changes in strength and flexibility between lower extremities with successful and unsuccessful outcomes. Data are reported as means ± SEs.

RESULTS

Treatment Outcome

The VAS pain scores with activities of daily living and with exercise decreased significantly after the 6-week treatment program (activities of daily living, 4.9 ± 0.3 to 2.7 ± 0.3, $P < .001$; exercise, 5.8 ± 0.4 to 3.0 ± 0.4, $P < .001$). Based on the improvements in VAS pain scales, 21 patients (26 knees) had a successful outcome, and 14 patients (17 knees) had an unsuccessful outcome.

Strength Testing

Before treatment, patients with unilateral PFPS demonstrated weakness on the involved side in hip flexion (14% deficit, $P < .001$) and abduction (14% deficit, $P < .0001$) but not in hip adduction (6% deficit, $P = .26$). Hip flexion strength

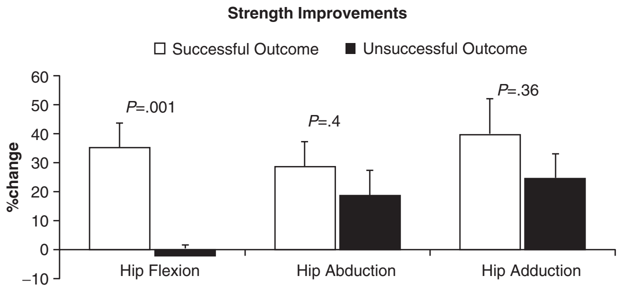

Figure 1. Percentage improvement in hip flexion, abduction, and adduction strengths in knees treated successfully and unsuccessfully after 6 weeks of rehabilitation. *P* values on the graph refer to the difference in strength improvements between successful and unsuccessful outcomes. All strength improvements were significant ($P < .05$), with the exception of hip flexion strength in lower extremities with unsuccessful outcomes.

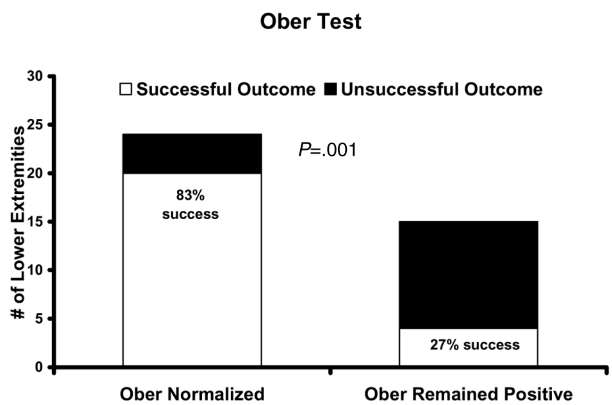

Figure 2. The effect of an improved Ober test result on the success of treatment for patellofemoral pain syndrome. Thirty-nine of 43 lower extremities had a positive test result before treatment. Of these, 15 remained positive after the 6-week treatment time; 24 results normalized. A successful outcome occurred in 20 of 24 (83%) lower extremities in which the Ober test result normalized, compared with only 4 of 15 (27%) in which the Ober test result remained positive ($P < .001$).

improved by 35% ± 8.4% in 26 lower extremities treated successfully, compared with –1.8% ± 3.5% in 17 lower extremities treated unsuccessfully ($P < .001$) (Figure 1). Improvements in hip abduction and adduction strengths were unrelated to outcome ($P > .3$). Hip abduction and adduction strengths improved in both lower extremities with successful outcomes ($P < .001$) and lower extremities with unsuccessful outcomes ($P < .05$).

Flexibility Tests

Before treatment, a positive Ober test result was found in 39 of 43 lower extremities. A successful outcome with a normalized Ober test result was seen in 83% of lower extremities (20/24 knees), compared with a 27% success rate (4/15 knees) if the Ober test result remained positive ($P < .001$) (Figure 2). A positive Thomas test result was found in 31 of 43 lower extremities before treatment. The Thomas test result normalized, and the treatment outcome was successful in 80% of lower extremities (16/20 knees), compared with an 18% treatment success rate (2/11 knees) if the Thomas test result remained positive ($P < .001$) (Figure 3).

