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Differences in Hip Kinematics, Muscle Strength, and Muscle Activation Between Subjects With and Without Patellofemoral Pain

Patellofemoral pain (PFP) remains one of the most perplexing and clinically challenging orthopaedic conditions. Despite the high incidence of PFP,[9,11] the pathomechanics of this disorder remain poorly understood. Given as such, considerable research efforts have focused on identifying the root cause of this condition.

Recently, it has been postulated that patellofemoral joint dysfunction may be the result of abnormal proximal joint control.[12,17,20] More specifically, altered patellofemoral joint mechanics may be the result of abnormal femur kinematics as opposed to abnormal patellar kinematics. Powers and colleagues[21] reported that lateral subluxation of the patella during weight bearing was the result of the femur internally rotating underneath the patella. This finding is relevant with respect to patellofemoral joint biomechanics, as Lee and colleagues[10] have reported that internal rotation of the femur increases patellofemoral joint stress. Furthermore, it has been proposed that hip adduction can contribute to dynamic valgus of the lower extremity, thereby increasing the lateral forces acting on the patella.[17] For these reasons, excessive hip internal rotation and adduction have been implicated as being contributory to PFP.

Altered hip kinematics observed in persons with PFP may be related to hip muscle weakness. Ireland and colleagues[8] reported that females with PFP demonstrated significant weakness in hip abduction and external rotation, when compared to a pain-free control group. Recent studies by Robinson and Nee,[22] Cichanowski et al,[3] and Bolgla et al[2] have confirmed the presence of hip muscle weakness in this population. Clinical evidence that hip muscle weakness may play a role in PFP has been provided by Mascal and colleagues.[12] These authors reported on 2 patients with PFP who

• **STUDY DESIGN:** Controlled laboratory study using a cross-sectional design.

• **OBJECTIVES:** To determine whether females with patellofemoral pain (PFP) demonstrate differences in hip kinematics, hip muscle strength, and hip muscle activation patterns when compared to pain-free controls.

• **BACKGROUND:** It has been proposed that abnormal hip kinematics may contribute to the development of PFP. However, research linking hip function to PFP remains limited.

• **METHODS AND MEASURES:** Twenty-one females with PFP and 20 pain-free controls participated in this study. Hip kinematics and activity level of hip musculature were obtained during running, a drop jump, and a step-down maneuver. Isometric hip muscle torque production was quantified using a multimodal dynamometer. Group differences were assessed across tasks, using mixed-design 2-way analyses of variance and independent t tests.

• **RESULTS:** When averaged across all 3 activities, females with PFP demonstrated greater peak hip internal rotation compared to the control group (mean ± SD, 7.6° ± 7.0° versus 1.2° ± 3.8°; $P<.05$). The individuals in the PFP group also exhibited diminished hip torque production compared to the control group (14% less hip abductor strength and 17% less hip extensor strength). Significantly greater gluteus maximus recruitment was observed for individuals in the PFP group during running and the step-down task.

• **CONCLUSION:** The increased peak hip internal rotation motion observed for females in the PFP group was accompanied by decreased hip muscle strength. The increased activation of the gluteus maximus in individuals with PFP suggests that these subjects were attempting to recruit a weakened muscle, perhaps in an effort to stabilize the hip joint. Our results support the proposed link between abnormal hip function and PFP. *J Orthop Sports Phys Ther 2009;39(1):12-19. doi:10.2519/jospt.2009.2885*

• **KEY WORDS:** *biomechanics, kinematics, knee, motion analysis, patella*

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demonstrated excessive hip adduction and internal rotation (based on visual observation), as well as weakness of the hip extensors and abductors. A 14-week program of hip muscle strengthening resulted in improved hip kinematics (decreased hip adduction and internal rotation, as quantified by 3-dimension motion analysis), improved hip muscle strength, and decreased symptoms.

To date, only 2 studies have examined hip kinematics in individuals with PFP. Willson and Davis[24] reported that persons with PFP demonstrated greater amount of hip adduction during running, single-leg squatting, and repetitive single-leg jumps, when compared to pain-free individuals. However, these same subjects were found to have less hip internal rotation compared to the control group during these tasks. Willson and Davis[24] hypothesized that the observed decrease in hip internal rotation in the individuals with PFP might have been the result of a compensatory strategy to limit potentially painful motion. A recent publication by Bolgla and colleagues[2] investigated hip kinematics in females with PFP during stair descent. Despite significant decreases in hip muscle strength in those with PFP, no differences in hip adduction and internal rotation motion were observed between PFP and control subjects. These authors stated that a lack of group differences in hip kinematics may have been related to the fact that a relatively low-demand task was evaluated in their study.

