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RESEARCH REPORT

Hip Strength in Females With and Without Patellofemoral Pain

Mary Lloyd Ireland, MD[1]
John D. Willson, MSPT[2]
Bryon T. Ballantyne, PT, MA[2]
Irene McClay Davis, PT, PhD[3]

Study Design: Cross-sectional.
Objectives: To determine if females with anterior knee pain are more likely to demonstrate hip abduction or external rotation weakness than a similar, asymptomatic, age-matched control group.
Background: Diminished hip strength has been implicated as being contributory to lower-extremity malalignment and patellofemoral pain. The identification of reliable and consistent patterns of weakness in this population may assist health care professionals establish a more effective treatment plan.
Methods and Measures: Hip abduction and external rotation isometric strength measurements were recorded for the injured side of 15 female subjects with patellofemoral joint pain (mean ± SD age, 15.7 ± 2.7 years; age range, 12-21 years). These were compared with strength measurements from the corresponding hip of 15 age-matched female control subjects (mean ± SD age, 15.7 ± 2.7 years; age range, 12-21 years). All strength measurements were made using hand-held dynamometers.
Results: Subjects with patellofemoral pain demonstrated 26% less hip abduction strength ($P<.001$) and 36% less hip external rotation strength ($P<.001$) than similar age-matched controls.
Conclusions: The results indicate that young women with patellofemoral pain are more likely to demonstrate weakness in hip abduction as well as external rotation than age-matched women who are not symptomatic. *J Orthop Sports Phys Ther. 2003;33:671-676.*

Key Words: *anterior knee pain, hip abduction, hip external rotation, knee, patella*

Patellofemoral joint pain (PFP) remains one of the most common orthopaedic complaints among adolescents and young adults, with reported incidence rates among athletes greater than 25%.[2,26,31,38] It has also been reported that females, as compared with their male counterparts, are significantly more likely to experience PFP.[9,35] Typically, patients complain of generalized retropatellar symptoms that present insidiously and tend to be exacerbated by prolonged sitting or repetitive weight-bearing activities over a flexed knee. Unfortunately for these individuals, this pain often becomes a chronic condition that may fail to respond to conservative measures.

Current literature suggests that, in the absence of direct trauma, the etiology of PFP is multifactorial. Factors related directly to the patellofemoral joint, including vastus medialis obliquus insufficiency, decreased hamstring, quadriceps, or iliotibial band flexibility, patella alta, and femoral anteversion, have received the most attention.[7,10,18,26,29,31,37,38] Such factors may also contribute to PFP through their role in causing patellofemoral malalignment, which is a universally accepted contribution to PFP.[12,31]

Factors distal to the knee have also been frequently suggested to contribute to patellofemoral malalignment and pain. Numerous authors have explored the relationship between excessive or prolonged foot pronation during functional activities and lateral patellar compression syndrome.[28,30,36] Specifically, considering the "screw-home" mechanism of the tibiofemoral joint, these authors report that the tibia must be externally rotated relative to the femur so that knee extension can be achieved during the midstance and terminal stance phases of gait. However, it is hypothesized that, in the presence of excessive or prolonged foot pronation, the tibia remains internally rotated as the knee begins to extend. To compensate for this excessive tibial

[1] *Orthopedic Surgeon, Kentucky Sports Medicine Clinic, Lexington, KY.*
[2] *Clinical Research Coordinator, Joyner Sportsmedicine Institute, Lexington, KY.*
[3] *Associate Professor, University of Delaware, Department of Physical Therapy, Newark, DE; Clinical Research Coordinator, Joyner Sportsmedicine Institute, Lexington, KY.*
The protocol for this study was approved by Essex Institutional Review Board, Inc.
Send Correspondence to John D. Willson, Joyner Sportsmedicine Institute, 601 Perimeter Dr., Suite 110, Lexington, KY 40517. E-mail: jdwillson@yahoo.com

internal rotation, it is thought that the femur must internally rotate excessively, such that the tibia is in relative external rotation.[36] This compensation creates a larger quadriceps angle and may significantly increase lateral retropatellar contact pressure.[17,21,27]

Proximal factors including hip muscle weakness have also been proposed to contribute to patellofemoral malalignment and the development of PFP.[12,34] Recent kinetic analysis of running reveals that, although the largest knee joint moments occur in the sagittal plane, the knee is also subject to significant frontal and transverse plane moments.[24] Additional research has shown that women, as compared to their male counterparts, exhibit significantly greater external knee valgus moments[33] and associated movement into knee valgus[23] and hip internal rotation.[22] The ability of women to control these motions may depend on the strength of proximal muscle groups that are antagonistic to these movement tendencies. In the absence of sufficient proximal strength, the femur may adduct or internally rotate, further increasing lateral patellar contact pressure.[17,21,27] Repetitive activities with this malalignment may eventually lead to the retropatellar articular cartilage damage generally associated with this syndrome.

