[RESEARCH REPORT]

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A Comparison of Hip Strength Between Sedentary Females With and Without Patellofemoral Pain Syndrome

Patellofemoral pain syndrome (PFPS) is a common source of anterior knee pain in athletes and sedentary females and represents approximately 20% to 40% of all individuals with knee conditions treated in specialized centers of orthopaedic and sports medicine.[8,36] A steadily growing body of literature suggests a possible relationship between PFPS and lack of adequate control of hip movement during weight-bearing activities.[5,8,11,15] Powers et al,[33] using dynamic magnetic resonance imaging, observed that, during the performance of a single-limb squat by subjects with patellar instability, the femur adducted and rotated internally while the patella remained in a static position, suggesting movement of the femur on the patella. These observations contribute to the hypothesis that hip muscles weakness may be related to excessive femoral adduction and medial rotation during functional activities,[19,22] leading to an increase in knee dynamic valgus and a decrease in patellofemoral joint contact area, which are suggested as possible factors leading to PFPS.[32,33,37] Recently, Prins and Wurff[34] reported strong evidence that females with PFPS exhibit specific impaired strength of the hip musculature (hip abductors, lateral rotators, and extensors), based on the action of these muscles in controlling lower extremity motion.

• **STUDY DESIGN:** Cross-sectional study.

• **OBJECTIVE:** To compare the hip strength of sedentary females with either unilateral or bilateral patellofemoral pain syndrome (PFPS) to a control group of sedentary females of similar demographics without PFPS.

• **BACKGROUND:** It has been suggested that hip muscle weakness may be an important factor in the etiology of young female athletes with PFPS. This syndrome is also common in sedentary females and it is unclear if similar findings of hip weakness would be present in this population.

• **METHODS:** Females between 15 and 40 years of age (control group, n = 50; unilateral PFPS, n = 21; bilateral PFPS, n = 29) participated in the study. Strength for all 6 hip muscle groups was measured bilaterally on all subjects using a handheld dynamometer.

• **RESULTS:** The hip musculature of sedentary females with bilateral PFPS was statistically weaker (range, 12%-36%; $P<.05$) than that of the control group for all muscle groups. The hip abductors, lateral rotators, flexors, and extensors of the injured side of those with unilateral PFPS group were statistically weaker (range, 15%-20%; $P<.05$) than that of the control group, but only the hip abductors were significantly weaker when compared to their uninjured side (20%; $P<.05$).

• **CONCLUSION:** This study demonstrates that hip weakness is a common finding in sedentary females with PFPS. *J Orthop Sports Phys Ther 2010;40(10):641-647. doi:10.2519/jospt.2010.3120*

• **KEY WORDS:** *chondromalacia, handheld dynamometry, knee, patella*

However, Chichanowski et al[9] reported that females with PFPS demonstrated overall hip weakness. Thus it is still unclear if the identified weakness is specific to certain hip muscle groups, as opposed to all 6 hip muscles groups, which would indicate overall hip weakness, and have potential implications for rehabilitation. Furthermore, studies have suggested that females with unilateral and bilateral knee pain belong to the same group, although direct comparisons of hip strength between these groups have not been performed.[15,35] If females who have unilateral or bilateral PFPS do not present the same hip weakness pattern, this could also impact clinical decisions. In addition, overall hip weakness could be associated with increased pain and reduced functional status, suggesting that a program of con-

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servative treatment aimed at improving the strength of all 6 hip muscle groups may reduce pain and increase function in sedentary females with PFPS.

Historically, this syndrome has been cited as the most common overuse injury in athletes or physically active individuals.[36] However, studies have shown that in subjects with PFPS, simple daily activities, such as negotiating stairs[33] and single-limb squats,[20] are sufficient to change knee and hip kinematics. In our clinical practice, we see a high incidence of PFPS in sedentary women, and hip musculature weakness seems common in this group. However, there is a lack of evidence in the literature regarding hip muscle impairments in the sedentary population.

Therefore, the aims of this investigation were to compare the hip strength of sedentary females with either unilateral or bilateral PFPS with a control group of sedentary females of similar demographics without PFPS. We hypothesized that females with unilateral pain would present specific weakness of their injured limb when compared to their uninjured side and the control group, while females with bilateral pain would present overall hip weakness when compared with the control group.

