

# Management of Patellofemoral Pain Targeting Hip, Pelvis, and Trunk Muscle Function: 2 Case Reports

Catherine L. Mascal, PT, BSc<sup>1</sup>

Robert Landel, DPT, OCS<sup>2</sup>

Christopher Powers, PT, PhD<sup>3</sup>

**Study Design:** Case report.

**Objective:** To describe an alternative treatment approach for patellofemoral pain.

**Background:** Weakness of the hip, pelvis, and trunk musculature has been hypothesized to influence lower-limb alignment and contribute to patellofemoral pain. Two patients who had a chief complaint of patellofemoral pain and demonstrated lack of control of the hip in the frontal and transverse planes during functional movements were treated with an exercise program targeting the hip, pelvis, and trunk musculature.

**Methods and Measures:** The patients presented in these 2 case reports did not exhibit obvious patellar malalignment or tracking problems; however, on qualitative assessment, both demonstrated excessive hip adduction, internal rotation, and knee valgus during gait and while performing a step-down maneuver. In addition, both patients exhibited weakness of the hip abductors, extensors, and external rotators, as demonstrated by hand-held dynamometry testing. Treatment in both cases occurred over a 14-week period and focused on recruitment and endurance training of the hip, pelvis, and trunk musculature. Functional status, pain, muscle force production, as well as subjective and objective assessment of lower-extremity kinematics during gait and a step-down maneuver were assessed preintervention and postintervention.

**Results:** Both patients experienced a significant reduction in patellofemoral pain, improved lower-extremity kinematics during dynamic testing, and were able to return to their original levels of function. Gluteus medius force production improved by 50% in patient A and 90% in patient B, while gluteus maximus force production improved 55% in patient A and 110% in patient B. Objective kinematic improvements in the step-down task also were demonstrated in patient A.

**Conclusion:** Assessment and treatment of the hip, pelvis, and trunk musculature should be considered in the rehabilitation of patients who present with patellofemoral pain and demonstrate abnormal lower-extremity kinematics. *J Orthop Sports Phys Ther* 2003;33:642-660.

**Key Words:** case study, knee pain, lower-extremity rehabilitation, therapeutic exercise

Patellofemoral pain (PFP) is recognized as one of the most common lower-extremity disorders encountered by orthopaedic physical therapists.<sup>28,59</sup> Despite its prevalence, however, the etiology of this pain syndrome and specific treatment of this condition remain vague and controversial.

The premise behind most treatment approaches is that PFP is the result of abnormal patellar tracking and/or malalignment. Given as such, interventions are often focused locally, and typically include quadriceps strengthening, patellar taping, patellar bracing, stretching, and soft tissue mobilization.<sup>6,19,46,59</sup> Despite the longevity of such treatment approaches, with papers as early as 1922 advocating quadriceps strengthening exercises,<sup>35</sup> intervention outcomes have been mixed.<sup>2,11,29,30</sup> In addition, the 2001 Philadelphia Panel systematic review failed to find a sufficient number of high-quality randomized control trials to recommend any clinically important benefit from exercise, massage, heat, or combined therapies for patients with PFP.<sup>44</sup>

One possible reason for the relatively poor outcomes associated with the treatment of PFP may be related to the assumption that

<sup>1</sup> Staff Physical Therapist, Kern and Associates Physical Therapy, Santa Monica, CA. At the time these cases were managed, Catherine Mascal was a resident in the Orthopaedic Physical Therapy Residency Program at the University of Southern California, Los Angeles, CA.

<sup>2</sup> Associate Professor of Clinical Physical Therapy, Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA.

<sup>3</sup> Associate Professor and Director, Musculoskeletal Biomechanics Research Laboratory, Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA. Send correspondence to Christopher M. Powers, Department of Biokinesiology and Physical Therapy, University of Southern California, 1540 E. Alcazar Street, CHP 155, Los Angeles, CA 90089-9006. E-mail: powers@usc.edu

The methods described in this paper are standard care for patients seen in this clinic. Therefore, Institutional Review Board approval was not necessary for these case reports.

subluxation is the result of the patella moving on the femur. While this may be the case during non-weight-bearing activities in which the femur is fixed (eg, during knee extension in sitting), recent evidence suggests that subluxation during weight-bearing activities may be the result of the femur rotating underneath the patella in the transverse plane.<sup>60</sup> Therefore, a treatment program that addresses the control of femoral motion may play a role in the treatment of certain patients with PFP.

When treating patients with PFP who demonstrate lack of control of hip adduction and internal rotation during weight-bearing activities such as walking and descending stairs, one goal may be to optimize muscle function to control these motions, as such movement can result in genu valgus, an increase in the dynamic Q angle, and greater lateral forces acting on the patella.<sup>9,21-23,40,45</sup> With this in mind, it also would appear reasonable to strive for optimal function of the abdominal, pelvis, and spinal musculature, as it is theorized that this is an important factor when addressing lower-extremity muscle strength training.<sup>10,18,47,50</sup> To date, no patient outcomes have been described for an intervention focusing on control of hip and pelvis motion in individuals with PFP.

The purpose of these 2 case reports was to illustrate that an exercise program focusing primarily on the hip, pelvis, and trunk musculature could have a positive effect on PFP, functional status, and lower-limb positioning during gait and a step-down task. As one of the hallmark signs of PFP is an exacerbation of symptoms during stair descent,<sup>9,24</sup> 2 patients are presented who reported pain and the inability to control motion at the hip during this activity.

## CASE DESCRIPTIONS

### General Demographics

Patient A was a 20-year-old female with a body mass index (BMI) of 22 (normal weight). She was a part-time student and also worked three 10-hour days a week as a waitress in a restaurant. Patient B was a 37-year-old female with a BMI of 27 (somewhat overweight). She worked full time as an accounts assistant in a hospital finance department.

### History of Presenting Condition

Patient A described a history of right patellofemoral pain, which commenced after traumatically dislocating her patella twice, 9 and 2 years prior. In both instances, the mechanism was described as an awkward fall onto a twisted knee, and the patella was self-reduced following the trauma. After the last dislocation in November 2000, she underwent an unsuccessful course of physical therapy that consisted of a progressive aerobic walking program and

quadriceps strengthening exercises. She also was given a neoprene support that she wore regularly while working as a waitress. Radiographic work-up included axial view radiographs taken in June 2001 that were unremarkable. The severity of pain had gradually become worse over the previous 2 years, however, she was not taking pain medication. She described no other ipsilateral or contralateral lower-extremity symptoms.

Patient B described a 2-year history of right patellofemoral pain. The onset of symptoms was insidious, with no known precipitating event. The severity of the condition had progressed to the point that she had fallen 3 times over the last 18 months due to a painful giving-way of her knee. She took Naproxen only when the pain was severe (approximately 2 to 3 times a week). She had not undertaken any previous physical therapy treatment. Work-up included axial view radiographs taken in March 2002 that were unremarkable. She described no other ipsilateral or contralateral lower-extremity symptoms.

### Presenting Complaints

Patient A's symptoms were described as an intermittent sharp pain in the right retropatellar region. She stated that walking for 2 hours, or descending 2 flights of stairs exacerbated her pain. Alleviating factors included ice, rest, and a neoprene knee support. Her activity level included 3 days a week at college, with prolonged periods of sitting in class, and working as a waitress in a restaurant for 3 other days during the week. Typically, her symptoms occurred after working for 2 hours, at which time she would start wearing the neoprene support. Patient A did not participate in any regular physical exercise, but stated a desire to start jogging, which she had not done for the previous 4 to 5 years.