Although some authors have postulated that hip weakness may have a role in the etiology of patellofemoral pain,[12,14,34] no studies have documented this weakness in a symptomatic population. Therefore, the purpose of this investigation was to examine hip strength in women with PFP. It is hypothesized that women with PFP will demonstrate decreased hip abduction and external rotation strength versus their nonsymptomatic, age-matched counterparts.

METHODS

Subjects

Fifteen female subjects with PFP were recruited for this study (mean ± SD age, 15.7 ± 2.7 years; age range, 12-21 years; mean ± SD weight, 63.1 ± 16.5 kg; weight range, 43.5-93.0 kg). Fifteen age-matched female control subjects who denied any history of previous knee injury or pain were also recruited from the community for the purpose of comparison (mean ± SD age, 15.7 ± 2.7 years; age range, 12-21 years; mean ± SD weight, 56.6 ± 12.5 kg; weight range, 37.2-81.6 kg). All subjects reported routine participation in either recreational or organized sports such as basketball, volleyball, track, equestrian, swimming, or cheerleading. Prior to participation in the study, informed consent was received from all participants and by the parents of those participants less than 18 years of age. The study protocol was approved by Essex Institutional Review Board, Inc.

Inclusion criteria for the PFP group were satisfied through a thorough evaluation at a local orthopaedic practice. Each subject with PFP reported complaints of patellofemoral joint pain for at least 3 months duration associated with activities including sports, climbing stairs, or prolonged sitting. Objective signs were also consistent with PFP, including pain with compression of the patella into the femoral condyles or palpation of the posterior surface of the patella. The subjects with PFP also underwent a physical examination by the same orthopaedic surgeon to exclude the possibility of concurrent ligament instability or meniscal pathology. Potential subjects from either group who reported a history of patellar dislocation, knee surgery, or other significant trauma to either lower extremity were excluded from the study.

One limb was used for comparison between groups for each subject. In cases of unilateral pain, measurements were recorded for the injured limb and the corresponding limb of the age-matched control subject. For subjects with bilateral symptoms, their dominant limb (identified by asking which leg the patient would use to kick a ball as hard as possible) was used for comparison with the corresponding limb of the age-matched control subject. Bilateral symptoms were present in 8 subjects. Five subjects presented with right-sided symptoms and 2 subjects had symptoms on their left side.

Procedure

Subjects underwent isometric muscle strength testing for hip abduction and external rotation using hand-held dynamometers and stabilization straps. Testing for each subject took approximately 10 minutes and was randomly performed according to muscle action. The test positions were selected based on their similarity to traditional manual muscle testing procedures[20] and have been reported to be highly reliable for testing isometric strength with hand-held dynamometers.[6,19]

Hip abduction isometric strength testing was performed with subjects positioned in sidelying on a treatment table (Figure 1). A pillow was placed between the subjects' legs, using additional toweling as needed, such that the hip of the leg to be tested was abducted approximately 10° as measured with respect to a line connecting the anterior superior iliac spines. A strap placed just proximal to the iliac crest and secured firmly around the underside of the table was used to stabilize the subjects' trunk. The center of the force pad of a Nicholas hand-held dynamometer (Lafayette Instruments, Lafayette, IN) was then placed directly over a mark located 5.08 cm proximal to the lateral knee joint line. This dynamometer uses a load cell force-detecting system to

TABLE. Isometric hip strength comparison between female subjects with patellofemoral joint pain (PFP) and a control group. All values are expressed as a percentage (mean ± SD [95% confidence interval]) of body weight (kg).