Although studies by Willson and Davis[24] and Bolgla et al[2] have not confirmed the presence of abnormal kinematics in females with PFP, these authors have acknowledged study design issues that might have limited the ability to detect kinematic differences. As a result, the current study attempts to expand work in this area through a more comprehensive assessment of hip mechanics in females with PFP. More specifically, we sought to determine whether individuals with PFP demonstrate differences in hip kinematics, hip muscle strength, and hip muscle

TABLE	Subject Characteristics		
Variable	PFP (n = 21)	Controls (n = 20)	P Value
Age (y)	27 ± 6	26 ± 5	.48
Height (m)	1.7 ± 8.1	1.7 ± 6.0	.65
Mass (kg)	64.7 ± 10.4	62.9 ± 6.6	.52

Abbreviation: PFP, patellofemoral pain.
* Values are mean ± SD.

activation patterns during functional tasks, when compared to a control group. Hip muscle activation was evaluated to gain insight into the neuromuscular control strategies and/or neuromotor deficits exhibited by this population.

Based on existing literature in this area, we hypothesized that females with PFP would demonstrate greater amounts of hip adduction and hip internal rotation motion, when compared to pain-free controls. We also hypothesized that females with PFP would exhibit diminished strength of the hip abductors and extensors, and decreased neuromuscular activation of the hip musculature, when compared to females without PFP. Our hypotheses related to hip strength and neuromuscular activation are based on the premise that diminished strength and/or muscle activation could result in altered hip kinematics.

METHODS

Subjects

TWO GROUPS OF SUBJECTS WERE recruited for this study. Twenty-one females with PFP, between the ages of 18 and 45 years, comprised the experimental group, while 20 pain-free age-matched females served as a control group. The groups were similar in terms of age, height, and body mass (**TABLE**). Only females were studied because of the higher incidence of PFP in females compared to males, and because of potential differences in hip structure between sexes.[5,7,11,23] Individuals over the age of 45 were excluded from the study to control for the possible effects of overt

degenerative joint disease. Subjects in the PFP group were recruited via personal communication and word of mouth from local physical therapy and orthopaedic clinics in the Los Angeles area. Although some individuals had a physician diagnosis of PFP, this was not requisite for admission into the study. Control subjects were recruited primarily from the university setting, using posted flyers. In general, both groups consisted of young, active females.

For purposes of this study, subjects with PFP were screened through physical examination by a licensed physical therapist to rule out ligamentous instability, internal derangement, patellar tendinitis, and large knee effusion.[18,19] Only those subjects meeting the following criteria were admitted to the experimental group: (1) pain located specifically around the patellofemoral articulation (vague or localized); (2) readily reproducible pain (3 out of 10 on a visual analog scale) with at least 2 of the following functional activities commonly associated with PFP: stair ascent or descent, squatting, kneeling, prolonged sitting, or isometric quadriceps contraction; and (3) reports of pain greater than 3 months' duration.[20] Approximately 50% of the subjects that were screened were included in the study. The most common reasons for exclusion included pain in the patellar tendon (as opposed to the patellofemoral joint) and the lack of pain reproduction with aggravating tasks.

Individuals with PFP were excluded from participation if they reported any of the following: (1) previous history of knee surgery, (2) history of traumatic patellar

dislocation, or (3) neurological involvement that would influence gait. The control group was selected based on the same criteria as the experimental group, except that subjects had none of the following: (1) history or diagnosis of knee pathology or trauma, (2) current knee pain or effusion, (3) knee pain with any of the activities described for the individuals in the PFP group, and (4) any condition that would influence gait.

Instrumentation

Three-dimensional motion analysis was performed using a computer-aided video motion analysis system (Vicon; Oxford Metrics Ltd, Oxford, UK). Kinematic data were sampled at 120 Hz. Reflective markers (14-mm spheres), placed on specific anatomical landmarks, were used to determine lower extremity joint motions in the sagittal, frontal, and transverse planes. Ground reaction forces were obtained using 3 force plates (model OR6-6-1; Applied Marine Technology, Inc, Newton, MA) at a rate of 1560 Hz.

Electromyographic (EMG) signals of selected lower extremity muscles were recorded at 1560 Hz, using preamplified bipolar, grounded, surface electrodes (Motion Control, Salt Lake City, UT), hardwired to an analog-to-digital converter with heavy-duty insulated cable. Differential amplifiers were used to reject the common noise and amplify the remaining signal (gain, 2000).

Hip strength testing was performed with a Primus RS dynamometer (BTE Technologies, Hanover, MD). The Primus RS is capable of isometric, isokinetic, and isotonic testing modes.

Procedures

Subjects participated in 2 testing sessions. First, subjects underwent kinematic evaluation while performing 3 tasks: running, a drop jump, and a step-down maneuver. On a separate day, subjects returned for hip strength testing. This was done to prevent any possible influence of fatigue on the biomechanical evaluation.

