Hip Strength in Collegiate Female Athletes with Patellofemoral Pain

HEATHER R. CICHANOWSKI[1–3], JOHN S. SCHMITT[4], ROB J. JOHNSON[2,5,6], and PAUL E. NIEMUTH[4]

[1]Healthpartners Specialty Center, Orthopaedics & Sports Medicine, St. Paul, MN; [2]Primary Care Sports Medicine, Department of Family Medicine, Hennepin County Medicine Center, Minneapolis, MN; [3]Department of Family Medicine and Community Health, University of Minnesota, Minneapolis, MN; [4]Physical Therapy Program, College of St. Catherine, Minneapolis, MN; [5]Department of Family Medicine and Community Health, University of Minnesota, Minneapolis, MN; and [6]Sports Medicine, University of Minnesota Athletics, Minneapolis, MN

ABSTRACT

CICHANOWSKI, H. R., J. S. SCHMITT, R. J. JOHNSON, and P. E. NIEMUTH. Hip Strength in Collegiate Female Athletes with Patellofemoral Pain. *Med. Sci. Sports Exerc.*, Vol. 39, No. 8, pp. 1227–1232, 2007. **Purpose:** Decreased hip strength has been theorized to contribute to the development of patellofemoral pain. The purpose of this study was to test for strength differences of six hip muscle groups in collegiate female athletes diagnosed with unilateral patellofemoral pain compared with the unaffected leg and noninjured sport-matched controls. **Methods:** At four Division III schools, all collegiate female athletes experiencing unilateral patellofemoral pain were recruited during the 2004–2005 academic school year. The athletes were diagnosed with patellofemoral pain by sports medicine–trained family physicians or orthopedic surgeons. Hip strength of six different muscle groups was tested using a handheld dynamometer. The highest value of two trials was used, and strength values were normalized to body weight. The measurements from the injured leg were compared with the uninvolved leg and also with uninjured control subjects matched for sport. **Results:** Thirteen athletes were diagnosed with unilateral patellofemoral pain. The injured-side hip abductor ($P = 0.003$) and external rotator muscle groups ($P = 0.049$) were significantly weaker than the noninjured sides. There were no significant differences in the other hip muscles tested. In addition, the injured legs were significantly weaker in five of the six hip muscle groups compared with the control group. **Conclusions:** The results of this study show that hip abductors and external rotators were significantly weaker between the injured and unaffected legs of the injured athletes. In addition, injured collegiate female athletes exhibited global hip weakness compared with age- and sport-matched asymptomatic controls. Screening for hip muscle weakness and adding strengthening exercises to the affected hip muscles may be important factors in managing female athletes with patellofemoral pain. **Key Words:** ANTERIOR KNEE PAIN, HIP ABDUCTION, HIP EXTERNAL ROTATION, MUSCLE IMBALANCE

Among all sports-related knee injuries, patellofemoral pain is one of the most common (2,6,7,30). Up to one quarter of all knee injuries treated at sports medicine centers involve patellofemoral pain (2,7). It is also well documented that women are more likely than men to develop patellofemoral pain (6,13,30).

Despite the high prevalence of patellofemoral pain among active individuals, clinical assessment and treatment are quite challenging because of its multifactorial etiology and poorly understood mechanisms. Potential contributing factors that have been studied include increased Q angle (19), hypermobile patella (35), decreased quadriceps flexibility (28,35), hamstring flexibility (28,35), and iliotibial (IT) band flexibility (34), quadriceps weakness (8), and ligamentous laxity (35). Fulkerson (11,12) has identified malalignment of the extensor mechanism as one of the principal factors in the development of patellofemoral pain. Pain then theoretically develops from overload of the patellar retinaculum and subchondral bone.

To date, much focus has been given to factors relating directly to the patellofemoral joint. Factors below the knee have been studied, including abnormal foot pronation and subsequent rotation of the lower extremity (24). Factors above the knee, including the muscles that control and stabilize the pelvis, have recently received attention in association with the development of patellofemoral pain. Several authors have implicated poor pelvic muscular control contributing to patellofemoral malalignment and subsequent patellofemoral pain (11,23,29). In addition, evidence has shown that during weight-bearing activities, altered patellofemoral tracking may be the result of the femur rotating medially beneath the patella rather than the patella moving laterally on the femur (25). The hip muscles help control pelvic stability and leg alignment in the frontal, sagittal, and transverse planes (26). In the absence of sufficient hip strength, particularly the hip abductors and external rotators, there may be excessive femoral internal rotation, hip adduction movements, and subsequent