	PFP Group*	Control Group*
Hip abduction†	23.3 ± 6.9 (19.8-26.7)	31.4 ± 6.2 (28.4-34.5)
Hip external rotation†	10.8 ± 4.0 (8.8-12.8)	16.8 ± 5.5 (14.0-19.6)

*n = 15.
†Significant difference between groups ($P<.001$).

measure static force ranging from 0 to 199.9 kg, with accuracy to 0.1 kg ± 2%, and has been reported to have excellent interrater reliability for testing hip abduction isometric strength.[11] The dynamometer was secured between the leg and a second strap that was wrapped around the leg and the underside of the table. The strap eliminated the effect of tester strength on this measure, which has been reported to be a limitation of hand-held dynamometry.[4] After zeroing the dynamometer, the subject was instructed to push the leg upward with maximal effort for 5 seconds. The force value displayed on the dynamometer was recorded and the device was rezeroed. One practice trial and 3 experimental trials were performed, with 15 seconds of rest between trials. The peak value from the 3 experimental trials was recorded.

Hip external rotation (ER) isometric strength testing was performed with subjects positioned on a padded chair with the hips and knees flexed to 90° (Figure 2). To prevent substitution by the hip adductors, a strap was used to stabilize the thigh of the tested leg and a towel roll was placed between the subjects' knees. The dynamometer was then placed such that the center of the force pad was directly over a mark that was 5.08 cm proximal to the medial malleolus. A strap around the leg and around the base of a stationary object held the dynamometer in place during contractions. After zeroing the dynamometer, the subject was instructed to push the leg inward with maximal effort for 5 seconds. The force value displayed on the dynamometer was recorded and the device was rezeroed. One practice trial and 3 experimental trials were performed with 15 seconds of rest between trials. The peak value from the 3 experimental trials was recorded.

Data Analysis

We used a clinically significant strength difference of 15% between groups and estimates of sample variability from previous literature[3,5] to perform an a priori power analysis. This analysis suggested that 25 to 30 subjects would provide adequate protection from type I and II errors using $\alpha = .05$ and $\beta = .20$. However, during data collection, it became evident that the true difference between groups was significantly larger than the difference used in the power analysis. Therefore, data analysis was performed after 15 subjects had been tested per group. Independent *t* tests were used to compare hip abduction and exter-

FIGURE 1. Isometric strength testing of hip abduction using straps and hand-held dynamometer.

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FIGURE 2. Isometric strength testing of hip external rotation using straps and hand-held dynamometer.

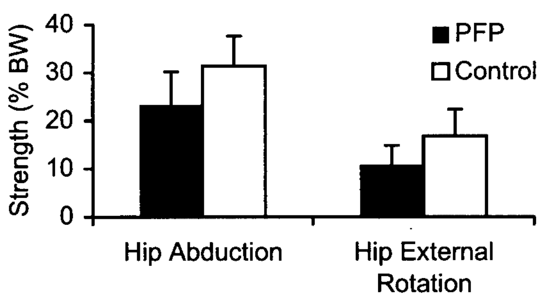

FIGURE 3. Isometric strength comparisons in percent body weight (% BW) between a control group and subjects with patellofemoral joint pain (PFP) for hip abduction and external rotation. Error bars represent 1 standard deviation. (The PFP groups are significantly different [$P<.001$]).

nal rotation strength between subjects with patellofemoral pain and their age-matched control subjects. Prior to data analysis, strength measurements, recorded in kg, were normalized to body weight for each subject.

RESULTS

Subjects with patellofemoral pain syndrome exhibited significantly lower isometric strength values than their healthy, age-matched counterparts for both hip abduction ($P<.001$) and external rotation ($P<.001$) (Table). On average, these subjects were 26% weaker in hip abduction and 36% weaker in hip external rotation than the members of the control group (Figure 3).

DISCUSSION

The role of hip strength in the etiology of knee pain has received increased attention in recent years. However, in the absence of objective evidence, this relationship has been reported based on observation and professional conjecture. The purpose of this investigation was to compare hip strength between females with and without PFP. While the strength test results for the healthy control subjects in this study are in line with established isometric norms,[5,6] females with PFP demonstrated significant weakness.