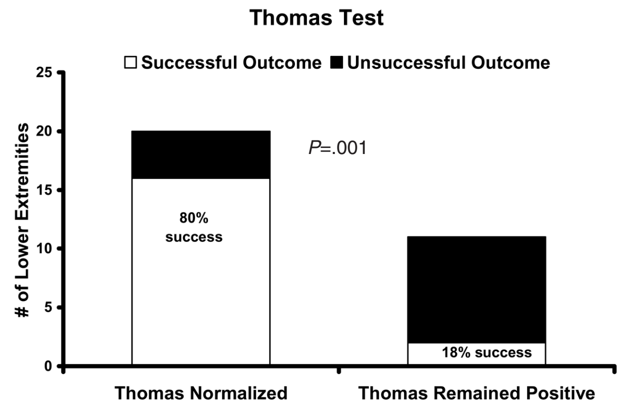

Figure 3. The effect of an improved Thomas test result on the success of treatment for patellofemoral pain syndrome. Thirty-one of 43 lower extremities had a positive test result before treatment. Of these, 11 remained positive after the 6-week treatment time; 20 results normalized. A successful outcome occurred in 16 of 20 (80%) lower extremities in which the Thomas test result normalized, compared with only 2 of 11 (18%) in which the Thomas test result remained positive ($P < .001$).

Physical Examination and Symptoms

The results of the clinical tests were quite varied in this patient population, with less than 50% of the knees having a positive result for any of tests before treatment. Significant improvements after the treatment protocol were found for medial facet and retinaculum tenderness (positive test results, 47% pretreatment vs 12% posttreatment; $P < .01$). This result was not the case for lateral facet tenderness (positive test results, 21% pretreatment vs 14% posttreatment; $P = .41$) or lateral retinaculum tenderness (positive test results, 21% vs 7% posttreatment; $P = .08$). Significant improvements ($P < .05$) were found for the compression and grind tests (positive test results, 42% pretreatment vs 21% posttreatment for both tests). As expected, before treatment, the majority of patients had pain in the involved knee(s) during squatting, stair climbing, and prolonged sitting. Thirty-four of 43 knees (71%) had pain with squatting, 39 knees (91%) had pain with stair climbing, and 27 knees (63%) had pain with prolonged sitting. After the 6-week treatment regimen, 13 knees (33%) had pain with squatting, 17 knees (40%) had pain with stair climbing, and 15 knees (35%) had pain with prolonged sitting (all significant decreases in pain, $P < .01$).

Combination of Strength and Flexibility Improvements

Lower extremities were categorized as (1) having improved hip flexion strength (> 20% improvement) or (2) having no change in hip flexion strength (≤ 20% improvement). They were also categorized as having (1) no improvement in Ober or Thomas tests if the test results remained positive or as having (2) normal Ober and Thomas test results if a positive result normalized or if a normal or loose result remained at that grade. A combination of improved hip flexion strength as well as normal Ober and Thomas test results was seen in 93% (14/15 lower extremities) of successfully treated cases, compared with a 75% success rate (9/12 lower extremities) if 2 of the 3 factors improved, a 27% success rate (3/11 lower extremities) if only 1 factor improved, and 0% success (0/5 lower extremities) if there was no change in hip flexion strength (< 20%) and if both Ober and Thomas test result remained positive (Figure 4). Treatment success was significantly higher for lower extremities meeting all 3 criteria compared with those meeting only one ($P < .01$) or none ($P < .001$) of the criteria. Treatment success was also higher for lower extremities meeting 2 of the 3 criteria compared with those meeting only one ($P < .05$) or none ($P < .01$) of the criteria.

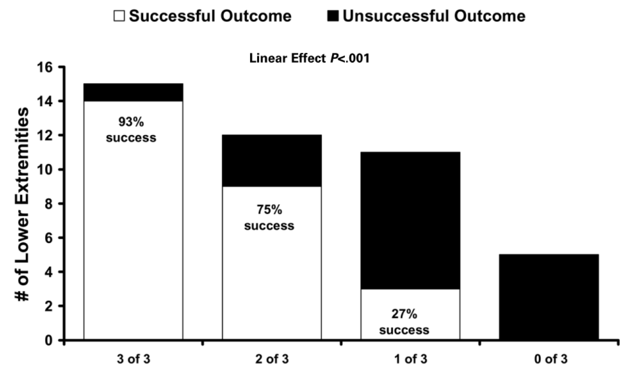

Figure 4. The effect of a combination of (1) improved hip flexion strength (> 20% improvement), (2) normalized Ober test result (or normal Ober test result before and after treatment), and (3) normalized Thomas test result (or normal Thomas test result before and after treatment) on treatment success. The *x*-axis refers to the number of factors (3/3 to 0/3) a patient achieved. The white bars represent successful outcomes; the black bars represent unsuccessful outcomes ($P < .001$, Mantel-Haenszel χ^2 test for linear association).