All testing took place at the Muscu-loskeletal Biomechanics Research Laboratory at the University of Southern California. Prior to testing, all procedures were explained, and each subject signed a human subject consent form, as approved by The Institutional Review Board of the University of Southern California. After agreeing to participate, subjects' age, height, and mass were recorded. For subjects with unilaterally occurring PFP, only the painful limb was tested. In cases of bilateral pain, the most painful side at the time of testing (as determined by self report) was tested. In total, 13 right limbs and 8 left limbs were evaluated. For the control subjects, a similar distribution of right and left extremities was tested (13 right limbs and 7 left limbs). To control for the potential influence of footwear on lower extremity mechanics, subjects were provided with an appropriately sized pair of the same style of athletic shoes (New Balance Athletic Shoes, Inc, Boston, MA). Individuals involved in the testing of subjects were not blinded to group assignment.

Biomechanical Evaluation

Prior to EMG electrode placement, the skin was shaved, abraded with coarse gauze, and cleaned with isopropyl alcohol. Surface EMG electrodes were then placed over the gluteus maximus and gluteus medius, in accordance with previously published literature.[1,4,14] These 2 muscles were evaluated, as they are largely responsible for the control of hip internal rotation and adduction during dynamic tasks. The gluteus maximus electrode was placed over the muscle belly, midway between the second sacral vertebra and the greater trochanter. The gluteus medius electrode was placed 25-mm inferior to the iliac crest, directly superior to the greater trochanter. Electrodes were connected to an EMG receiver unit, which was carried in a small pack on the subject's back.

To allow for comparison of EMG signal intensity between subjects and muscles, and to control for signal variability induced by electrode placement, EMG data were normalized to the EMG acquired during a maximal voluntary isometric contraction (MVIC). Gluteus medius MVIC testing was performed with the subject positioned in side lying, with the bottom hip and knee comfortably flexed for balance. The upper limb was placed in 20° of hip abduction, 5° extension, and slight external rotation. A nylon strap was positioned at the lateral epicondyle of the femur to resist hip abduction.

The gluteus maximus MVIC was performed with the subject in prone on an examination table. Subjects maintained 90° of knee flexion and were allowed to hold the table for stabilization. A nylon strap was secured over the posterior thigh, 5 cm proximal to the popliteal crease, to resist hip extension. For all tests, participants were instructed to push as hard as possible into the strap for 5 seconds (1 trial only). Verbal encouragement was given throughout testing.

Following MVIC testing, reflective markers (14-mm spheres) were placed over the following bony landmarks: the first and fifth metatarsal heads, medial and lateral malleoli, medial and lateral femoral epicondyles, the joint space between the fifth lumbar and the first sacral spinous processes, and bilaterally over the greater trochanters and iliac crests. In addition, triads of rigid reflective tracking markers were placed on the lateral surfaces of the subject's thigh, leg, and heel counter of the shoe. Once all markers were secured, a standing calibration trial was captured. After the calibration trial, anatomical markers were removed. The tracking markers remained on the subject throughout the entire data collection session.

Practice trials of walking and running allowed subjects to become familiar with the instrumentation. Once the subjects indicated they were comfortable with the procedures, kinematic and EMG data were collected simultaneously during a predetermined running velocity (180 m/min) along a 15-m walkway. A trial was considered successful if the subject's in-

strumented foot landed within the borders of the force plate. For the step-down maneuver, subjects were instructed to lower themselves from an elevated force plate over a 2-second period, to touch their heel on the lower step, and to return to the starting position over a 2-second period.[24] A metronome was used to guide step-down rate. The depth of the step for this task was normalized to the subjects' height (10% of total body height). Finally, subjects performed a drop jump task as described by Pollard and colleagues.[16] Each subject started from a standing position on a 35-cm platform and was instructed to drop onto 2 force plates (1 for each foot) and jump upward as high as possible. Three trials of data were collected for each activity. Order of tasks was randomized for each subject.

Strength Evaluation

As noted above, subjects returned on a separate day for hip strength testing. To evaluate hip extensor torque, subjects were positioned in prone, with bilateral lower extremities off the edge of the dynamometer testing table. The hip was positioned in 30° of flexion and the knee was flexed to 90° (**FIGURE 1A**). The axis of rotation of the dynamometer was aligned with the hip joint center in the sagittal plane. The lever arm was attached to a resistance pad, which was positioned just superior to the popliteal space.

For hip abductor torque testing, subjects were placed in side lying on the dynamometer testing table. The target hip was placed superior and positioned in a neutral position (0° flexion, 0° abduction, 0° rotation). The axis of the dynamometer was aligned with the hip joint center in the frontal plane. The lever arm was attached to a resistance pad, which was positioned at the subject's lateral femoral epicondyle of the lower extremity being tested.