Address for correspondence: Heather R. Cichanowski, M.D., Healthpartners Specialty Center, 435 Phalen Blvd., St. Paul, MN 55130; E-mail: hcichano@yahoo.com.
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increased knee valgus motion with weight-bearing activities (11,14,22). This increased valgus motion at the knee can lead to an increased dynamic Q angle, which alters patellofemoral tracking and increases lateral patellar-contact pressure (20). Repetitive motions with this malalignment can eventually lead to pain by overloading and causing injury to the patellar retinaculum, retropatellar articular cartilage, and subchondral bone (11,12,14).

Although this mechanism has not been validated, studies have supported this theory (22). Ireland et al. (14), have shown that young active women (mean age 15.7 yr) with patellofemoral pain have significantly weaker hip abductors and external rotators than do noninjured, age-matched controls. Niemuth et al. (21), looking at a group of men and women runners (mean age 37.4 yr), have shown that certain hip muscle weaknesses may relate to lower-extremity injury, including patellofemoral pain. These authors found weaker hip abductors and hip flexors in those with lower-extremity injuries compared with noninjured controls. Both authors analyzed strength as a percentage of body weight. To date, no studies have tested all six hip muscle groups in a female collegiate population with patellofemoral pain.

The purpose of this study, which was conducted among Division III collegiate female athletes at four schools in the Twin Cities area of Minnesota, was to test for differences in strength of six hip muscle groups in athletes diagnosed with unilateral patellofemoral pain compared with the unaffected legs and with noninjured, sport-matched controls. The hypothesis was that women with patellofemoral pain would have weaker hip muscle strength, particularly the hip abductors and external rotators, versus the unaffected legs and their sport-matched, noninjured counterparts.

METHODS

Subjects. Subject recruitment took place during the 2004–2005 academic school year. Injured subjects were Division III female athletes participating in any varsity sport with unilateral knee pain who presented to the athletic trainer, physical therapist, or physician in the school's athletic training room. An injury was defined as pain to a localized area that required a change or reduction in training or sport participation and treatment or attention from the athletic trainer, team physician, or other medical staff. All subjects were examined by a team physician who was either certified by the American Board of Family Medicine in sports medicine or currently in a sports medicine fellowship training program, or by a sports medicine fellowship trained orthopedic surgeon. Subjects qualified if the physician diagnosis was consistent with patellofemoral pain syndrome. Exam criteria of patellofemoral pain syndrome used in this study included pain with patellar compression, tenderness with palpation of the posteromedial or posterolateral patellar facets, and pain with resisted isometric quadriceps contraction (8,14,22). Subjects were excluded if they had recent knee trauma, history of previous knee surgeries, bilateral knee symptoms, patellar dislocations or subluxations, concomitant diagnosis of bursitis, tendonitis or internal knee derangement, lower-extremity trauma, back pain, hip pain, sacroiliac joint pain, hamstring pain, or if they were pregnant.

Control subjects were matched by sport and were recruited by the athletic trainer or physical therapist. Control athletes were excluded if they had recent knee trauma, history of previous knee surgeries, patellar dislocations or subluxations, lower-extremity trauma, back pain, hip pain, sacroiliac joint pain, hamstring pain, or if they were pregnant. This investigation was approved by the institutional review boards from Hennepin County Medical Center and the participating schools, including the College of St. Catherine, University of St. Thomas, Bethel University, and Augsburg College. Fourteen subjects received a diagnosis of patellofemoral pain syndrome. The subjects were then asked whether they wished to participate in the study. None of the fourteen subjects refused to participate. One subject was disqualified when she revealed later that she had bilateral knee pain. Thirteen age-, gender-, and sport-matched noninjured collegiate athletes were asked whether they wished to participate, and none refused. Written informed consent was obtained from all subjects. Subjects were not compensated for participating in the study. No athlete experienced any

