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Hip Strength Is Greater in Athletes Who Subsequently Develop Patellofemoral Pain

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Abstract

Background—Hip and knee strength abnormalities have been implicated in patellofemoral pain (PFP) in multiple studies. However, the relationship is unclear, as many of these studies have been retrospective.

Purpose—To compare prospective hip and knee isokinetic strength in young female athletes who subsequently went on to develop PFP relative to their uninjured, healthy peers.

Study Design—Descriptive epidemiology study.

Methods—Adolescent female athletes (N = 329) were tested for isokinetic strength of the knee (flexion and extension) and hip (abduction) and screened for the prevalence of PFP before their basketball seasons. After exclusion based on current PFP symptoms, 255 participants were

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prospectively enrolled in the study. A 1-way analysis of variance was used to determine between-group differences in incident PFP and the referent (no incident PFP) participants.

Results—The cumulative incidence rate for the development of PFP was 0.97 per 1000 athlete-exposures. Female athletes who developed PFP demonstrated increased normalized hip abduction strength (normalized torque, 0.013 ± 0.003) relative to the referent control group (normalized torque, 0.011 ± 0.003) ($P < .05$). Unlike hip strength, normalized knee extension and knee flexion strength were not different between the 2 groups ($P > .05$).

Conclusion—The findings in this study indicate that young female athletes with greater hip abduction strength may be at an increased risk for the development of PFP. Previous studies that have looked at biomechanics indicated that those with PFP have greater hip adduction dynamic mechanics.

Clinical Relevance—Combining the study data with previous literature, we theorize that greater hip abduction strength may be a resultant symptom of increased eccentric loading of the hip abductors associated with increased dynamic valgus biomechanics, demonstrated to underlie increased PFP incidence. Further research is needed to verify the proposed mechanistic link to the incidence of PFP.

Keywords

patellofemoral pain; hip strength; anterior knee pain; female athlete

Patellofemoral pain (PFP) is a very common diagnosis in female athletes, with a higher incidence rate of 2.23 times greater than that of male athletes.⁶ Despite a high prevalence in the athletic population and substantial research, the exact cause of PFP is still unknown and is theorized to be multifactorial. Focus has shifted from local factors (eg, quadriceps angle, quadriceps strength) to more proximal factors such as hip biomechanics and strength.

When looking at proximal mechanics, hip rotation has been evaluated by many authors, often with varying protocols. McKenzie et al²⁴ compared recreational female athletes diagnosed with PFP with a control group during stair stepping and found greater hip internal rotation during stair descent. This finding was consistent with data by Souza and Powers,⁴¹ who also found increased hip internal rotation in patients with PFP during running, a drop jump, and step-down. However, 2 additional studies found conflicting data, in which patients with PFP had decreased hip internal rotation compared with controls across multiple functional activities.^{30,48} While hip rotation findings have been inconsistent among biomechanical studies, patients with PFP have consistently demonstrated greater hip adduction compared with control groups.^{24,29,30,48}

Altered neuromuscular recruitment strategies in patients with active, symptomatic PFP have also been reported.^{5,36,48} A recent systematic review by Barton et al⁴ analyzed prospective and case-control studies that evaluated the association of gluteal electromyography with PFP and concluded that there is moderate to strong evidence that gluteus medius activity is delayed and shorter in duration during stair maneuvering in patients with PFP. However, this is activity specific, as there is only limited evidence that gluteus medius activity is delayed and shorter in duration during running.⁴

Hip strength is another important factor in PFP and the focus of this study. Previous literature evaluating hip strength in patients with PFP demonstrated varying testing methods. Some studies evaluated isometric strength, while others looked at eccentric strength and, oftentimes, in different positions (prone, side lying, or standing). Despite these differences, there is a generalized conclusion among authors of retrospective studies that participants who already carry a diagnosis of PFP have decreased hip abduction, or gluteus medius, strength in the extremity with PFP whether compared with the contralateral limb or to a healthy control.^{5,21,35,36,41}

Despite these consistent findings in regards to hip abduction weakness, recent prospective literature has been contradictory. Thijs et al⁴⁴ enrolled female participants in a “start to run” program and measured hip strength before participation. This study did not demonstrate any hip strength differences between those who went on to develop PFP and those who remained healthy. However, another prospective study that also looked at runners, including male athletes, concluded that greater hip abduction strength predisposes athletes to the incidence of PFP.¹⁴ Interestingly, this study also found that although patients with PFP had greater hip strength at baseline, their strength had decreased significantly at the time of diagnosis.¹⁴

Another area of conflicting strength data is in regards to hip external rotation strength. A recent report by Finnoff et al¹⁴ prospectively identified decreased hip external rotation strength in those developing PFP, contradictory to the earlier prospective finding by Boling et al⁷ of increased hip external rotation strength. The purpose of our study was to provide prospective data in regards to hip and knee strength and the incidence of PFP among young female athletes because this is the population at greatest risk of this diagnosis.