Patient B's symptoms were described as an intermittent throbbing right retropatellar pain that was aggravated by stair descent. Alleviating factors included rest and Naproxen. Patient B stated that she enjoyed walking for 30 to 45 minutes, 3 to 4 times a week; however, she had not been able to do this for the last 3 weeks due to the increased severity of her pain.

Patient A's goals were to commence a jogging program and to be able to work at the restaurant pain free, without the use of her neoprene support. Patient B's goals were to return to her previous level of walking, go dancing once a week, and ascend/descend stairs pain free.

### TESTS AND MEASURES

As regular clinical service was being provided for these 2 patients, both were exempt from requiring Institutional Review Board approval.

## Functional Status

Prior to treatment, both patients completed a self-administered functional assessment tool that has been validated for the evaluation of patellofemoral joint disorders (Appendix).<sup>33</sup> This questionnaire is used to qualitatively assess an individual's functional status and patellofemoral pain experienced during specific functional tasks. The maximum total score of this assessment tool is 100, with higher scores indicating greater levels of function with lower levels of pain. The preintervention function scores were 76 and 70 for patient A and patient B, respectively.

## Pain

Both patients used a 10-cm visual analogue scale (VAS) to indicate the greatest amount of pain during their most pain-provoking activities, with 0 representing no pain and 10 representing the worst pain imaginable. This method of evaluation has been shown to be both reliable and valid for measuring pain.<sup>13,48,53</sup> The initial VAS score for patient A was 5/10 after walking for 2 hours, and 4/10 after climbing 2 flights of stairs. The initial VAS score for patient B ranged from 7/10 while descending a single step to 10/10 on descending an entire flight. A VAS score of 8/10 was reported for walking 2 miles.

## Differential Diagnostic Screening

Active, passive, and accessory mobility of the rearfoot, tibiofemoral joint, hip joint, and lumbar spine were assessed. Clinical tests as described in Magee<sup>36</sup> were carried out to eliminate these structures as potential sources of the subjects' symptoms. This screening examination revealed no abnormalities and both patients demonstrated a full pain-free range of knee motion. Negative test results were also found for the following conditions: ligamentous instability of the knee; intracapsular knee pathology; patellar tendonitis; pes anserine bursitis; iliotibial band friction syndrome; and referred pain from the hip, sacroiliac region, or lumbar spine.

## Patellofemoral Joint Examination

Examination of the patellofemoral joint included static and dynamic patellar positional tests that have been described elsewhere.<sup>9,18,61</sup> Although these procedures have been shown to demonstrate poor-to-fair intertester reliability,<sup>17</sup> the purpose of using them in these case reports was to identify any gross positional abnormalities. Assessment of static patellar position and orientation was performed for medial/lateral glide, medial/lateral rotation, and anteroposterior and lateral tilt, as described by McConnell.<sup>18</sup> Assessment of dynamic patellar tracking was performed during non-weight-bearing knee extension (45°-0°). Neither patient demonstrated any obvious anomalies in terms of static patellar alignment or dynamic tracking.

Clinical tests that have been described to assess patellofemoral dysfunction also were performed.<sup>29</sup> These included the patellar compression test<sup>54</sup> and the apprehension (Fairbanks) test.<sup>14</sup> Passive patellar mobility was examined and compared to the unaffected side. Symptom reproduction was evaluated during resisted knee extension at various knee flexion angles and palpation was performed for retinaculum tenderness. Patient A presented with a positive compression and apprehension test, and pain with resisted knee extension from 10° to 0° of knee flexion. She had normal passive patellar mobility. Patient B had slight pain on patellar compression and moderate tenderness with palpation of the right medial retinaculum. She had pain on resisted knee extension from 20° to 0° knee flexion, and had normal passive patellar mobility with slight pain at end range medial and lateral translation.

Quadriceps strength was assessed using a Microfet2 hand-held dynamometer (Hoggan Health Industries, Inc., Draper, UT). This method of measuring muscle strength has been validated and the intertester reliability has been shown to be good to excellent.<sup>3-5</sup> Quadriceps muscle strength testing was performed in the position recommended by Kendall<sup>31</sup>; however, the knee was maintained in 30° of flexion to avoid

**TABLE.** Hand-held dynamometry, preintervention and postintervention results. Values given are the average of 3 trials. Numbers in parentheses are subjective muscle strength ratings based on an isometric break test where 5/5 is maximal strength (ie, unable to "break" the muscle's isometric hold).<sup>38</sup>

	Patient A			Patient B		
	Pretest Force (N)	Posttest Force (N)	Increase (%)	Pretest Force (N)	Posttest Force (N)	Increase (%)
Quadriceps	155.8 (3+/5)	186.9 (3+/5)	20	267.0 (4/5)	293.7 (4/5)	10
Gluteus maximus	129.0 (4-/5)	200.0 (4/5)	55	89.0 (3+/5)	186.9 (4/5)	110
Gluteus medius	53.4 (3+/5)	80.1 (4-/5)	50	44.5 (3+/5)	84.6 (4/5)	90
Hip lateral rotator group	26.7 (3+/5)	111.3 (4/5)	317	120.1 (4-/5)	138.0 (4-/5)	15
Hip medial rotator group	84.6 (4-/5)	120.1 (4/5)	42	62.3 (4-/5)	106.8 (4/5)	71

quadriceps inhibition due to pain. Resistance was given at the distal tibia, 10 cm proximal to the lateral malleolus, and the average of 3 trials was recorded. Preintervention force results are presented in the Table. Patient A was subjectively assigned a manual muscle test grade of 3+/5, while patient B was assigned a manual muscle test grade of 4/5.

### Standing Posture

Lower-extremity alignment was assessed qualitatively in a relaxed standing posture. Neither patient demonstrated significant rearfoot varus/valgus or genu varus/valgus. There also was no observable squinting of the patellae, which is indicative of femoral anteversion. This was confirmed by performing Craig's test in prone.<sup>36</sup> Limb length (as measured from the anterior superior iliac spine to the medial malleolus) was assessed bilaterally in the supine position and was found to be equal when measured to the nearest 0.5 cm.

### Dynamic Assessment

*Gait* Observational gait analysis was performed as the patients walked at a self-selected pace along a 10-m walkway. Both patients demonstrated normal sagittal plane motion of the ankle, knee, and hip joints. Abnormalities were noted, however, in the frontal and transverse planes. During stance phase on the affected side, the following deviations were observed: (a) excessive hip adduction during weight acceptance, (b) excessive internal hip rotation in early midstance, and (c) notable contralateral pelvic drop during midstance. These deviations were evident in both patients. Neither demonstrated excessive or prolonged subtalar joint pronation or excessive tibial internal rotation during the stance phase of gait.

*Step-Down Task* Patients also were evaluated dynamically during an activity that required greater demands on the lower-extremity muscles. The step-down task involved observing each patient stepping down slowly from a 20.4-cm-high (8-in) step during a 3-second period. Both patients demonstrated significant hip adduction and slight internal rotation of the stance limb and an appreciable contralateral pelvic drop. In both cases, this motion resulted in substantial valgus at the knee (Figure 1).

### Muscle Strength Examination: Hip and Abdominal Musculature

Based on the significant frontal and transverse plane deviations at the hip during the dynamic examination, a decision was made to assess the strength of the hip and trunk muscles. These included the gluteus maximus, gluteus medius, internal

and external rotators of the hip, and the abdominal musculature. Muscle strength testing of the hip was performed using a hand-held dynamometer in test positions described by Kendall.<sup>31</sup> Subjectively, both patients demonstrated significant weakness of the ipsilateral gluteus medius (grade 3+/5 in both cases), and gluteus maximus (grade 4-/5 and 3+/5 for patients A and B, respectively). In addition, significant ipsilateral weakness of the hip lateral rotators was observed in patient A (grade 3+/5). The force and quadriceps values recorded with the hand-held dynamometer during these muscle tests are presented in the Table.