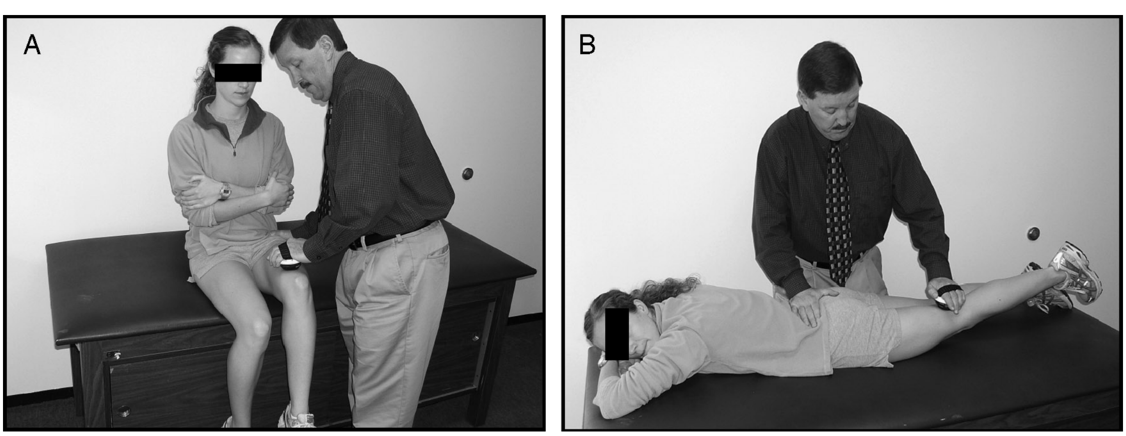

FIGURE 1—Isometric strength testing of hip flexors (*A*) and hip extensors (*B*) using a handheld dynamometer.

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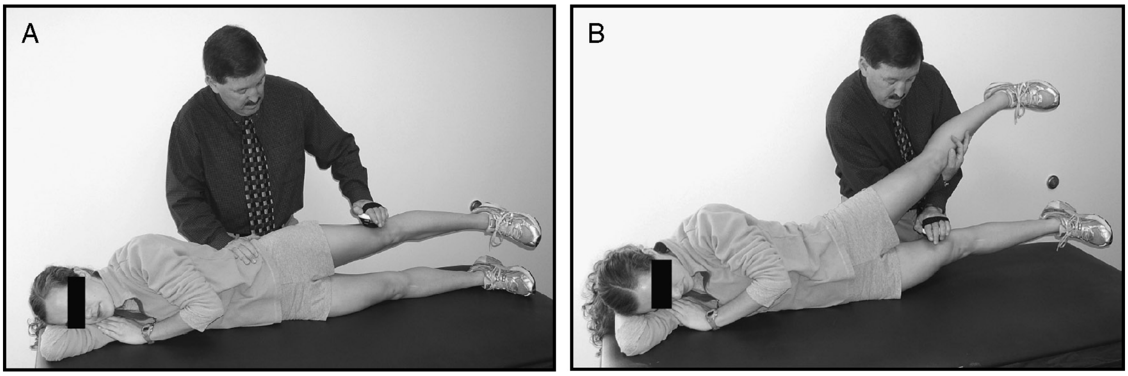

FIGURE 2—Isometric strength testing of hip abductors (*A*) and hip adductors (*B*) using a handheld dynamometer.

injury from participation, and confidentiality was assured before testing.

Self-reported weights of the subjects were recorded along with other demographic information, including age, year in college, years of sport played in college, years of sport played in high school, and dominant leg. Dominant leg was identified by asking which leg the athlete would use to kick a ball. The injured athletes also were asked about duration of knee pain and lost practice time.

Procedure. The muscle testing consisted of performing a maximal isometric contraction to each of the six muscle groups of the hip joint. The six muscle groups were tested in antagonistic pairs: hip flexors/extensors, hip abductors/adductors, and internal/external rotators. All six muscle groups were tested in succession on the first trial, with a 3- to 5-min rest and then completion of the second trial. Measurements were recorded by a physical therapist who was board certified in both orthopedic and sports physical therapy. The tester was blinded as to the identity of the control versus the injured subject and to the injured versus the uninjured leg. Peak muscle force was recorded using a Microfet (Hogan Industries, Draper, UT) handheld dynamometer, a load-cell recording device that displays a digital force readout and the length of time of a muscle contraction. Muscle testing was performed using the "make test" method of muscle testing in which the subject applied a maximum muscle contraction to the examiner's hand holding the dynamometer (27). The muscle contraction was held for 2 s, as recorded by a timer within the Microfet. The highest peak force from two trials was used for strength comparisons. Bohannon and Saunders (3) have shown that a single peak trial is adequate for measuring muscle strength. Reliability of handheld dynamometer muscle testing in the lower extremities has been well established (4,15,32).