METHODS

Female basketball players from a single-county Kentucky public school district consisting of 5 middle schools participated in this study. A total of 329 athletes participated in the initial preseason screening (Figure 1). Athletes participated as part of school-sponsored teams, which resulted in greater than 95% recruitment. An institutional review board approved the data collection procedures and consent forms. Parental consent and athlete assent were obtained before the initiation of data collection. Before the start of their competitive seasons, athletes were screened for prior and existing knee injuries using the Anterior Knee Pain Scale (AKPS) questionnaire.^{11,19,47} Participants with an AKPS score of 100 were deemed to be healthy candidates and underwent strength testing without the need for any further assessment.

All participants with an AKPS score of less than 100 underwent a more thorough evaluation to determine the origin and presentation of their self-reported knee pain. This assessment included completion of the International Knee Documentation Committee form, a standardized history form documenting current and prior knee symptoms and injuries, and a comprehensive knee examination performed by a sports medicine-trained physician. Further questioning specifically addressed the athlete’s knee pain severity, time missed from sports participation because of knee pain, timing of knee pain with activity, knee pain after play, duration of knee pain, and symptoms related to knee pain. The physical examination

included palpation for tenderness at the patellar facets, distal pole of the patella, tibial tubercle, Hoffa fat pad, quadriceps tendon, patella tendon, medial patellofemoral ligament, medial and lateral patellofemoral joints, medial and lateral femorotibial joint lines, pes anserinus, Gerdy tubercle, and iliotibial band. Clinical tests for ligament instability, meniscal tearing, and patellar apprehension and mobility were also performed. PFP was operationally defined as retropatellar or peripatellar pain around the patellofemoral joint. The physician determined a diagnosis of PFP based on findings during the physical examination as detailed above. Participants with acute knee injuries or prevalent PFP, as diagnosed by the physician after history and physical examinations ($n = 46$), were excluded from the study. After eliminating those who did not meet the stated criteria, 283 healthy participants remained and underwent strength testing.

Isokinetic knee extension/flexion (concentric/concentric muscle action) strength was measured with the participant seated on the dynamometer with the hip flexed to 90° and the knee flexed to 90° . The test session consisted of 10 knee flexion/extension repetitions for each leg at 300 deg/s. Peak flexion and extension torques were recorded (ft·lb). Concentric hip abduction strength was measured with the participant standing erect and a stabilization strap around the pelvis. The test leg was positioned lateral to the opposite leg in a position of 0° of hip and knee flexion. The axis of hip abduction/adduction was aligned with the axis of rotation of the dynamometer. Each participant performed 5 warm-up movements. The warm-up was immediately followed by the test session, consisting of 5 maximum-effort hip abduction with passive adduction repetitions at 120 deg/s. Isokinetic torque measures were converted to newton meters and were normalized to leg length by mass and are described as normalized torque (NT). These data were obtained before the start of the participants' basketball season. Twenty-eight athletes did not have complete strength data and thus were excluded from the study. The remaining athletes ($n = 255$) were then monitored by certified athletic trainers for the incidence of PFP during their competitive seasons.

Athlete Surveillance, Follow-up, and Incident Diagnosis

The athletes were monitored on a weekly basis for athlete-exposures (AEs), new PFP injuries, or any other lower extremity injuries with resultant time loss by a certified athletic trainer. PFP was operationally defined as retropatellar or peripatellar pain around the patellofemoral joint. The athletic trainer assessed the development of new PFP based on findings during the athlete's physical examination. AEs were defined as 1 game or practice session. The AEs of athletes with preseason PFP, or other athletes who were excluded, were not included in the compilation of total AEs. At the time of a missed game or practice or postseason follow-up, the AKPS questionnaire was readministered to all participants. Athletes with a positive score on the AKPS and all athletes who had been examined pre-season underwent a further evaluation with a standardized personal interview and physical examination by the same physician. These data were compiled to calculate the pre-season prevalence and in-season injury incidence of PFP.¹⁸

Statistical Analysis

A 1-way analysis of variance (ANOVA) was used to determine significant differences in knee and hip strength between the incident PFP and control groups. Statistical means $\pm$ SDs

of all variables of interest were calculated for each of the strength variables. A 1-way between-groups univariate ANOVA was employed to investigate the group differences (control vs PFP) on the dependent strength variables for each limb. Statistical analyses were conducted in SPSS (version 17.0; SPSS Inc). Statistical significance was established a priori at $P < .05$ to test the hypothesis that hip strength would be altered in athletes at risk of developing PFP.