Tests to ascertain neuromuscular control of pelvic motion have been described in detail by Sahrman<sup>50</sup> and Farrell.<sup>15</sup> Four of these tests were performed and included: (1) evaluation of the patient moving from double- to single-limb stance, noting signs of pelvic drop and observing the lateral translation of the pelvis; (2) maintenance of a static bridge position against a manual rotational displacement force applied to the pelvis in the transverse plane; (3) evaluation of the patients' ability to prevent pelvic tilting in the frontal plane during a single-hip abduction motion in a sidelying position; and (4) prevention of pelvic motion in the transverse plane during an abduction/external rotation movement of the hip



FIGURE 1. Photograph of patient A demonstrating marker placement and experimental setup. Prior to the intervention, substantial knee valgus was observed during this procedure.

in hook lying. Spinal or pelvic motion during tests (3 and 4) was evaluated by palpating the anterior superior iliac spines (ASIS). Both patients demonstrated poor control of motion as demonstrated by significant observable and palpable translation of the pelvis during all of the above tests.

### Biomechanical Evaluation

In addition to the physical examination, patient A underwent biomechanical testing at the Musculoskeletal Biomechanical Research Laboratory at the University of Southern California. The purpose of this testing was to document lower-extremity kinematics during the step-down maneuver and to provide objective data for posttreatment comparison.

Three-dimensional kinematics of the lower extremity were obtained using methodology described in previous publications.<sup>51,52</sup> Data were obtained while patient A performed a step-down maneuver from a 20.4-cm-high (8-in) step with the symptomatic side as the supporting limb (Figure 1). The patient was instructed to perform this maneuver slowly over the course of 3 seconds. Three trials of data were collected and averaged for analysis. Variables of interest were hip adduction, hip internal rotation, and contralateral pelvic drop. When averaged across the entire stance phase, patient A demonstrated 1.4° of hip internal rotation, 8.7° of hip adduction, and 3.9° of contralateral pelvic drop during the step-down test (Figure 2).

### ASSESSMENT

Given the subjective and objective information obtained in the examination, it was our impression that neither patient demonstrated significant abnormalities specific to the patellofemoral joint that could account for subjective complaints of PFP. Both patients, however, demonstrated significant weakness of the hip and abdominal musculature, and a reduced ability to control hip and pelvis motion during dynamic testing. We theorized that this poor neuromuscular control was responsible for the increased internal rotation/adduction of the hip observed during gait and the step-down maneuver, and that these femoral motions may have contributed to the PFP symptoms.<sup>45</sup> Therefore, it was our hypothesis that exercises focused on addressing the documented muscular weaknesses and abnormal movement patterns would aid in pain resolution, improve functional status, and result in improved gait kinematics during level walking and the step-down maneuver.

### INTERVENTION

#### Foundations for Treatment

Both patients were scheduled to attend physical therapy once or twice a week over a 3-month period.

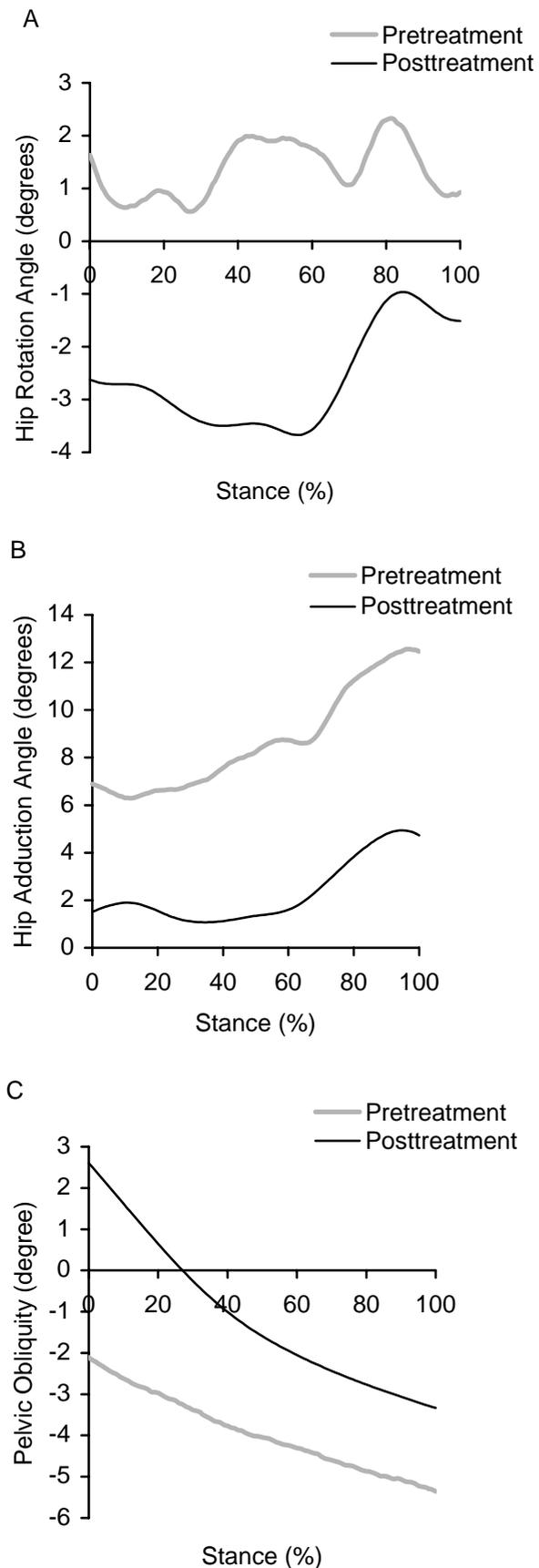
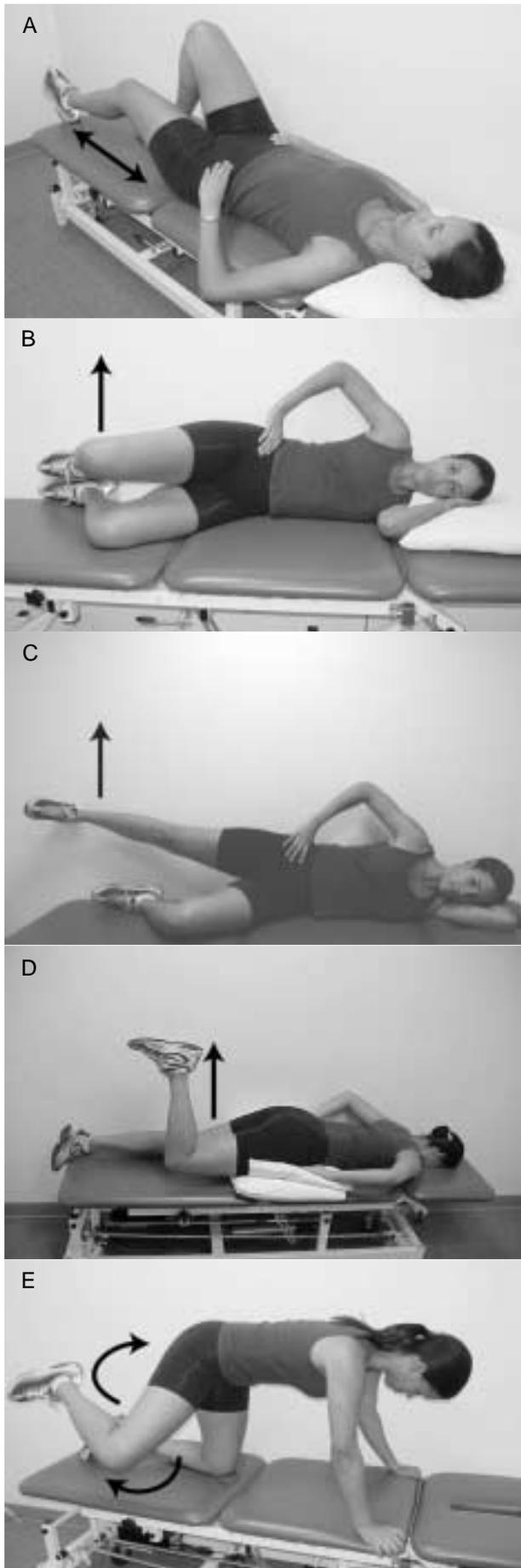