Muscle force data were recorded and normalized to body weight. Muscle testing was performed using the standard positions recommended by the manufacturer, which also were consistent with the methods of muscle testing described by Reese (27). Patients were not allowed to self-stabilize during the testing procedure by holding onto the table or by pushing against the table. Figure 1 shows isometric strength testing of the hip flexors and extensors. Hip flexion was tested in a

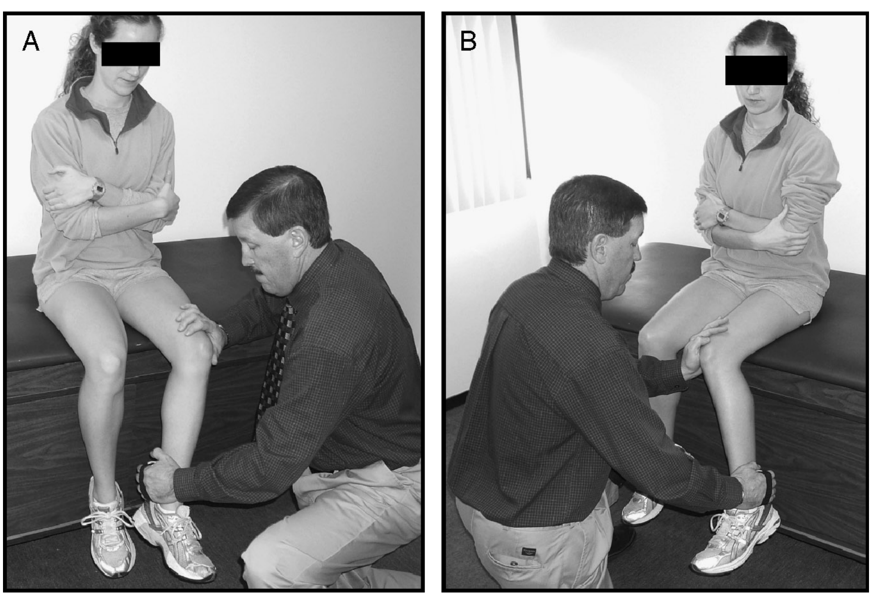

FIGURE 3—Isometric strength testing of hip external rotators (*A*) and hip internal rotators (*B*) using a handheld dynamometer.

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seated position with the hip and knee at 90°. Resistance was applied at the knee approximately 2 cm proximal to the femoral condyles. Hip extension was tested in a prone position with the knee extended. Resistance was applied approximately 2 cm proximal to the popliteal crease. Figure 2 demonstrates isometric strength testing of the hip abductors and adductors. Hip abduction was tested with each subject lying on her side, with the hip in a neutral position and the knee extended. Resistance was applied approximately 2 cm proximal to the lateral femoral condyle. Adduction was tested with each subject lying on her side, with the hip in a neutral position and the knee extended. Resistance was applied approximately 3 cm proximal to the medial femoral condyle. As seen in Figure 3, isometric strength of the hip external and internal rotators was tested in a seated position with both the hip and the knee flexed at 90°. Resistance was applied approximately 2 cm proximal to the medial malleolus of the ankle for external rotation and 2 cm proximal to the lateral malleolus of the ankle for internal rotation.

Data analysis. Data were analyzed using Number Cruncher Statistical Software 2001 (Kaysville, UT). Peak hip isometric strength values were normalized to each subject's body weight. For those with patellofemoral pain, paired *t*-tests were used to compare the mean peak hip strength between the injured and noninjured legs. Two-sample *t*-tests were used to compare demographic variables and mean peak normalized hip strength values between the injured leg of those diagnosed with patellofemoral pain and a randomly selected leg from each member of the control group. Our preliminary analysis showed no significant differences for mean peak hip strength values between the dominant and nondominant legs of the control group. A significance level of 0.05 was used for all comparisons. With 13 subjects per group and a large effect size of 1.0, we had 70% power to detect significant differences between groups with the two-sample *t*-test (5).

RESULTS

Demographics of the injured and control groups. Baseline data can be seen in Table 1. The injured subject group was composed of 13 collegiate athletes. Five subjects were soccer players, three were involved in hockey, and one each participated in volleyball, tennis, cross-country running, basketball, and track. Time of symptom duration ranged from 2 to 52 wk, with an average of 16.2 ± 16.9 (mean ± SD) weeks. Twelve athletes were right leg dominant. Eight athletes injured their right leg, and five athletes injured their left leg. Inspection of the data revealed no pattern related to leg dominance, given that 6 of 13 athletes injured the nondominant leg.