For both strength-testing assessments, subjects performed a 5-second isometric contraction. To facilitate a maximal effort, subjects received verbal encouragement. A total of 3 trials were collected for each
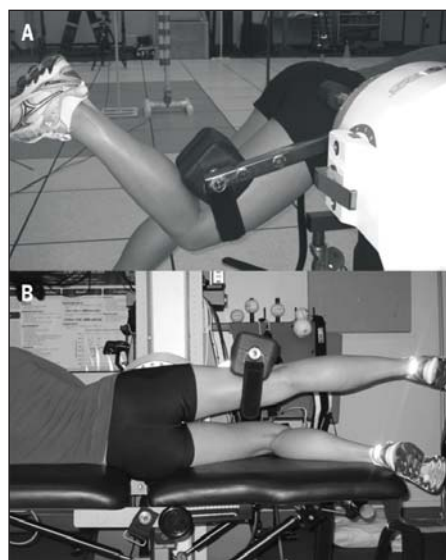

FIGURE 1. Hip muscle strength testing positions using the BTE dynamometer. (A) hip extension, (B) hip abduction.

of the 2 testing positions. A 1-minute rest was given between each trial.

Data Analysis

Reflective markers were identified manually within the VICON Workstation software. Visual 3D software (C-Motion, Rockville, MD) was used to quantify 3-D kinematics of the hip, based on standard anatomical conventions (ie, relative motion between the pelvis and thigh segments). EMG signals were band pass filtered (35-500 Hz) and a 60-Hz notch filter was applied. Data were full-wave rectified and a moving-average smoothing algorithm (75-millisecond window) was used to generate a linear envelope. EMG processing and smoothing was performed using EMG Analysis software (Motion Lab Systems, Baton Rouge, LA). The intensity of muscle activation was expressed as a percentage of EMG obtained during the MVIC.

Kinematic variables of interest consisted of peak hip internal rotation and peak hip adduction during the stance phase of each task. The average EMG signal intensity over the stance phase of each task served as the EMG variable of interest. Average EMG intensity (as opposed to peak EMG) was evaluated to provide a more global assessment of muscle ac-

tivation patterns throughout each activity. The stance phase of running and the drop jump task was identified, based on the ground reaction force data, as the period from initial contact to foot-off. The step-down cycle was determined by the stance limb knee flexion angle (the initial starting position to peak knee flexion and back to the starting position).

Hip torque data were transferred from the BTE dynamometer workstation to a personal computer and imported into Excel software (Microsoft Office, 2003, Redmond, WA). Peak torque values were identified for each trial and were normalized to body mass. For all variables, the average of 3 trials was used for statistical analysis.

Statistical Analysis

To determine if hip kinematics varied between groups across the 3 tasks evaluated, mixed-design 2-way analyses of variance (ANOVAs) (group by task), with task as a repeated factor, were performed. This analysis was repeated for each dependent variable of interest. For all ANOVA tests, significant main effects were reported if there were no significant interactions. If a significant interaction was found, the individual effects were analyzed separately. Independent t tests were used to determine if strength measures differed between the 2 groups. Statistical analyses were performed using SPSS statistical software (SPSS Inc, Chicago, IL), with a significance level of $P<.05$.