METHODS

Subjects

Fifty women between the ages of 15 and 40 (mean ± SD age, 24.6 ± 6.4 years; height, 161.8 ± 6.8 cm; body mass, 59.7 ± 11.8 kg) diagnosed with either unilateral (n = 21) or bilateral (n = 29) PFPS were recruited from a private orthopedic clinic. The inclusion criteria were history of unilateral or bilateral anterior knee pain for at least the past 6 weeks and the presence of pain for at least 3 of the criteria described by Thomee et al,[40] which consist of pain when squatting, climbing up or down stairs, kneeling, sitting for long periods, performing resisted isometric knee extension at 60° of knee flexion, and palpating the medial or lateral facet of the patella. Potential participants were excluded if there were any other associated knee conditions such as patellar instability, previous knee surgery, or meniscal, ligament, tendon, or cartilage injury. A standard knee clinical examination was performed to rule out concomitant pathology of the lower extremities.

Fifty subjects of similar demographics, who presented to the clinic with upper extremity tendinopathies and without lower extremity involvement, were recruited from the same clinic to serve as control group (mean ± SD age, 24.1 ± 6.3 years; height, 161.2 ± 5.9 cm; body mass, 57.9 ± 8.3 kg). The subjects for both groups were excluded if they had any neurological diseases, hip or ankle injuries, lumbar or sacroiliac joint pain, or rheumatoid arthritis, or were pregnant.

All females included in this study were sedentary (did not perform sports activities any day of the week for at least the previous 6 months), according to the criteria of the American College of Sports Medicine.[44]

Before taking part in this study, all subjects were informed and signed an informed consent approved by The Ethics Committee on Research of the Federal University of São Paulo.

Procedure

A single orthopaedic physician with more than 20 years of clinical experience determined subject participation based on the inclusion and exclusion criteria and informed the examiner which subjects were assigned to the control or the PFPS group. Consequently, while the examiner was aware of group assignment for those with PFPS, he was not aware of the side involved or if involvement was unilateral or bilateral. All data were collected by a single examiner, a physical therapist with 7 years of experience. The subjects were first tested for muscle strength, then personal data were collected: body mass, height, age, injured limb, level of pain, and duration of symptoms. Finally, a questionnaire was completed to evaluate lower limb functional ability during daily activities.

FIGURE 1. Strength measurements for the hip abductors and adductors.

Muscle Strength Measurement A Nicholas handheld dynamometer (Lafayette Instrument Company, Lafayette, IN) was used to measure strength. Measurements with this instrument have been shown to have good to excellent interrater and intrarater reliability for measurements of hip strength in women with PFPS.[1,29] This instrument is also widely used clinically to measure muscle strength.[3,4]

The strength of the abductors was evaluated with the subject positioned in sidelying on the examination table. The limb to be evaluated was positioned by the examiner at approximately 20° of abduction, 10° of extension, and hip neutral rotation (**FIGURE 1**).[35] Hip adductors were evaluated with the subject positioned in sidelying on the side of the lower limb being evaluated. The limb was positioned with the knee extended and the hip in neutral rotation. The contralateral limb was positioned by the examiner at 90° of hip and knee flexion and was supported by pillows (**FIGURE 1**).[17]

For the hip lateral rotators, the subject was sitting on the table with hips and knees flexed at 90°. The subject was then asked to keep the arms held against the

FIGURE 2. Strength measurements for the hip lateral and medial rotators.

body, and the hip was positioned in slight lateral rotation, with the medial malleolus aligned with the midline of the body. In this position, the subject performed a maximum isometric contraction of the hip lateral rotators, with resistance to movement applied just superior to the medial malleolus.[35] The medial rotators were evaluated in hip neutral rotation, with resistance to movement applied just above the lateral malleolus (**FIGURE 2**).[9]

For the hip flexors, the subject was asked to sit on the table, with arms held against the body and hips and knees at 90° of flexion. With 1 hand, the examiner positioned the dynamometer 3 cm above the superior pole of the patella, on the anterior aspect of the thigh (**FIGURE 3**).[9] Finally, strength of the hip extensors was evaluated with the subject in prone on the table, with the knee flexed at 90° and hip in slight lateral rotation. Resistance was applied to the distal posterior thigh region (**FIGURE 3**).[35]

During strength testing, we used 2 submaximal trials to familiarize the subjects with each test position. This was followed by 2 trials with maximal isometric effort for each muscle group. For data

FIGURE 3. Strength measurements for the hip flexors and extensors.

analysis, the average values of the 2 trials with maximum effort were used.

The interval between the second submaximal contraction and the first maximal isometric contraction was 10 seconds. The duration of each maximal isometric contraction was standardized at 5 seconds, with a resting time of 30 seconds between maximal isometric contractions. Testing order for limbs and muscle groups was randomized. After evaluation of a muscle group on 1 side, a standard 1-minute rest was given before evaluating the same muscle group on the opposite lower limb. When the examiner observed any compensation during a test, values were disregarded and the test was repeated after 20 seconds of rest.