DISCUSSION

The importance of hip strengthening and flexibility in the treatment of PFPS has received increased attention in recent years. Until now, this treatment approach has been theoretical[27] or based on a case study.[20] It is hypothesized that by dynamically controlling femoral rotation, a patient can improve patellofemoral joint mechanics. In the present study, 66% of PFPS patients had a successful outcome after a 6-week therapeutic exercise protocol emphasizing strength and flexibility of the hip musculature. The treatment protocol was effective in improving flexibility in the iliopsoas and iliotibial band regions and in improving hip flexion, abduction, and adduction strengths. Treatment success was related to improvements in iliopsoas and iliotibial band flexibility and improvements in hip flexion strength. The substantial improvement in hip flexion strength (35%) in patients with a successful outcome contrasted with no change in hip flexion strength (–1.8%) in the patients with an unsuccessful outcome. Improvements in hip abduction and adduction strengths were not different between patients with successful and unsuccessful outcomes. Both groups showed improvements in hip abduction strength (28% vs 18%, respectively) and adduction strength (40% vs 24%, respectively). This study was designed with sufficient statistical power to detect a minimum difference in strength of approximately 18% between groups. The moderate between-group differences in strength improvements for abduction (10%) and adduction (16%) have questionable clinical significance. By contrast, the dramatic difference in hip flexion strength improvements between the successful and unsuccessful outcomes is clearly clinically relevant. When hip flexion strength improved by greater than 20%, 17 of 19 (89%) lower extremities had a successful outcome, compared with 9 of 24 (38%) lower extremities in which hip flexion strength improvements were at 20% or less ($P < .001$, χ^2 test). By contrast, when hip abduction strength improved by greater than 20%, only 14 of 22 (64%) lower extremities had a successful outcome, compared with 12 of 21 (57% success) for the remaining lower extremities ($P = .63$, χ^2 test). Similarly, when hip adduction strength improved by greater than 20%, only 13 of 21 (62%) lower extremities had a successful outcome, compared with 13 of 22 (59% success) for the remaining lower extremities ($P = .85$). It therefore appears that hip abduction and adduction strength improvements are not essential for the successful resolution of PFPS.

Mascal et al[20] published the only other intervention study testing the effectiveness of a hip strength and flexibility program in 2 patients with PFPS. In that study, 2 patients with PFPS participated in a 14-week therapeutic exercise program. The program was very similar to the rehabilitation guidelines presented in the current study. After completion of the intervention, both patients reported a significant reduction in patellofemoral pain, an increase in hip abduction and extension isometric force production, and an ability to return to their original functional status. In addition, 1 patient who underwent motion analysis demonstrated a 1.2° decrease in femoral internal rotation and a 5.4° decrease in ipsilateral hip adduction during a step-down task after participating in the intervention. Although hip flexion strength was not measured in the current study, it was given as an early exercise in the supine position.

The exact mechanism by which increased hip strength and flexibility is associated with a reduction in PFPS is unclear. Nicholas et al,[22] Bullock-Saxton,[6] Janda,[13] Beckman and Buchanan,[2] and Jaramillo et al[14] have demonstrated that weakness proximal to the symptomatic area is often present with lower-extremity injury conditions. Whether this weakness is a precursor to the condition or a consequence of the condition is unknown.

The treatment protocol prescribed for the patients in this study was based on (1) the clinical observation of hip flexion weakness in patients with PFPS,[22] (2) the biomechanical observation that femoral rotation affects patellofemoral contact forces,[18] and (3) the theory that proximal control of pelvic and femoral stability may be related to PFPS.[20,27] One theoretical mechanism for success is that factors responsible for positive Ober and Thomas test results move the pelvis into an anterior pelvic tilt, resulting in femoral internal rotation. This femoral internal rotation would influence patellar alignment and kinematics.[30] Increasing the flexibility of the hip flexors and ITB would allow the pelvis to rotate posteriorly, creating relative femoral external rotation and helping to align the patella in the trochlear groove of the femur.[27] An additional improvement in hip flexor 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. Furthermore, the iliopsoas muscle is a secondary femoral external rotator, and strengthening this muscle helps align the trochlear groove with the patella. In addition, increased flexibility in the hip flexors and ITB may reduce the tension on the lateral retinaculum and allow the patella to track properly. Evidence to support these theories has been provided by Powers et al[30] using dynamic MRI methods during a single-legged partial squat. The primary contributor to lateral patellar tilt and displacement in a group of patients with patellar instability was femoral internal rotation and not patellar motion. Previously, Lee et al[18] demonstrated increased patellofemoral compression forces with increasing femoral internal rotation in a cadaveric model.