TABLE 1. Comparison of demographic variables (mean ± SD).

Variable	Knee-Pain Subjects	Controls	*P* Value
Age (yr)	19.3 ± 1.1	19.5 ± 1.3	0.635
Body weight (kg)	68.6 ± 15.5	61.4 ± 9.0	0.163
High school years in sport	4.08 ± 0.49	3.69 ± 0.75	0.136
College years in sport	1.77 ± 0.93	1.92 ± 1.04	0.739*

* Data nonnormal; *P* value based on Mann–Whitney *U*-test.

The control group was composed of 13 collegiate athletes. The sport distribution was the same as in the injured group. Eleven reported their dominant leg as their right, and two reported their dominant leg as their left. There were no statistical differences between age, body weight, or years of high school sport and college sport participation between the subject and control groups.

TABLE 2. Mean peak hip strength comparisons normalized to body weight (kg) between the injured legs and noninjured legs of athletes diagnosed with patellofemoral pain (mean ± SD).

Hip Motion	Injured Leg	Noninjured Leg	*P* Value
Flexion	0.274 ± 0.07	0.282 ± 0.06	0.466
Extension	0.304 ± 0.08	0.309 ± 0.09	0.563
Abduction	0.290 ± 0.08	0.330 ± 0.07	0.003*
Adduction	0.198 ± 0.07	0.195 ± 0.05	0.650
Internal rotation	0.179 ± 0.04	0.190 ± 0.04	0.111
External rotation	0.170 ± 0.04	0.182 ± 0.04	0.049*

* $P < 0.05$.

Muscle strength data. Paired *t*-tests were used to compare the mean peak normalized hip strength between the injured leg and noninjured leg of those with patellofemoral pain. As seen in Table 2, the mean force produced by the injured hip abductor muscle group was significantly weaker than the mean force produced by the noninjured leg (P = 0.003). Similarly, the mean force produced by the injured external rotator muscle group was significantly weaker than the mean force produced by the noninjured leg (P = 0.049). No differences were noted with the hip flexors, extensors, adductors, or internal rotators.

Two-sample *t*-tests were used to compare the mean peak normalized hip strength values of the injured athletes' affected leg versus the mean normalized hip strength of a randomly selected leg from each of the control subjects. As seen in Table 3, the injured athletes' legs were found to have globally weaker hip strength compared with the controls. The only muscle group that was not significantly weaker was the hip adductors.

DISCUSSION

This study found global hip muscle weakness in Division III collegiate female athletes diagnosed with patellofemoral pain compared with control subjects. Within the injured group, hip abductors and external rotators were especially weak. These results support the theory that proximal weakness is associated with patellofemoral pain.

TABLE 3. Mean peak hip strength comparisons normalized to body weight (kg) between injured legs of knee pain subjects and randomly selected legs from control subjects (mean ± SD).

Hip Motion	Knee-Pain Subjects	Controls	*P* Value
Flexion	0.274 ± 0.07	0.329 ± 0.05	0.033*
Extension	0.304 ± 0.08	0.363 ± 0.05	0.029*
Abduction	0.290 ± 0.08	0.368 ± 0.06	0.010*
Adduction	0.198 ± 0.07	0.236 ± 0.04	0.087
Internal rotation	0.179 ± 0.04	0.211 ± 0.03	0.049*
External rotation	0.170 ± 0.04	0.201 ± 0.03	0.033*

* $P < 0.05$.

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It is well documented that women experience patellofemoral pain more frequently than men. Studies have shown that women tend to exhibit certain motor-control strategies during weight-bearing dynamic activities that lead to increased knee valgus angles (17) and greater peak hip internal rotation and hip adduction angles compared with men (9). With the hip muscles (particularly the hip external rotators and abductors) contributing to pelvic stability and femoral movements, strengthening these muscles along with other traditional treatments of patellofemoral pain may lead to better femoral control and decreased potential for patellofemoral pain.

Few studies have looked at rehabilitation programs focusing on hip strength in those with lower-extremity overuse injuries. In a population of runners diagnosed with iliotibial band syndrome, Fredericson et al. (10) found significant hip abductor weakness in the legs of male and female runners with iliotibial band syndrome compared with their unaffected legs and compared with unaffected runners. After a 6-wk rehabilitation program focusing on hip abductor strengthening, 22 of the 24 runners returned to running pain free. These authors postulate that gluteus medius weakness resulted in decreased control of thigh abduction and external rotation. Strengthening the gluteus medius lead to greater control of these thigh movements and, subsequently, to less knee valgus motion and decreased pain. Strengthening these hip muscles in those with patellofemoral pain also might lead to less knee valgus motion and, subsequently, less lateral patellar-contact pressure and decreased pain.