RESULTS

Of the 255 participants prospectively screened and included in the analysis, 38 female athletes developed PFP, and 217 did not develop PFP. The cumulative incidence rate for the development of PFP, unilateral or bilateral, was 0.97 per 1000 AEs. Young female athletes who developed PFP were not different in age (mean, 12.7 ± 0.9 years), mass (mean, 51.4 ± 13.2 kg), height (mean, 158.9 ± 7.3 cm), or leg length (mean, 83.8 ± 4.2 cm) compared with the referent control group ($P > .05$) (Table 1). Female athletes who developed PFP ($n = 38$) demonstrated greater normalized hip strength (0.013 ± 0.003 NT) relative to the referent control group (0.011 ± 0.003 NT) ($P < .05$) on their right side. Likewise, the study participants who developed PFP demonstrated greater normalized hip strength on their left side (0.012 ± 0.003 NT) relative to the referent control group (0.011 ± 0.003 NT) ($P < .05$).

Unlike the hip strength measures, normalized knee extension and knee flexion strength were not different between the female athletes with incident PFP compared with the referent control group ($P > .05$) (Figure 2). Normalized knee extension strength was similar between groups on the right (controls: 0.016 ± 0.003 ; PFP: 0.016 ± 0.002 ; $P > .05$) and left limbs (controls: 0.016 ± 0.003 ; PFP: 0.016 ± 0.002 ; $P > .05$). Normalized knee flexion strength was also similar between groups on the right (controls: 0.010 ± 0.003 ; PFP: 0.010 ± 0.003 ; $P > .05$) and left limbs (controls: 0.011 ± 0.003 ; PFP: 0.011 ± 0.003 ; $P > .05$).

DISCUSSION

As previously mentioned, PFP is one of the most common diagnoses in sports medicine, accounting for nearly 25% of all identified knee injuries.^{3,20,43} It is a common problem, encompassing a complex of symptoms without a single identifiable cause. Multiple intrinsic anatomic factors combine with extrinsic training factors to produce a pain syndrome that can be difficult for clinicians to diagnose. Understanding the anatomy and extensor mechanism of the knee joint is crucial to appreciating the multifactorial nature of PFP. Multiple structures are involved in patellar function, including the patella itself, the vastus lateralis muscle, vastus medialis muscle, quadriceps tendon, iliotibial band, patellar tendon, and tibial tubercle. PFP is diagnosed if patients have anterior knee pain, with or shortly after activity, medial and/or lateral patellar facet tenderness, and Hoffa fat pad syndrome with fat pad swelling and tenderness over the medial or lateral fat pad.²⁷

The objective of this study was to obtain prospective data of hip and knee strength in young female athletes and relate the findings to the incidence of PFP through the athletes' seasons. Our findings indicate that young female athletes with greater hip abduction strength may be at an increased risk for the development of PFP. This is consistent with another prospective

data set collected by Finnoff et al,¹⁴ who measured hip abduction, adduction, flexion, extension, internal rotation, and external rotation strengths of high school running athletes before their track and/or cross-country seasons. The authors concluded that stronger hip abductors, more importantly in relation to their hip adductor strength, and weaker hip external rotators were associated with an increased incidence of PFP. Thijs et al⁴⁴ performed a very similar study with isometric strength measurements using a hand-held dynamometer but found no relationship between strength and incidence of PFP. Before this, hip abduction weakness had been associated with patients with PFP. The retrospective design of many of these previous studies, in which participants were tested for muscle strength after presenting with PFP, does not allow for the determination of muscle weakness as a cause or result of PFP. This discrepancy likely contributes to the conflicting results that have been produced.