RESULTS

Kinematics

A significant group effect (no interaction) was observed for peak hip internal rotation. When averaged across all tasks, the individuals in the PFP group demonstrated greater amount of peak hip internal rotation, compared to the control group (mean ± SD, 7.6° ± 7.0° versus 1.2° ± 3.8°; $P<.001$; F value, 16.638; df, 1). The largest difference in peak hip internal rotation was observed during running (mean ± SD, 11.8° ± 6.9°
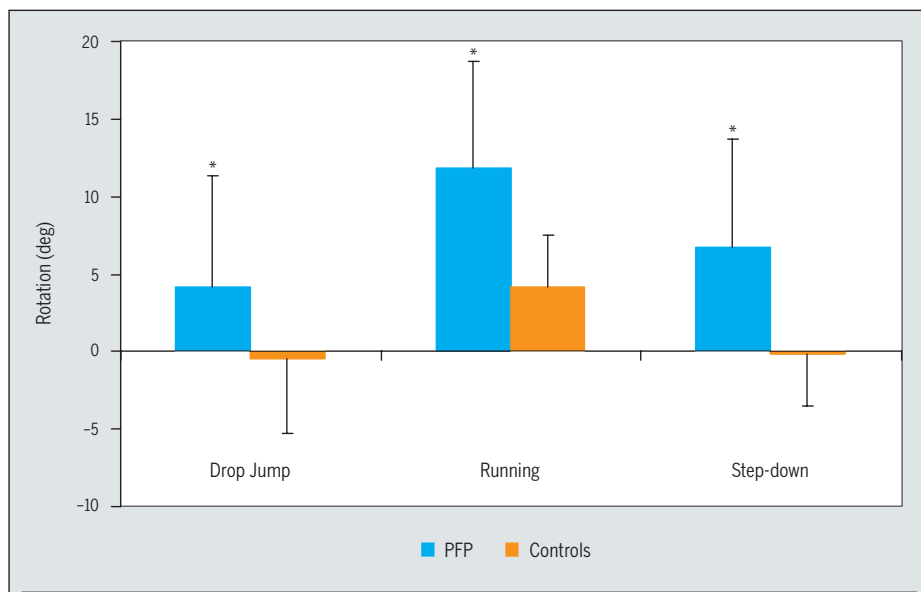
FIGURE 2. Comparison of peak hip internal rotation across the functional tasks evaluated. Data are mean ± SD. Negative values represent external rotation and positive values represent internal rotation. *Individuals with patellofemoral pain (PFP) significantly greater than controls, when averaged across all tasks ($P<.05$).
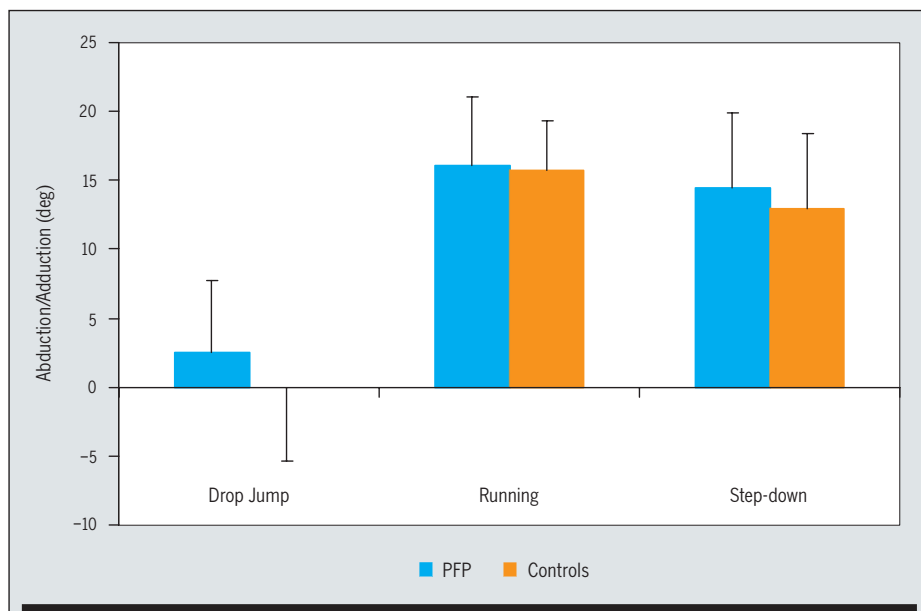

FIGURE 3. Comparison of peak hip adduction across the functional tasks evaluated. Data are mean ± SD. Negative values represent abduction and positive values represent adduction. No significant interaction or differences between groups ($P>.05$). Abbreviation: PFP, patellofemoral pain.

versus 4.2° ± 3.4°) (**FIGURE 2**). No significant group effect or interaction was found for peak hip adduction ($P = .273$; F value, 1.238; df, 1) (**FIGURE 3**).

Isometric Torque Testing

Females with PFP generated significantly less peak isometric hip abduction torque when compared to the control group