FIGURE 2. Kinematic plots demonstrating patient A's lower-extremity motion (preintervention and postintervention) during the step-down task. (A) Hip internal rotation. (B) Hip adduction. (C) Frontal plane pelvic motion of the contralateral pelvis.



**FIGURE 3.** Non-weight-bearing exercises performed with the spine maintained in a neutral position (weeks 0-6). (A) Alternate hip and knee flexion/extension motions. (B) Gluteus medius exercises involving hip abduction/external rotation. (C) Progression of gluteus medius exercise. Placing the uppermost knee in extension increases the lever arm. The hip should be held in less than 25° external rotation and slight extension. (D) Gluteus maximus strengthening was facilitated by extending the hip with the knee held in greater than 90° of knee flexion. Anterior pelvic tilt palpated by the patient's fingers on the anterior superior iliac spine indicates end range active hip extension. (E) Hip abductor and external rotator strengthening was progressed by assuming a quadrupedal starting position and performing an external rotation/abduction/extension motion of the lower extremity against gravity.

The patients were educated regarding their condition and the intended treatment approach and realistic goal setting was discussed.

Both patients were placed on an exercise program initially focused on controlling pelvic motion while performing active lower-extremity movement. According to Nadler et al,<sup>41</sup> it is important to establish satisfactory lumbopelvic control to ensure that the proximal attachment site for the hip abductors and lateral rotators is stable. Such stability is thought to promote greater torque production by these muscles during exercise and minimize frontal-plane motion (ie, contralateral pelvic drop or spinal side flexion) during single-limb stance activities.

The hip muscles (particularly gluteus maximus and medius, hip abductors, and lateral rotators) were progressively strengthened first in the non-weight-bearing position, then in the weight-bearing position, using functional movement patterns. By focusing on the maintenance of a stable pelvis while introducing active hip motions, it was thought that proprioceptive awareness also would be enhanced.<sup>15,50,58</sup>

Specific recommendations for muscle strength training are controversial and a variety of training protocols have been established. It is generally agreed, however, that an exercise load that causes fatigue after 10 to 15 repetitions for 2 to 3 sets, performed 3 times a week for 6 to 12 weeks, will lead to improved muscle strength.<sup>16,32,47</sup>

Based on these parameters, a progression criterion for the proposed exercise program was formulated. When the patient could perform a specific exercise (or a 10-second isometric muscle contraction), for 2 sets of 15 repetitions, while maintaining a neutral spinal position, the exercise would be progressed by increasing resistance. Both patients were given a home exercise program that they were to perform twice 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 the patient was able to correctly carry out the movement in the clinic with minimal verbal prompts.

As muscle strength and motor control improved, patients were progressed to complex coordinated motor patterns involving functional activities. At this time, they gradually reinstated their previous in-

volvement in identified sport and social activities. Specific details concerning the various exercises employed are discussed below.

### Non-Weight-Bearing Exercise (Weeks 0-6)

Prior to initiating the dynamic strengthening program of the hip musculature, the patients were taught to perform isometric contractions of the abdominals, gluteus medius, and gluteus maximus. Abdominal strengthening exercises were performed in a hook-lying position as described by Taylor and O'Sullivan.<sup>58</sup> A pressure cuff provided feedback of the spinal position during the hook-lying exercise. The cuff was placed between the lumbar spine and the treatment table and inflated slightly. The patients were asked to maintain a stable pressure reading (interpreted as minimal spinal motion), while performing concurrent hip and knee flexion with alternate legs (Figure 3A). Following principles of motor learning and skill acquisition,<sup>62</sup> the pressure cuff feedback was provided at a reduced schedule and gradually removed.

Isometric strengthening exercises for the gluteus medius were performed in sidelying with the hips and knees slightly flexed to minimize contribution from the tensor fascia lata (TFL). The TFL was judged to be contributing excessively when there was palpable activity in the muscle belly during the exercise. Initially, patient B had great difficulty in minimizing TFL activity. She was, therefore, instructed to initiate her isometric gluteus medius contractions in sidelying in front of a wall with her feet against it, so that by applying slight pressure to the wall, active hip extension was encouraged, thereby reinforcing the gluteus medius contraction.

Isometric gluteus maximus exercises were performed as described by Sahrman.<sup>50</sup> This involved lying in prone with 1 knee flexed to 90°. The patients were instructed to contract the ipsilateral gluteal muscle, while keeping the leg as relaxed as possible, thus minimizing hamstring muscle activity.

When a stable spinal position could be maintained while performing concurrent hip and knee flexion with alternate legs, and the progression criteria were achieved for isometric gluteus maximus and medius contractions, the patients were progressed to dynamic exercises. This occurred at week 3 for patient A, and week 4 for patient B. The subsequent program of dynamic hip-strengthening exercises for the lateral rotators and the abductors of the hip predominately targeted the gluteus medius and maximus.

Gluteus medius exercises were done in sidelying, with hips and knees flexed, performing hip abduction with external rotation, while maintaining a neutral spinal position by coactivating the transversus abdominus (Figure 3B). The patients were instructed to keep both feet together and lift the uppermost knee as high as possible, while concurrently palpating

their ASIS ipsilateral to the side of lower-extremity motion. This was done to ascertain when pelvic rotation occurred. The patients were instructed to stop when movement was felt. Throughout the remaining exercise progressions, the patients were continually encouraged to maintain a static pelvic position, with emphasis being placed on the patients self-monitoring their performance using tactile and visual (mirror) feedback.

Performing the sidelying hip abduction exercise with an extended knee initially increased the resistance of the previously described exercise (Figure 3C). To isolate the gluteus medius and minimize tensor fascia lata activity, the hip was maintained in a slightly extended position and externally rotated to less than 25°. Care was taken that the pelvis and lumbar spine remained stable throughout, ensuring isolation of the movement to the hip joint.

During this time, gluteus maximus exercises were also given in a prone position over a pillow with the knee held in at least 90° flexion (Figure 3D).<sup>50</sup> Patients were instructed to extend their slightly externally rotated hip until they felt approximation of the ASIS on the pillow indicating an anterior tilt of the pelvis and lumbar spine extension. Throughout the range of motion, the patients were encouraged to focus on contraction of the gluteal muscles and minimize activity of the hamstrings.