The apparent strength difference between groups in this study supports the suggestions of other authors who have associated PFP with hip muscle weakness.[6,32,34] Sommer[34] visually observed a stereotypical motion pattern into knee valgus and femoral internal rotation during the acceleration phase before take-off during jumping in healthy, fatigued, male and female subjects. Similarly, more recent, sophisticated kinematic analysis of subjects during athletic movements has confirmed this movement pattern, particularly in women.[22,23,33] Our results indicate that females with PFP may have insufficient strength to resist these external valgus and internal rotation moments. Consequently, the femur may excessively adduct and internally rotate during athletic movements, promoting lateral patellar tracking and increasing lateral retropatellar contact pressure.[17,21,27] Repetitive movements with this alignment may cause injury to the retinaculum, retropatellar articular cartilage, or subchondral bone.[12]

These results in combination with previous empirical evidence suggest that proximal stabilization programs may be beneficial for the treatment of PFP.[8,11,34] Fredericson et al[11] documented the tendency for distance runners who present with iliotibial band syndrome to have weakness in hip abduction. Following a 6-week rehabilitation protocol with a focus on gluteus medius strengthening, over 90% of the patients were pain free and had returned to their prior level of function. The authors felt that strengthening of the gluteus medius fostered increased control of thigh adduction and internal rotation tendencies during running, thereby minimizing the valgus vector at the knee. Our results indicate that hip abduction and external rotation strengthening may also benefit individuals with PFP by improving stability in the frontal and transverse planes of motion during running and other sport-specific activities.

Unfortunately, studies that investigate the relationship between lower-extremity frontal- or transverse-plane stability and the prevention of knee injuries are scarce. Hewett et al[14] demonstrated a 50% reduction in knee adduction/abduction moments during the landing phase of a vertical jump following a 6-week training program that included lower-extremity plyometric drills as well as general strength and flexibility exercises. Although this intervention program did not focus on hip muscles specifically, the decrease in frontal plane knee moment was the only significant predictor of the athlete's risk for knee ligamentous injury. Subsequent prospective analysis has shown that female athletes who participated in this program over the course of the sport season had a significantly lower incidence of serious knee ligamentous injury than those who did not.[13] Because only ligamentous injuries were included for analysis in this study by Hewett et al,[13] the value of a prophylactic hip strengthening program for nonsymptomatic athletes in the prevention of PFP remains purely speculative. Prospective studies are needed to truly validate this relationship.

A limitation of the cross-sectional nature of this study lies in our ability to discern cause and effect. Symptomatic individuals in our study had at least a 3-month history of PFP. Therefore, the strength differences observed in this study may be the consequence of disuse atrophy or altered motor recruitment patterns.[14] However, whether hip muscle weakness precipitated the PFP symptoms or not, measures to improve the strength of these muscles is likely to have a positive influence on patients with this clinical presentation, either as a prophylactic measure of prevention or as a rehabilitation response to minimize the risk for further injury.

Strength measurements in this study were reported in units of force instead of torque. Although the females in both groups were similar in many respects, including age, weight, and participation in recreational or varsity sports, we did not control for possible differences in leg length between groups. Therefore, a systematic difference in moment arm between groups could have biased our results. We chose to report force, rather than torque, to facilitate the comparison of our results to previously established normative values that were also reported in units of force (or percent body weight).[1,3,5,19] Future studies using hand-held dynamometry should weigh the merits of reporting force versus torque. However, when reporting units of force, we acknowledge that some assurance of equality of height between groups should be included.

Future study of a prospective nature is necessary to more completely delineate the role of proximal muscle strength in the etiology of lower-extremity injuries including PFP. These studies should include males as well as subjects of different age groups to determine if our results translate to individuals other than young females. Future studies are also indicated to evaluate the influence of proximal muscle weakness on lower-extremity kinematics and kinetics. In addition to hip abduction and external rotation strength, these studies could include strength measures of other proximal muscle groups including the abdominals, quadratus lumborum, gluteals, and back extensors which further contribute to proximal stability.[14,15,16,25] Reliable dynamometry techniques for these muscles must first be described.

Based on the results of this study, clinicians should be encouraged to perform a thorough musculoskeletal evaluation of the hip musculature when designing a treatment program for individuals with PFP. Exercises to address weakness in hip abduction or external rotation may foster a more effective and lasting recovery with respect to each patient's goals.

CONCLUSION

The results of our investigation indicate that females presenting with PFP demonstrate significant hip abduction and external rotation weakness compared to age-matched, nonsymptomatic controls.

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