(mean ± SD, 1.39 ± 0.41 versus 1.62 ± 0.26 Nm/kg of body mass; $P = .02$; t value, −2.07; df, 39) (**FIGURE 4**). Similarly, the individuals in the PFP group generated significantly less hip extension torque when compared to the control group (mean ± SD, 1.98 ± 0.50 versus 2.35 ± 0.38 Nm/kg of body mass; $P = .005$; t value, −2.69; df, 39) (**FIGURE 4**).
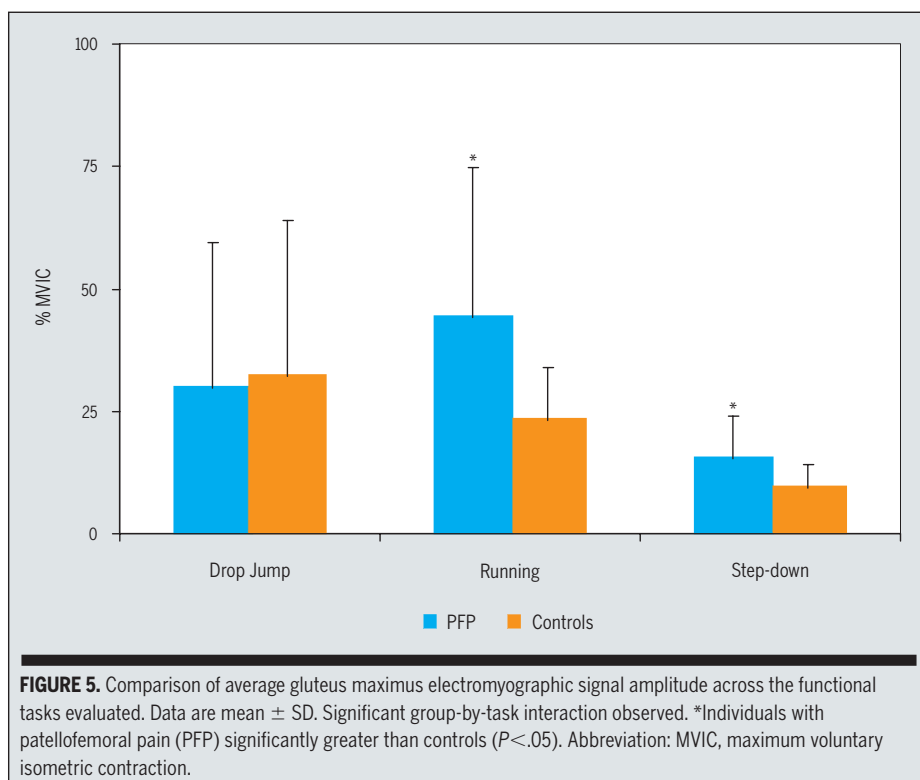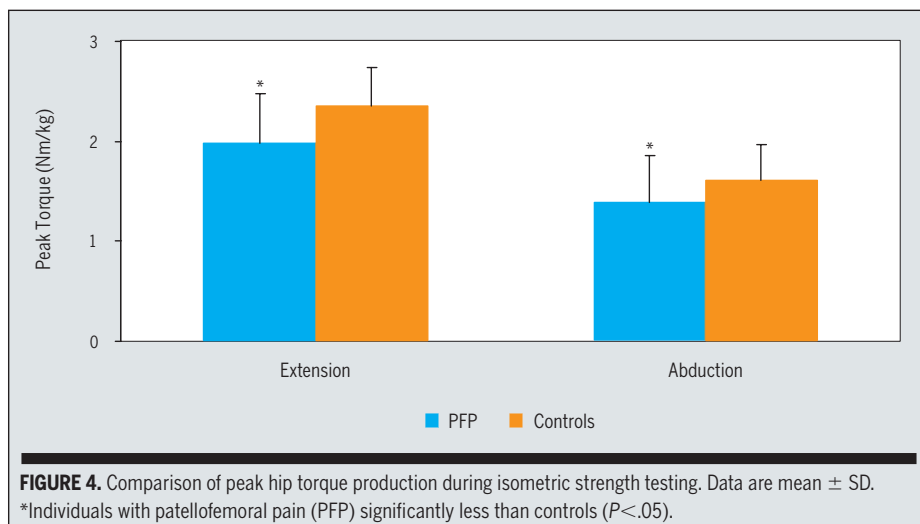
EMG

With respect to gluteus maximus EMG signal amplitude, there was a significant group-by-task interaction ($P = .041$; F value, 3.60; df, 1). Post hoc analysis revealed increased activation of the gluteus maximus in females with PFP during the step-down and running tasks, compared to the control group (mean ± SD, 44.1% ± 30.6% versus 23.1% ± 11.7% and 15.2% ± 8.8% versus 9.3% ± 4.8% MVIC, respectively) (**FIGURE 5**). No significant group-by-task interaction was found for average gluteus medius EMG ($P = .332$; F value, 1.14; df, 38) (**FIGURE 6**).

DISCUSSION

CONSISTENT WITH THE HYPOTHESES proposed, differences in hip function were observed in females with PFP, when compared to pain-free controls. More specifically, individuals in the PFP group demonstrated increased hip internal rotation, decreased hip muscle strength, and differences in hip muscle recruitment. With respect to hip kinematics, females with PFP demonstrated greater amount of hip internal rotation when averaged across all tasks evaluated. This finding is consistent with previous investigations linking abnormal femur rotation and PFP. Using dynamic magnetic resonance imaging, Powers et al[21] reported that lateral patellar tilt and lateral patellar displacement during a weight-bearing squat was the result of internal rotation of the femur, as opposed to movement of the patella. The concept of femoral internal rotation being contributory to abnormal patellofemoral joint mechanics is supported by the work of Lee et al,[10] who found that increased femoral internal rotation resulted in significant increases in patellofemoral joint contact pressures.

Our finding of greater hip internal rotation in females with PFP during weight-bearing tasks is in contrast to the results of a recent study by Willson and Davis.[24] These authors reported that females with PFP demonstrated significantly less hip

FIGURE 4. Comparison of peak hip torque production during isometric strength testing. Data are mean ± SD. *Individuals with patellofemoral pain (PFP) significantly less than controls (*P*<.05).