When patients were able to perform 2 sets of 15 repetitions of the above exercises, they were progressed to the quadruped position to perform hip external rotation/abduction, and hip extension (Figure 3E). The demand was further increased by applying an external load using either Theraband (Hygenic Corporation, Akron, OH) tied around the thighs, or a soft weight around the ankles. The amount of weight was increased, using the guidelines mentioned previously, in 1-lb (0.5-kg) increments.

### Weight-Bearing Exercise (Weeks 6-10)

Once the patients were able to isolate the muscles of interest during non-weight-bearing exercises, they were progressed to weight-bearing exercises, which included isometric and dynamic exercises in single-limb stance. At this time the patients were introduced to the concept of neutral lower-extremity alignment as described by McConnell.<sup>38</sup> This involved alignment of the lower extremity such that the ASIS and knee remained positioned over the second toe, with the hip positioned in approximately 10° of external rotation.

The patients were then instructed to stand next to a wall with the stance limb furthest from the wall. They were asked to contract their transversus abdominus and gluteal muscles and then to assume a single-limb stance position by flexing the contralateral knee with the hip in a neutral position (Figure 4A). Patients then performed isometric external rotation

of the stance leg while concurrently pushing the bent leg into the wall. No movement of the pelvis was allowed, as confirmed by palpating the ASIS. In addition to challenging the abductors and external rotators of the unsupported leg, this exercise also required the stance leg to maintain relative hip abduction despite the creation of an adduction torque by the body's center of mass during single-limb stance.<sup>42</sup>

When the patients were able to perform 2 sets of fifteen 10-second repetitions of this exercise without excessive motion of the pelvis or lower extremity, simultaneous upper-extremity exercises in single-limb stance were added. The exercise initially involved ipsilateral upper-extremity activities and was then progressed to include the contralateral arm.

Evidence suggests that performing exercises in single-limb stance enhances gluteus medius activity,<sup>20</sup> and carrying a load in the arm contralateral to the stance limb leads to higher gluteus medius EMG activity than if applied on the ipsilateral side.<sup>42</sup> Patients were given a combination of fast upper-extremity activities, such as ball throws against a wall, alternate biceps curls, and rowing exercises, using Theraband and pulley systems (Figure 4B) to provide light resistance. Throughout these tasks, the patients were instructed to maintain neutral lower-extremity and pelvis alignment, palpating the ASIS of the stance limb using the free hand to monitor motion.

At week 8, weight-bearing exercises for the abductors and external rotators of the hip were added. These were undertaken using the Clinical Reformer Pilates exercise equipment (Current Concepts Corp., Sacramento, CA). This device consists of a horizontally moving carriage on which the patient can lie, kneel, sit, or stand. Resistance is provided using springs, with fewer springs increasing the demand on

the trunk stability musculature and more springs increasing the lower-extremity demand. Postural alignment and symmetrical strengthening were emphasized during all exercises.<sup>55</sup> To target the hip abductors and trunk muscles, the patients stood on the Clinical Reformer, assuming a neutral lower-extremity alignment, with 1 foot on the carriage. They were then instructed to perform a double hip abduction movement against light resistance while maintaining a level pelvic position and neutral lower-extremity alignment (Figure 4C).

Using the stated progression criteria, the patients were instructed to maintain a neutral lower-extremity alignment while in single-limb stance, and to rotate the upper body and trunk medially against resistance provided by Theraband (Figure 4D). This task produced relative external rotation of the hip performed in a weight-bearing position.

#### Functional Training (Weeks 10-14)

To reinforce the concept of maintaining neutral lower-extremity alignment during functional tasks, the patients were introduced to shallow-squatting activities. These were initially performed on the Clinical Reformer, using a leg press motion (Figure 5A). The benefit of utilizing the Clinical Reformer is that it allows the subject to perform a weight-bearing activity with a load significantly less than body weight. This will lessen joint reaction forces,<sup>7,37</sup> especially if performed in knee flexion ranges less than 45°. The exercise was then progressed by securing Theraband around the distal aspect of the thighs to encourage activation of the external hip rotator/abductor musculature throughout the range of hip flexion/extension movement, and to provide proprioceptive



**FIGURE 4.** Weight-bearing exercises (weeks 6-10). (A) Isometric hip abduction performed in weight bearing against a wall. (B) Upper-extremity activities performed in a single-leg stance. (C) Bilateral standing hip abduction performed on the Clinical Reformer. The patient's right leg is on a platform that moves to the right against spring resistance as she concurrently pushes both legs apart against resistance, while maintaining a stable pelvic position. (D) Holding Theraband and rotating the body medially while maintaining a static lower extremity produces relative external rotation at the hip.

input. The spring resistance to the leg press maneuver was then gradually increased as symptoms and strength gains dictated. When the patients could consistently demonstrate neutral lower-extremity alignment bilaterally throughout the semisquat activity against the maximum spring resistance for 2 sets of 15 repetitions, they were progressed to a single-leg squat while maintaining the required neutral alignment of the lower extremity (Figure 5B). When the progression criterion was achieved, they then progressed to the same motion in standing, first with a double- and then a single-leg squat exercise. At this time, patient A was able to perform a double- and single-leg shallow squat to 40° symptom free, and patient B was able to perform the double-leg shallow squat to 40° symptom free, with mild discomfort (VAS score, 2/10) on the single-leg squat. Once the patients were able to control a single-leg shallow squat in standing, they were given shallow lunging exercises (Figure 5C) from 0° to 45° knee flexion, using Theraband, as described above, around the anterior lunging thigh to promote activity of the hip abductors and external rotators. Both patients also began an aerobic conditioning exercise program using a stair-climbing machine (ClimbMaster, Tetrax Fitness Equipment, Irvine, CA) and were instructed to maintain the neutral lower-extremity alignment during stair-climbing activities.

As the patients' pain resolved, interventions were targeted at improving their functional limitations to achieve their stated goals. At week 8, when patient A was able to perform a shallow unilateral squat symptom free, and had no pain on stair climbing, she commenced a progressive independent running/walking program. At week 9, when patient B was able to perform a single-leg stance activity demonstrating neutral lower-extremity alignment of the stance limb during contralateral lower- and upper-extremity activities, she was encouraged to return to her walking program.

## RESULTS

Both patients were re-evaluated at week 14, 3 months after the commencement of the treatment program. Patient A had undergone 14 visits, while patient B had undergone 18 visits.

### Functional Status

The postintervention functional assessment scores increased from 76 to 85 and from 70 to 84 for patients A and B, respectively.

### Pain

Patient A reported no pain on walking or standing during her 10-hour work shift and she no longer required her neoprene support. In addition, she was