Mascal et al. (18) have published two case reports on females with patellofemoral pain. Both cases exhibited excessive hip adduction, internal rotation, and knee valgus during gait as well as hip abductor, extensor, and external rotator weakness. Rehabilitation focusing on strengthening the hip, pelvis, and trunk muscles decreased their knee pain and allowed them return to their previous level of activity. Knee valgus and hip internal rotation and adduction with gait were also reduced. Tyler et al. (31) evaluated 35 men and women diagnosed with patellofemoral pain and placed them on a rehabilitation program focusing on improving hip strength and flexibility. Before starting the treatment program, hip flexion, abduction, and adduction strength measurements were taken. Those with unilateral patellofemoral pain had significantly weaker hip abduction and flexion strength on the affected leg compared with the unaffected leg. After the 6-wk rehabilitation program, they found that improvements in hip strength (primarily hip flexion) combined with increased hip flexibility were associated with a significant decrease of knee symptoms.

A recent study investigated hip strength and soft-tissue flexibility of 30 individuals with patellofemoral pain compared with matched controls (22). They report no differences in the strength of the hip external rotators and abductors. However, when looking at the published data, the P value for the paired t-test for hip abduction strength was 0.016. These authors acknowledged that they may not have had enough statistical power to establish significance with their chosen alpha value (0.007). These authors conclude that associations exist between patellofemoral pain and weak hip abductors, but the clinical significance is unknown. They do mention, however, that it seems reasonable to assess this variable in patients, and more clinical investigation is warranted.

Our study found that the injured athletes displayed global weakness in five of the six hip muscle groups tested in comparison with control athletes. This finding may be consistent with general weakness attributable to reduced training, because the injured athletes in this study reported a mean symptom duration of 16 wk. However, reduced training would not explain the relative hip abductor and external rotator strength deficit between the affected and unaffected legs. We believe that although global weakness may result from reduced training, hip abductors and external rotators may play a more crucial role in the development of patellofemoral pain. However, given the retrospective design of our study, no definite conclusions about causation can be determined.

Does hip weakness lead to patellofemoral pain, or does patellofemoral pain lead to the development of hip weakness? Our retrospective study design does not allow us to determine the temporal relationship between hip weakness and the onset of patellofemoral pain. In 2004, Leetun et al. (16) published a prospective study that looked at core stability measures, including hip muscle strength, as risk factors for lower-extremity injuries in athletes. The authors measured hip abductor and external rotator strength, abdominal muscle firing, and back extensor and quadratus lumborum endurance in uninjured collegiate male and female athletes and in those who subsequently sustained injuries throughout the athletic season. Males had stronger hip external rotator and abductor strength and greater quadratus lumborum endurance compared with females. Those male and female athletes who sustained injuries during the season had significantly weaker hip abductor and external rotator strength compared with uninjured athletes. A logistic regression analysis showed that hip external rotator strength was the only significant individual predictor of injury status. This prospective study supports the theory that certain hip muscle weakness may be a factor contributing to the development of patellofemoral pain.

A limitation to our study is that we relied on self-reported body weights, which may have affected the accuracy of our normalized strength values. Another limitation is that we did not take any measures to evaluate for leg length. Leg length is a possible confounding variable; this may have affected strength measurements (14,16). However, we minimized this bias by using all women and sport-matched controls. Handheld dynamometry also has its limitations, mainly involving the strength and technique of the tester, especially in larger, lower-extremity muscle groups (1,33). However, in our study, the same person, who was experienced in the use of handheld dynamometry, performed all of the muscle testing.

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CONCLUSIONS

The results of this study show that hip abductors and external rotators were markedly weaker between the injured and unaffected legs of the injured athletes. This finding highlights the association between hip abduction and external rotation weakness and patellofemoral pain. In addition, injured collegiate female athletes exhibited global hip weakness compared with age- and sport-matched asymptomatic controls. On the basis of our results, we recommend screening for hip muscle weakness, especially hip abductors and external rotators, in athletes with patellofemoral pain. Future research is needed to determine whether adding exercises to address these weaknesses may hasten recovery and allow for faster return to preinjury activity levels.

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