Pilot Study for Muscle Strength

Because some studies have demonstrated possible examiner influence on test reliability,[5,42] a pilot study was conducted during the 6 weeks prior to data collection, with the aim of assessing the reliability of our strength measurements using a handheld dynamometer.

We measured muscle strength of all 6 muscle groups of the hip for 15 sedentary females (mean ± SD age, 23 ± 3.3 years; height, 160 ± 3.1 cm; body mass, 53 ± 6.6 kg). Seven of the 15 had PFPS (4 unilateral, 3 bilateral). The subjects were tested according to the protocol described above, with 1 week between the 2 testing sessions. Results indicated excellent reliability, intraclass correlation coefficients ($ICCs_{3,1}$)[12,18] between 0.92 and 0.99 for all muscle groups except for the hip flexors, which were 0.82 for the right limb and 0.76 for the left limb.

Functional Evaluation

We used the Knee Outcome Survey activities of daily living scale to measure function. The activities of daily living scale contains 14 items. Each item is based on 6 points, where the highest score represents no difficulty performing the task and the lowest score represents complete inability to perform the activity. Studies have demonstrated adequate reliability of this questionnaire in subjects diagnosed with PFPS.[16,23] Pain was measured with an 11-point visual analog scale, where 0 corresponded to no pain and 10 corresponded to worst imaginable pain.[8,29]

Data Analysis

Separate 1-way analyses of variance (ANOVAs) were used to compare demographics, function, pain, and duration of symptoms data among the 3 groups. For the group with bilateral symptoms, data for both limbs were initially averaged, as there was no significant difference between limbs. Strength data, measured in kilograms, were normalized to body mass, also measured in kilograms using the following formula: (kg strength/kg body weight) × 100.[35]

As a preliminary step in the data analysis, we performed separate dependent *t* tests to compare side-to-side differences for each muscle group for each group of subjects (control, bilateral PFPS, and unilateral PFPS). This preliminary analysis was followed by separate independent *t* tests to compare each muscle groups of the injured side of the unilateral PFPS group versus the average of both sides for the control group, as well as the average

TABLE 1 BASELINE CHARACTERISTICS (MEAN ± SD) OF THE SUBJECTS IN EACH GROUP

	Control (n = 50)	Unilateral PFPS (n = 21)	Bilateral PFPS (n = 29)
Age (y)*	24.1 ± 6.3	23.7 ± 6.7	25.2 ± 6.2
Weight (kg)*	57.9 ± 8.3	60.4 ± 11.8	59.2 ± 12.0
Height (cm)*	161.2 ± 5.9	163.1 ± 5.0	160.8 ± 7.8
Duration of symptoms (mo)†	0	30.7 ± 31.7‡	54.8 ± 51.6‡
VAS (0-10)†	0	6.3 ± 1.7‡	5.3 ± 1.7‡
ADLS (0-100)†	99.8 ± 0.8	70.7 ± 16.8‡	75.7 ± 17.4‡

Abbreviations: ADLS, activities of daily living scale; PFPS, patellofemoral pain syndrome; VAS, visual analog scale.
* *No difference among groups (P>.05).*
† *Based on the average of both sides for the group with bilateral PFPS.*
‡ *Statistically different from the control group (P<.0001), and no difference between the 2 groups with PFPS (P>.05).*

of both limbs of the bilateral PFPS group versus the average of both limbs for the control group. Graph Pad was used for data analysis. Statistical significance was set at .05.

RESULTS

Demographic data for the control group and both groups with PFPS are provided in **TABLE 1**. Age, weight, and height were similar for all 3 groups ($P>.05$). There was no difference of duration of symptoms, pain based on the visual analog scale, and activities of daily living scale score between those with unilateral and bilateral PFPS ($P>.05$).

Muscle strength data of both sides for the 3 groups of subjects are presented in **TABLE 2**. For the control group, hip strength was similar between sides ($P>.05$), except for the hip lateral rotators ($P<.001$).[13] Based on this overall strength similarity between sides, we opted to average both sides for the subsequent between groups analyses. For the group with bilateral PFPS, there was no significant strength difference between sides for all 6 muscle groups, allowing averaging of both sides for subsequent comparisons with the other groups of subjects. When comparing side-to-side differences for the group of subjects with unilateral PFPS, only the hip abductors of the injured side were weaker than those on the uninjured side ($P<.002$).

Compared to the control group, the subjects with unilateral PFPS had a strength deficit on the involved side of between 15% and 20% for the hip abductors, lateral rotators, flexors, and extensors ($P<.0002$, $P<.01$, $P<.009$, and $P = .037$, respectively). All 6 hip muscle groups were statistically weaker in the subjects with bilateral PFPS when compared to the control group ($P<.05$) (**TABLE 3**).