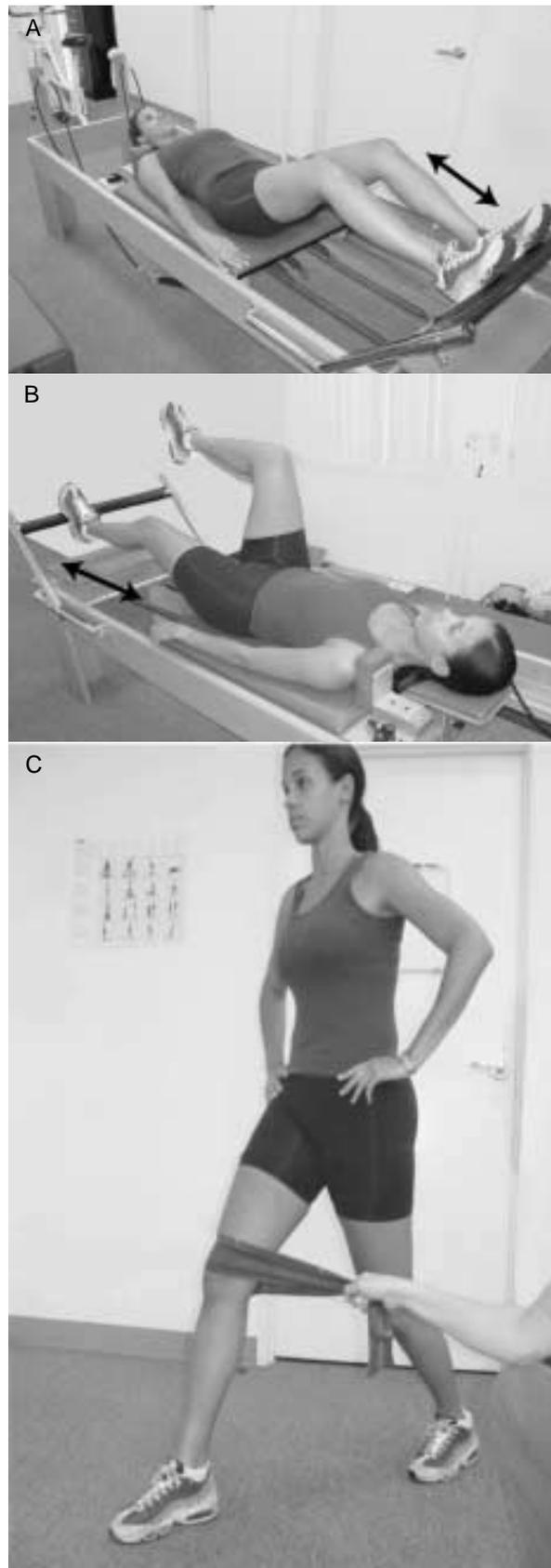


FIGURE 5. Functional training (weeks 10-14). (A) Double-limb squat performed on the Clinical Reformer. (B) Single-limb squat performed on the Clinical Reformer. (C) Lunges using Theraband around the affected leg were used to encourage external rotation and abduction of the hip throughout the range of motion.

now able to ascend and descend stairs without pain, had no feelings of weakness in her knee, and was able to run 2 to 3 miles without discomfort. She occasionally experienced a tight feeling in the right knee during a full squat to reach into low cupboards at work, but this did not limit her activity.

Patient B described a significant reduction in her pain level. She was now able to ascend and descend a flight of stairs symptom free with occasional discomfort (2/10) only if she had been on her feet for a considerable time. She could walk for 45 minutes and could perform house-cleaning chores that involved squatting without difficulty or pain.

### Patellofemoral Joint Examination

Re-evaluation of patient A's right patellofemoral joint demonstrated a negative apprehension test, but mild pain with patellar compression. She demonstrated pain-free isometric resisted knee extension in non-weight-bearing; however, some tightness was experienced at 20° of flexion. Patient B still demonstrated a mild positive patellar compression test with slight pain elicited and mild medial retinacular tenderness, but no pain on isometric resisted knee extension at 20° to 0°. She had full pain-free passive range of patella mobility.

### Muscle Strength Assessment

Re-evaluation of muscle strength using the handheld dynamometer revealed significant improvements in both patients (Table). Patient A demonstrated strength gains in all muscle groups, most notably the ipsilateral lateral rotators of the hip (317%), gluteus maximus (55%), gluteus medius (50%), and quadriceps (20%). Similarly, patient B demonstrated strength gains in the gluteus maximus (110%), gluteus medius (90%), the hip lateral rotator group (15%), and quadriceps (10%).

### Dynamic Assessment

*Gait* Based on observational assessment, both patients demonstrated improved gait kinematics at the hip in the frontal and transverse planes. In general, there was less hip adduction during weight acceptance, and a decrease in both hip internal rotation and contralateral pelvic drop during midstance.

*Step-Down Task* Both patients demonstrated significant improvements during the step-down maneuver. Both had a reduction in adduction/internal rotation of the stance limb, less knee valgus, and a smoother motion into hip flexion. Neither patient experienced pain during, or after, the step-down maneuver.

### Biomechanical Assessment

Postintervention kinematic analysis of the step-down maneuver was performed on patient A, as described earlier. When compared to pretreatment values, improvements were noted in all motions (Figure 6). Specifically, average hip internal rotation during stance improved from 1.4° of internal rotation to 2.6° of external rotation; hip adduction was observed to decrease from 8.7° to 2.3°; and contralateral pelvic drop was reduced from 3.9° to 1.1° (Figure 2). These objective measurements were in agreement with the clinical observations noted earlier.

### DISCUSSION

These case reports describe 2 patients with chief complaints of PFP who responded favorably to a strengthening program targeting the trunk, pelvis, and hip musculature. Clinically relevant results were achieved without treatment strategies commonly employed for the patellofemoral joint (ie, taping, vastus medialis oblique strengthening, or stretching regimens). This suggests that the underlying cause of PFP in certain individuals may not be restricted to the patellofemoral joint.

Carson and James<sup>9,25</sup> discussed the relevance of considering lower-extremity kinetic chain factors when evaluating and treating patients with a chief complaint of knee pain. In addition, research by Beckman and Buchanan,<sup>1</sup> Bullock-Saxton,<sup>8</sup> and Jaramillo et al<sup>26</sup> has demonstrated that weakness proximal to the symptomatic area is often present with distal lower-extremity pathologies. This weakness, however, may be a precursor to the pathology or the result of subsequent motor control changes.<sup>27</sup> Nevertheless, by addressing the identified weak proximal musculature in the patients in these cases, improvements were noted in both subjective and objective parameters.

It should be noted that during the exercise program, patients were continuously encouraged to monitor their performance of each motion. Such training would facilitate motor learning of correct movement patterns, which may be distinct from control of motion due to muscle strength alone.<sup>49</sup> It is, therefore, possible that the observed improvements in lower-extremity kinematics could have been the result of a combination of muscle strength and improved motor control of motion.

Both patients initially had a chief complaint of pain during stair ascent/descent and prolonged walking, and demonstrated poor control of the lumbopelvic/hip region during these activities. McFadyen<sup>39</sup> and Soderberg<sup>56</sup> concluded that the gluteus medius plays an important role in hip and pelvic stability during



**FIGURE 6.** Computer-generated skeletal representation of patient A's lower-extremity kinematics. (A) Prior to intervention. (B) Postintervention. Reduced hip adduction and internal rotation of the hip can be observed in B.

stair descent, especially during the last 85% of the stance phase. In the preintervention test, patient A demonstrated excessive hip adduction during the last 80% of stance phase, suggesting inadequate strength of the gluteus medius. As can be seen by the postintervention data (Figure 2B), hip adduction was reduced, especially during the last 80% of the step-down cycle, suggesting an improved control of this motion.

Although the measured changes in hip adduction during the step-down maneuver were relatively small (6.4° averaged across the stance phase), we believe

that this difference was clinically meaningful. For example, hip adduction would move the patella medially with respect to the ASIS, thereby increasing the dynamic Q angle.<sup>45</sup> Theoretically, any decrease in the hip adduction angle could result in a decrease in the dynamic Q angle, thereby reducing the lateral force acting on the patella.<sup>45</sup>

The gluteus maximus muscle has been shown to be a powerful external rotator of the hip,<sup>12</sup> and the function of its upper fibers have been found by Lyons et al<sup>34</sup> to be similar to that of gluteus medius during gait and stair ascent. The substantial changes found

in preintervention and postintervention muscle strengths and kinematic data evaluating hip external rotation (Figure 2A) indicate that the gluteus maximus may play an important role in the control of hip motion during gait and single-limb support activities.