Other than strength measurements, many studies have looked at hip mechanics in relation to PFP. As mentioned previously, greater hip adduction has been found in patients with PFP.^{24,29,30,48} Furthermore, greater internal rotation of the femur during running as well as greater hip adduction during running and a single-leg drop have been found in female patients, who are more prone to PFP.^{13,16,37} Increased hip adduction has been cited to be the primary contributor to excessive valgus stress on the knee and therefore affects the lateral forces acting on the patella.⁴⁹ Additionally, patients with PFP tend to internally rotate the femur to a greater extent during a weight-bearing squat. As the femur rotates internally, it displaces the patella laterally, reducing patellofemoral contact area.^{23,32,34} This change in alignment increases pressure on the lateral aspects of the patella^{22,38} and, when combined with the increased hip adduction mentioned previously, and repetition of these abnormal forces, can strain the patellar structures, leading to pain.^{8,17} Proximal hip mechanics, such as internal and external rotation, abduction, and adduction, have an effect on proper patellar function. The complex interactions of knee structures and mechanics create a balance of forces that act on the patella and allow it to serve its primary function of improving leverage for knee extension by tracking within the trochlear groove of the femur. Any process causing an imbalance of these forces is likely to cause dysfunction and pain in the knee joint. Understanding these influences is crucial as recent reports suggest that PFP risk factors may increase the risk for more severe injuries as female patients mature.²⁸

Anatomic risk factors can be divided into regional risk factors involving the foot, knee, or hip. Multiple authors have investigated foot and ankle biomechanics and have found distal risk factors of PFP to include increased navicular drop, decreased pronation and arch index, increased arch height, and increased passive ankle dorsiflexion.^{7,12,25,26} The knee has probably been the area of most concentrated research as local factors were investigated. In looking at a multitude of prospective and retrospective studies, it appears that anatomic risk factors about the knee include a hypermobile patella, shallow trochlear groove, patella alta, maltracking patella, and increased patellofemoral contact area.^{9,15,33,39,40,46,50}

Limitations

This study is not without limitations as there are several neuromuscular risk factors purported to be related to the incidence of PFP that were not investigated in the current investigation. Prospective findings include decreased knee flexion angle, decreased vertical

ground-reaction force, increased hip internal rotation angle, altered vastus medialis obliquus response time, and increased lateral pressure of the foot at contact.^{7,42,45,50} Retrospective studies have found a relationship between PFP and increased rearfoot medial collapse, decreased peak pressure of the medial forefoot, altered control of the medial thigh, delayed vastus medialis activation, and decreased trunk flexion.^{1,2,10,31} Finally, increased knee abduction impulse, moment, and load have all been identified as PFP risk factors as well.^{27,42} In addition, relative to the current outcome measure of hip abduction strength, consideration should be given to the skeletal alignment of adolescent female patients. Specifically, coxa vara/valga and femoral anteversion were not controlled for, which may have a direct effect on the moment arm for gluteus medius function. As a result of these various identifiable risk factors, the origin of PFP is likely multifactorial, and future prospective studies that include all the potential risk factors for PFP are needed to fully flesh out the cause in young girls. Finally, there were substantial efforts made to normalize data to protect against potential effects of maturational growth and moment arm length. The authors acknowledge that the statistical difference in normalized hip abduction strength should be interpreted with caution until future validation studies can confirm the clinical meaningfulness of the current results.

CONCLUSION

In summary, many retrospective studies have shown that patients with PFP have hip muscle weakness compared with controls; however, these studies do not determine whether muscle weakness is a cause or an effect of PFP. Our prospective study shows that before developing PFP, patients may actually demonstrate greater hip strength than those who remain healthy. We speculate that greater hip abduction strength may be a resultant symptom of increased eccentric loading of the hip abductors. If patients have increased hip adduction on landing, they require greater hip abductor strength to correct these faulty mechanics. As long as the greater hip abduction strength can correct for the increased hip adduction kinematics, the patient remains asymptomatic. When this compensatory balance fails, the patient may then have PFP. Future research is warranted to dissect the relative contributions of hip strength and recruitment and dynamic valgus alignments during landing to the pathomechanics of PFP.

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Figure 1.

Flowchart providing a graphical depiction of the study population as a whole and how the final sample of 255 participants was obtained.

Figure 2.
Normalized knee and hip strength for the referent control and incident patellofemoral pain groups.

TABLE 1

Participant Characteristics^a

	Age, y	Height, cm	Weight, kg	Body Mass Index, kg/m ²	Fat, %	Leg Length, cm	
						Right	Left
Control group	12.8	158.3	52.0	20.6	22.7	83.0	82.9
Incident PFP group	12.7	158.9	51.4	20.1	22.2	83.7	83.8

^aData are reported as means. PFP, patellofemoral pain.