FIGURE 5. Comparison of average gluteus maximus electromyographic signal amplitude across the functional tasks evaluated. Data are mean ± SD. Significant group-by-task interaction observed. *Individuals with patellofemoral pain (PFP) significantly greater than controls (*P*<.05). Abbreviation: MVIC, maximum voluntary isometric contraction.

internal rotation during running, jumping, and squatting, when compared to pain-free controls. When evaluating potential reasons for the contradictory results between Willson and Davis[24] and the current study, 2 important methodological differences emerge. First, Willson and Davis[24] normalized their hip internal rotation data to each subject's standing posture during a calibration trial. In other words, each subject's standing posture was considered as the zero position. Using this methodology, if a person were to stand in 15° of hip internal rotation during the calibration trial, then perform a dynamic task in 10° of hip internal rotation, motion would be reported as 5° of hip external rotation. Although we quantified the subjects' hip joint angle regardless of the standing posture, it should be noted that no group differences in hip rotation were observed during our static calibration trial (PFP, 1.1°; control, 0.8°; *P* = .63). Second, Willson and Davis[24] quantified kinematic variables at discrete points (ie, at peak knee extensor moment during running and hopping, and at 45° of knee flexion during the single-leg squat). In the current study, we elected to report peak stance phase kinematics regardless of when they occurred. These methodological differences may explain the discrepancies in reported hip internal rotation between studies.

Our finding of increased hip internal rotation in females with PFP also contrasts the findings of a study by Bolgla et al,[2] who reported no differences in hip kinematics during stair descent in a similar population. As stated previously, however, the authors discussed the possibility that the task evaluated may not have been of sufficient demand to elicit differences in hip kinematics. Another possible explanation for the lack of kinematic findings in the Bolgla et al[2] study may be related to the fact that these authors discarded the first 5 trials for each subject and only evaluated trials 6 through 10. It is possible that the kinematic pattern changed during the 10 trials (owing to pain), and that subjects adopted a compensatory movement strategy by the end of the data collection session.

In contrast to hip internal rotation, we did not find group differences in peak hip adduction. Although the average amount of peak hip adduction was greater in females with PFP (11.0°) compared to that of the control group (9.6°), this difference did not reach statistical significance. Although our findings are consistent with those of Bolgla et al[2], they differ from Willson and Davis,[24] who reported significantly greater hip adduction in females with PFP during running, hopping, and a single-leg squat. However, it should be noted that the group differences reported by Willson and Davis[24] were relatively small (3.5°).

The finding of increased hip internal rotation in females with PFP was accompanied by a significant decrease in hip extension strength. Given that the gluteus
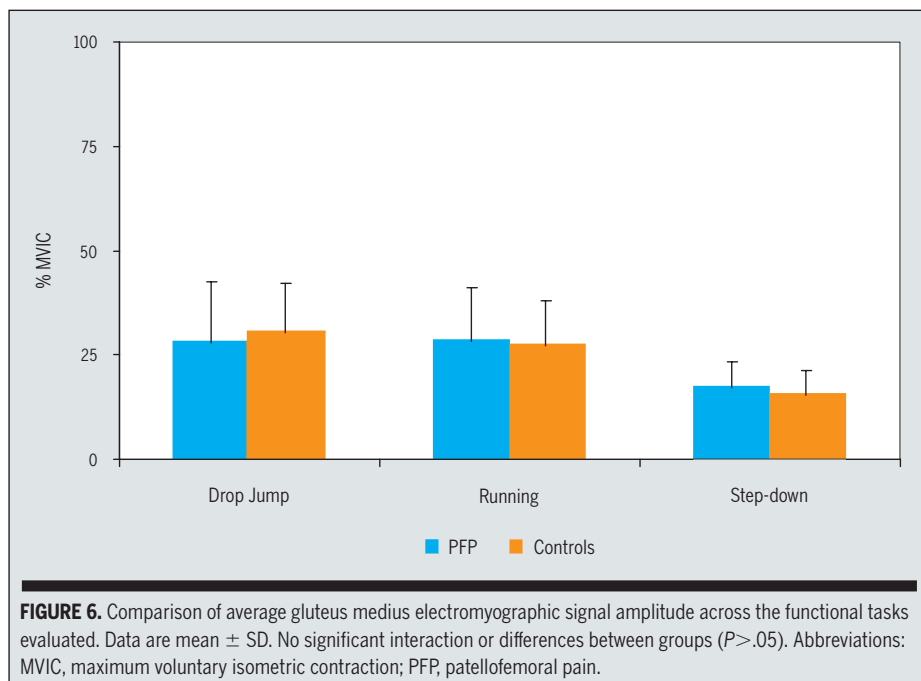
FIGURE 6. Comparison of average gluteus medius electromyographic signal amplitude across the functional tasks evaluated. Data are mean ± SD. No significant interaction or differences between groups (*P*>.05). Abbreviations: MVIC, maximum voluntary isometric contraction; PFP, patellofemoral pain.

maximus is the primary contributor to hip extension and external rotation,[13] we believe that the observed weakness of the hip extensors may have contributed to the increase in internal rotation during the functional tasks evaluated. On average, we found a 16% decrease in hip extensor torque production in subjects with PFP. While this finding is consistent with those of Cichanowski et al,[3] who also reported a 16% deficit in hip extension strength in females with PFP, when compared to pain-free controls, our findings are far less in magnitude (but similar in direction) than the 52% difference reported by Robinson and Nee.[22]

Females in the PFP group also demonstrated a 15% deficit in hip abductor strength compared to the control group. As noted above, this strength deficit did not translate into an increase in hip adduction during the tasks that were evaluated. One explanation for this discrepancy may be related to the fact that subjects could have compensated for hip abductor weakness by employing a lateral trunk lean. An ipsilateral trunk lean would decrease the demand on the stance limb abductors by shifting the center of mass over the hip joint center. Although this compensatory strategy was observed

in many subjects, trunk kinematics were not quantified as part of this study. Given as such, this hypothesis could not be verified.