The efficacy of quadriceps strengthening for PFP has been described by several authors,<sup>11,29,30</sup> and an argument could be made that in undertaking the above exercise program, strength changes in the quadriceps group may have also contributed to the decrease in symptoms. While this may be the case, it should be noted that the strength gains in the quadriceps were significantly less than in the other muscle groups. Therefore, the resultant improvement in the eccentric step-down activity and associated pain are unlikely to be solely due to changes in quadriceps strength.

The patients studied in these 2 case reports were selected based on their clinical presentation of suspected proximal weakness, as suggested by observational tests of gait and stair descent, and the lack of localized patellofemoral joint static positional faults and dynamic tracking problems. As always, careful selection of the appropriate patient for a particular intervention is important in achieving successful outcomes. With this in mind, we feel that the described treatment approach should be considered in the management of patients with PFP who present with similar clinical findings. This may be especially true of those patients in whom a traditional course of treatment has not produced satisfactory results.

## CONCLUSION

These case reports present 2 patients with PFP who demonstrated abnormal kinematics at the hip and who responded favorably to an exercise program specifically targeting the hip, pelvis, and trunk musculature. Further research is indicated to better define the relationship between proximal hip muscle weakness and PFP, and to identify patients who will best respond to this treatment approach.

## ACKNOWLEDGMENTS

The authors wish to thank Yu-Jen Chen, PT, MS, for assisting in the collection and processing of the kinematic data, and the staff at USC Physical Therapy Associates, where these patients received their care.

## REFERENCES

1. Beckman SM, Buchanan TS. Ankle inversion injury and hypermobility: effect on hip and ankle muscle electromyography onset latency. *Arch Phys Med Rehabil.* 1995;76:1138-1143.
2. Bizzini M, Childs JD, Piva SR, Delitto A. Systematic review of the quality of randomized controlled trials for patellofemoral pain syndrome. *J Orthop Sports Phys Ther.* 2003;33:4-20.
3. Bohannon RW, Andrews AW. Interrater reliability of hand-held dynamometry. *Phys Ther.* 1987;67:931-933.
4. Bohannon RW. Intertester reliability of hand-held dynamometry: a concise summary of published research. *Percept Mot Skills.* 1999;88:899-902.
5. Bohannon RW. Reference values for extremity muscle strength obtained by hand-held dynamometry from adults aged 20 to 79 years. *Arch Phys Med Rehabil.* 1997;78:26-32.
6. Brody LT, Thein JM. Nonoperative treatment for patellofemoral pain. *J Orthop Sports Phys Ther.* 1998;28:336-344.
7. Buff HU, Jones LC, Hungerford DS. Experimental determination of forces transmitted through the patellofemoral joint. *J Biomech.* 1988;21:17-23.
8. Bullock-Saxton JE. Local sensation changes and altered hip muscle function following severe ankle sprain. *Phys Ther.* 1994;74:17-28; discussion 28-31.
9. Carson WG, Jr., James SL, Larson RL, Singer KM, Winternitz WW. Patellofemoral disorders: physical and radiographic evaluation. Part I: Physical examination. *Clin Orthop.* 1984;165-177.
10. Clark MA. Core stabilization training in rehabilitation. In: Prentice WE, Voight ML, eds. *Techniques in Musculoskeletal Rehabilitation.* New York, NY: McGraw-Hill; 2001:259-278.
11. Dehaven KE, Dolan WA, Mayer PJ. Chondromalacia patellae in athletes. Clinical presentation and conservative management. *Am J Sports Med.* 1979;7:5-11.
12. Delp SL, Hess WE, Hungerford DS, Jones LC. Variation of rotation moment arms with hip flexion. *J Biomech.* 1999;32:493-501.
13. Downie WW, Leatham PA, Rhind VM, Wright V, Branco JA, Anderson JA. Studies with pain rating scales. *Ann Rheum Dis.* 1978;37:378-381.
14. Fairbank HAT. Derangement of the knee in children and adolescents. *Proc Roy Soc Med.* 1937;30:427-432.
15. Farrell JP, Koury M, Caroline DT. Therapeutic exercise for back pain. In: Twomey LT, Taylor JR, eds. *Physical Therapy of the Low Back.* New York, NY: Churchill Livingstone; 2000:327-350.
16. Franklin BA, Whaley MH, Howley ET. *ACSM's Guidelines for Exercise Testing and Prescription.* Philadelphia, PA: Lippincott Williams and Wilkins; 2000.
17. Fitzgerald GK, McClure PW. Reliability of measurements obtained with four tests for patellofemoral alignment. *Phys Ther.* 1995;75:84-90; discussion 90-82.
18. Grelsamer RP, McConnell J. *The Patella: A Team Approach.* Gathersburg, MD: Aspen Publishers; 1998.
19. Henry JH. Conservative treatment of patellofemoral subluxation. *Clin Sports Med.* 1989;8:261-278.
20. Hodges PW, Richardson CA. Contraction of the abdominal muscles associated with movement of the lower limb. *Phys Ther.* 1997;77:132-142; discussion 142-134.
21. Huberti HH, Hayes WC. Patellofemoral contact pressures. The influence of q-angle and tendofemoral contact. *J Bone Joint Surg Am.* 1984;66:715-724.
22. Hvid I, Andersen LI. The quadriceps angle and its relation to femoral torsion. *Acta Orthop Scand.* 1982;53:577-579.
23. Inman VT. Functional aspects of the abductor muscles of the hip. *J Bone Joint Surg Am.* 1947;53:577-579.
24. Insall J. Current Concepts Review: patellar pain. *J Bone Joint Surg Am.* 1982;64:147-152.