At baseline in the present study, patients with unilateral symptoms had significant weakness in hip flexion and abduction on the involved side (14% for both deficits). As previously stated, hip flexion weakness in patients with PFPS has been noted before.[22] More recently, hip abduction weakness (26% deficit) was found in female patients with PFPS.[12] Patients also showed weakness in hip external rotation strength (36% deficit), but hip flexion strength was not documented.[12] Hip flexion weakness has been associated with overuse injuries in recreational runners. Among the injured runners, the hip abductor and flexor muscle groups on the injured side were significantly weaker than those of the noninjured side. In addition, the hip adductor muscle group on the injured side was significantly stronger than that of the noninjured side.[23] Unfortunately, the incidence of PFPS was not reported in this study. These findings further emphasize the importance of addressing hip strength in patients with lower extremity injuries.

Treatment for PFPS typically focuses on quadriceps strengthening and/or quadriceps neuromuscular training.[†] Although quadriceps weakness is often assumed, it is difficult to obtain a valid assessment of strength given the high likelihood of pain or discomfort during testing. Additionally, the patient who tolerates quadriceps strength testing may subsequently have an exacerbation of symptoms due to the test protocol. Based on these concerns, no attempt was made to document quadriceps strength in this study.

Mixed results have been reported for various PFPS treatment protocols.[3,8,11,25] However, few studies have systematically analyzed the components relating to a successful outcome within a specific treatment protocol. Although only 60% of patients in the present study were successfully treated, success was clearly related to improvements in hip flexion strength as well as iliopsoas and iliotibial band flexibility. Therefore, the clinician can focus on these components in patients who have an unsuccessful outcome after a 6-week treatment regimen. It remains to be determined whether a treatment protocol that exclusively focuses on hip flexion strengthening and iliopsoas and iliotibial band stretching would prove more effective in the treatment of PFPS than did the more comprehensive protocol used here.

In this study, unsuccessful outcomes in the treatment of PFPS were associated with the failure to improve hip flexion strength and the failure to achieve normal results on the Ober and Thomas tests. Whether these failures were due to inappropriate execution of the exercises, a lack of compliance with the exercise prescription, or a combination of both was not determined. Patients with a successful outcome averaged 15 ± 1.1 visits to the clinic, whereas those with an unsuccessful outcome averaged 10 ± 1.3 visits ($P < .01$), indicating that unsuccessful outcomes were in part due to lack of compliance. In addition, it was not possible to reliably document compliance with the home program. Besides compliance, other factors that may have contributed to the unsuccessful results include inadequate training stimulus (intensity, duration, and frequency), interindividual differences in training response, misdiagnosis, or psychological factors. With respect to the training stimulus and training response, a longer or more intense period of training may have been required for some patients. With respect to misdiagnosis, despite a thorough evaluation, unrecognized conditions such as patellar plica may have contributed to patellofemoral symptoms. Finally, psychological factors have not been addressed with respect to PFPS, and they may contribute to symptoms in chronic cases. Although all patients in this study were symptomatic for at least 4 weeks, the actual duration of symptoms was not documented and may have contributed to unsuccessful results.

Although the current study emphasizes the role of hip flexion strength and iliopsoas and iliotibial band flexibility in the successful treatment of PFPS, it is important to emphasize that some potentially important factors were not addressed. The role of hip extension and hip rotation strengths was not examined. Skeletal alignment at the knee, ankle, and foot was not addressed. Furthermore, because PFPS has a high rate of recurrence, it remains to be determined if the successful outcomes can be sustained and if recurrences are due to a subsequent reversal of strength and flexibility improvements. No attempt was made to compare the effectiveness of the treatment protocol described here to other PFPS protocols; this area may be one of future research. Rather, the primary goal of this study was to determine if improvements in hip strength and flexibility were related to treatment success.

In conclusion, improvements in hip flexion strength combined with normalized iliotibial band and iliopsoas flexibility were associated with excellent results for patients

[†]References 1, 3, 7, 11, 15, 17, 25, 26, 28, 29, 34.

with PFPS. This study provides evidence that hip strength and flexibility should be an important consideration in the evaluation and treatment of patients with PFPS.

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