Our finding of hip abduction weakness in the PFP group is consistent with results of Ireland et al,[8] Robinson and Nee,[22] Cichanowski et al,[3] and Bolgla et al,[2] who reported significant decreases in hip abduction torque production in females with PFP. In contrast, Piva and colleagues[15] did not report differences in hip abductor strength in persons with PFP, when compared to pain-free individuals. However, it should be noted that Piva et al[15] included both males and females with PFP, as opposed to just females.

Contrary to our hypothesis, females in the PFP group exhibited 91% greater gluteus maximus muscle activity during running and 64% greater gluteus maximus muscle activity during the step-down task, compared to the control group. The observation of increased activation of the gluteus maximus in combination with the finding of decreased hip extension strength and increased hip internal rotation suggests that subjects with PFP were attempting to recruit a weak muscle, perhaps in an effort to control hip rotation. This premise is supported by the

fact that the 2 tasks that demonstrated increased gluteus maximus activation were the same tasks that also resulted in the greatest amount of hip internal rotation (**FIGURE 2**). Interestingly, there was no increase in gluteus maximus muscle activity during the drop jump task in the PFP group. One explanation for this finding could be related to the fact that the drop jump is a bilateral, as opposed to a single-limb, task. A single-limb activity may require greater neuromuscular control to provide stability in the frontal and transverse planes.

In contrast to the greater amount of gluteus maximus muscle activation in persons in the PFP group, we did not observe differences in gluteus medius EMG between groups. On average, gluteus medius EMG signal intensity in females with PFP was within 3% of the control group. As noted above, it is possible that the subjects with PFP were compensating for hip abductor weakness by employing an ipsilateral trunk lean. Further investigation into this issue is warranted.

The results of the current study add to the growing body of literature supporting the link between abnormal hip function and PFP in young females. Given that the patella articulates with the femur, our finding of altered hip function in females with PFP provides clinical support for previous mechanistic studies that have suggested that excessive femoral motions may contribute to faulty patellofemoral joint mechanics.[10,21] Taken together, our data suggest that assessment of hip kinematics and hip muscle performance should be considered as part of the examination of persons with PFP.

In light of our results, several limitations need to be acknowledged. First, the cross-sectional design of our study does not allow us to establish cause-and-effect relationships. While it is plausible that abnormal hip kinematics may be responsible for producing PFP, it is also possible that abnormal hip kinematics may be compensatory in nature (ie, the result of PFP). Evidence that abnormal hip kinematics may be contributory to PFP

is provided by Mascal and colleagues,[12] who reported that a program of hip and trunk strengthening resulted in improved hip kinematics and a corresponding decrease in pain in 2 patients with PFP. Although the results of this case series support the argument that abnormal hip kinematics may be the cause of symptoms, additional studies on larger patient populations would be required to draw definitive conclusions. A second limitation of our study is that we investigated hip function in young adult females with no evidence of patellofemoral joint instability. Therefore, generalizing our results to other populations must be made with caution (eg, males with PFP or persons with patellofemoral joint instability). Future studies should consider evaluating more varied patient populations. Lastly, we only investigated local factors with respect to the observed differences in hip kinematics between groups (ie, hip muscle strength and hip muscle EMG signal intensity). Future studies may want to consider the role of ankle/foot mechanics in contributing to proximal movement impairments.

CONCLUSION

INCREASED HIP INTERNAL ROTATION was observed in females with PFP during functional tasks. This finding was accompanied by decreased hip muscle strength and increased gluteus maximus EMG signal intensity. The increased muscle activation of the gluteus maximus in females with PFP suggests that these subjects were attempting to recruit a weakened muscle, perhaps in an effort to stabilize the hip joint. ◉

■ KEY POINTS

FINDINGS: When compared to a control group, increased hip internal rotation, decreased hip muscle strength, and increased gluteus maximus muscle activation was observed in females with PFP during functional tasks.

IMPLICATION: Our results add to the growing body of literature supporting the link between abnormal hip function and PFP in young females. Assessment of hip kinematics and hip muscle performance should be considered as part of the examination of persons with PFP.

CAUTION: Due to the cross-sectional nature of the current study, cause-and-effect relationships cannot be inferred.

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