25. James SL, Bates BT, Osternig LR. Injuries to runners. *Am J Sports Med.* 1978;6:40-50.
26. Jaramillo J, Worrell TW, Ingersoll CD. Hip isometric strength following knee surgery. *J Orthop Sports Phys Ther.* 1994;20:160-165.
27. Jenkins W, Bronner S, Mangine RE. Functional evaluation and treatment of the lower extremity. In: Brownstein B and Bronner S, eds. *Functional Movement in Orthopaedic and Sports Physical Therapy: Evaluation, Treatment, and Outcomes.* New York, NY: Churchill Livingstone; 1997:191-229.
28. Kannus P, Aho H, Jarvinen M, Niittymaki S. Computerized recording of visits to an outpatient sports clinic. *Am J Sports Med.* 1987;15:79-85.
29. Kannus P, Natri A, Paakkala T, Jarvinen M. An outcome study of chronic patellofemoral pain syndrome. Seven-year follow-up of patients in a randomized, controlled trial. *J Bone Joint Surg Am.* 1999;81:355-363.
30. Kannus P, Niittymaki S. Which factors predict outcome in the nonoperative treatment of patellofemoral pain syndrome? A prospective follow-up study. *Med Sci Sports Exerc.* 1994;26:289-296.
31. Kendall FP, McCreary EK, Provance P. *Muscles, Posture, and Pain.* Baltimore, MD: Williams and Wilkins; 1993.
32. Kisner C, Colby LA. *Therapeutic Exercise: Foundations and Techniques.* Philadelphia, PA: F. A. Davis; 1996.
33. Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O. Scoring of patellofemoral disorders. *Arthroscopy.* 1993;9:159-163.
34. Lyons K, Perry J, Gronley JK, Barnes L, Antonelli D. Timing and relative intensity of hip extensor and abductor muscle action during level and stair ambulation. An EMG study. *Phys Ther.* 1983;63:1597-1605.
35. Macausland WR, Sargent AF. Recurrent dislocation of the patella. *Surg Gynecol Obstet.* 1922;35:35-41.
36. Magee DJ. *Orthopedic Physical Assessment.* Philadelphia, PA: W. B. Saunders; 1997.
37. Maquet PGJ. *Biomechanics of the Knee: With Application to the Pathogenesis and the Surgical Treatment of Osteoarthritis.* New York, NY: Springer-Verlag; 1984.
38. McConnell J. Patellofemoral joint complications and considerations. In: Ellenbecker TS, ed. *Knee Ligament Rehabilitation.* New York, NY: Churchill Livingstone; 2000:202-224.
39. McFadyen BJ, Winter DA. An integrated biomechanical analysis of normal stair ascent and descent. *J Biomech.* 1988;21:733-744.
40. Messier SP, Davis SE, Curl WW, Lowery RB, Pack RJ. Etiologic factors associated with patellofemoral pain in runners. *Med Sci Sports Exerc.* 1991;23:1008-1015.
41. Nadler SF, Malanga GA, Bartoli LA, Feinberg JH, Prybicien M, Deprince M. Hip muscle imbalance and low back pain in athletes: influence of core strengthening. *Med Sci Sports Exerc.* 2002;34:9-16.
42. Neumann DA, Cook TM. Effect of load and carrying position on the electromyographic activity of the gluteus medius muscle during walking. *Phys Ther.* 1985;65:305-311.
43. Neumann DA, Soderberg GL, Cook TM. Comparison of maximal isometric hip abductor muscle torques between hip sides. *Phys Ther.* 1988;68:496-502.
44. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for knee pain. *Phys Ther.* 2001;81:1675-1700.
45. Powers CM. The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. *J Orthop Sports Phys Ther.* 2003;33:647-660.
46. Powers CM. Rehabilitation of patellofemoral joint disorders: a critical review. *J Orthop Sports Phys Ther.* 1998;28:345-354.
47. Prentice WE. Impaired muscle performance: regaining muscular strength and endurance. In: Prentice WE, Voight ML, eds. *Techniques in Musculoskeletal Rehabilitation.* New York, NY: McGraw-Hill; 2001:59-72.
48. Price DD, McGrath PA, Rafii A, Buckingham B. The validation of visual analogue scales as ratio scale measures for chronic and experimental pain. *Pain.* 1983;17:45-56.
49. Rose DJ. *A Multilevel Approach to the Study of Motor Control and Learning.* Boston, MA: Allyn and Bacon; 1997.
50. Sahrmann S. *Diagnosis and Treatment of Movement Impairment Syndromes.* St. Louis, MO: Mosby; 2002.
51. Salsich GB, Brechter JH, Farwell D, Powers CM. The effects of patellar taping on knee kinetics, kinematics, and vastus lateralis muscle activity during stair ambulation in individuals with patellofemoral pain. *J Orthop Sports Phys Ther.* 2002;32:3-10.
52. Salsich GB, Brechter JH, Powers CM. Lower extremity kinetics during stair ambulation in patients with and without patellofemoral pain. *Clin Biomech (Bristol, Avon).* 2001;16:906-912.
53. Scott J, Huskisson EC. Graphic representation of pain. *Pain.* 1976;2:175-184.
54. Scuderi GR. Surgical treatment for patellar instability. *Orthop Clin North Am.* 1992;23:619-630.
55. Siler B. *The Pilates Body.* New York, NY: Broadway; 2000.
56. Soderberg GL, Dostal WF. Electromyographic study of three parts of the gluteus medius muscle during functional activities. *Phys Ther.* 1978;58:691-696.
57. Steinkamp LA, Dillingham MF, Markel MD, Hill JA, Kaufman KR. Biomechanical considerations in patellofemoral joint rehabilitation. *Am J Sports Med.* 1993;21:438-444.
58. Taylor JR, O'Sullivan P. Lumbar segmental instability: pathology, diagnosis, and conservative management. In: *Physical Therapy of the Low Back.* New York, NY: Churchill Livingstone; 2000:201-247.
59. Thomee R, Augustsson J, Karlsson J. Patellofemoral pain syndrome: a review of current issues. *Sports Med.* 1999;28:245-262.
60. Ward SR, Powers CM, Fredericson M, Guillet M, Shellock FG. The influence of medial femoral rotation on lateral patellar tilt during weight bearing and non weight bearing movements. *Med Sci Sports Exerc.* 2002;34:S160.
61. Wilk KE, Davies GJ, Mangine RE, Malone TR. Patellofemoral disorders: a classification system and clinical guidelines for nonoperative rehabilitation. *J Orthop Sports Phys Ther.* 1998;28:307-322.
62. Winstein CJ. Knowledge of results and motor learning—implications for physical therapy. *Phys Ther.* 1991;71:140-149.

# Appendix

Functional assessment tool for patellofemoral joint disorders (from Kujala et al,<sup>33</sup> with permission from the Arthroscopy Association of North America).

## Kujala Questionnaire for Patellofemoral Joint Pain

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Age: \_\_\_\_\_

Knee: L/R

Duration of symptoms: \_\_\_\_\_ years \_\_\_\_\_ months

For each question, circle the latest choice (letter) which corresponds to your knee symptoms.

1. Limp
  - (a) None (5)
  - (b) Slight or periodical (3)
  - (c) Constant (0)
2. Support
  - (a) Full support without pain (5)
  - (b) Painful (3)
  - (c) Weight bearing impossible (0)
3. Walking
  - (a) Unlimited (5)
  - (b) More than 2 km (3)
  - (c) 1-2 km (2)
  - (d) Unable (0)
4. Stairs
  - (a) No difficulty (10)
  - (b) Slight pain when descending (8)
  - (c) Pain both when descending and ascending (5)
  - (d) Unable (0)
5. Squatting
  - (a) No difficulty (5)
  - (b) Repeated squatting painful (4)
  - (c) Painful each time (3)
  - (d) Possible with partial weight bearing (2)
  - (e) Unable (0)
6. Running
  - (a) No difficulty (10)
  - (b) Pain after more than 2 km (8)
  - (c) Slight pain from start (6)
  - (d) Severe pain (3)
  - (e) Unable (0)
7. Jumping
  - (a) No difficulty (10)
  - (b) Slight difficulty (7)
  - (c) Constant pain (2)
  - (d) Unable (0)
8. Prolonged sitting with the knees flexed
  - (a) No difficulty (10)
  - (b) Pain after exercise (8)
  - (c) Constant pain (6)
  - (d) Pain forces to extend knees temporarily (4)
  - (e) Unable (0)
9. Pain
  - (a) None (10)
  - (b) Slight and occasional (8)
  - (c) Interferes with sleep (6)
  - (d) Occasionally severe (3)
  - (e) Constant and severe (0)
10. Swelling
  - (a) None (10)
  - (b) After severe exertion (8)
  - (c) After daily activities (6)
  - (d) Every evening (4)
  - (e) Constant (0)
11. Abnormal painful kneecap (patellar) movements (subluxations)
  - (a) None (10)
  - (b) Occasionally in sports activities (6)
  - (c) Occasionally in daily activities (4)
  - (d) At least 1 documented dislocation (2)
  - (e) More than 2 dislocations (0)
12. Atrophy of thigh
  - (a) None (5)
  - (b) Slight (3)
  - (c) Severe (0)
13. Flexion deficiency
  - (a) None (5)
  - (b) Slight (3)
  - (c) Severe (0)