DISCUSSION

Despite hip weakness being a common finding in female athletes with PFPS, to our knowledge, there are no published studies that have focused on sedentary females with PFPS. These patients often report pain during daily activities requiring single-limb squats and negotiating stairs. The current study demonstrates that sedentary females with PFPS have overall weakness of hip musculature when compared to a matched group of sedentary females without PFPS. These findings may have implications for rehabilitation of these

TABLE 2 HIP STRENGTH NORMALIZED TO BODY WEIGHT (MEAN ± SD) OF THE FEMALE SUBJECTS WITH UNILATERAL (N = 21) AND BILATERAL (N = 29) PATELLOFEMORAL PAIN SYNDROME AND THE CONTROL GROUP (N = 50)

	Abductors	Adductors	Extensors	Flexors	Lateral Rotators	Medial Rotators
Control						
Right limb	14.5 ± 3.0	15.5 ± 3.6	22.1 ± 5.9	20.2 ± 4.3	15.6 ± 3.4‡	13.5 ± 3.2
Left limb	14.7 ± 3.0	14.7 ± 3.8	21.8 ± 5.6	18.5 ± 4.4	13.3 ± 3.2‡	15.1 ± 2.8
Unilateral						
Injured limb	11.7 ± 4.2†	14.1 ± 5.7	19.1 ± 10.0	16.3 ± 6.0	12.7 ± 4.1	13.6 ± 4.4
Uninjured limb	14.8 ± 4.1†	14.0 ± 5.2	20.6 ±10.0	18.5 ± 5.5	13.8 ± 3.9	14.8 ± 4.3
Bilateral						
Right limb*	9.3 ± 2.5	11.3 ± 3.7	15.8 ± 6.7	15.4 ± 4.6	12.4 ± 3.1	11.7 ± 3.5
Left limb*	9.6 ± 2.7	11.4 ± 2.8	14.3 ± 6.3	14.0 ± 3.7	10.7 ± 3.1	13.3 ± 3.9

* *There was no significant strength difference (P>.05) between sides for the bilateral group.*
† *There was no significant strength difference (P>.05) between sides for the unilateral group with the exception of the abductors (P<.002).*
‡ *There was no significant strength difference (P>.05) between sides for the control group with the exception of the lateral rotators (P<.001).*

TABLE 3 Hip Strength Normalized to Body Weight*

	Control (n = 50)	Unilateral PFPS (n = 21)	Bilateral PFPS (n = 29)
Abductors	14.6 ± 2.9	11.7 ± 4.2†	9.6 ± 2.8‡
Adductors	15.1 ± 3.7	14.1 ± 5.7	11.4 ± 3.3‡
Extensors	21.8 ± 5.6	19.1 ± 10.0†	15.8 ± 9.0‡
Flexors	19.4 ± 4.3	16.3 ± 6.0†	14.9 ± 4.3‡
Lateral rotators	14.5 ± 3.5	12.7 ± 4.1†	12.1 ± 3.9‡
Medial rotators	14.3 ± 3.1	13.6 ± 4.4	12.7 ± 3.8‡

Abbreviation: PFPS, patellofemoral pain syndrome.
* *Data, presented as mean ± SD, are for the involved side of the group with unilateral PFPS and the average of both sides for the other 2 groups.*
† *Significantly different when compared to the control group (P<.01), except for the hip extensors (P = .037).*
‡ *Statistically different when compared to the control group (P<.0001).*

individuals. It could be argued that to avoid muscular imbalance, these results suggest the need to strengthen all hip muscle groups in this population, as opposed to simply those that have been most studied based on their antigravity role (hip abductors, external rotators, and extensors).

When comparing the injured side of females with unilateral PFPS to the control group in the present study, they had approximately 20% less strength of the hip abductors, lateral rotators, and flexors, as well as 15% less strength of the hip extensors. Our findings of weakness for the hip abductors and lateral rotators are in agreement with data reported in several other studies[5,11,15,43] that also used handheld dynamometry to measure strength in females with and without PFPS. In a separate study, Tyler et al[41] found hip abductor and flexor weakness, but they did not assess the hip lateral rotators. Chichanowski et al[9] also reported that females with unilateral symptoms demonstrated a generalized decrease in hip muscle strength, except for the hip adductors. Although it has been the focus of a limited number of studies, our findings of the absence of weakness of the hip adductors[41] and medial rotators[2] in the unilateral pain group is consistent with what has been reported in previous studies. However, it is noteworthy that, when performing a side-to-side comparison in the group with unilateral PFPS, weakness of the injured side (20%) was only noted for the hip abductors. Chichanowski et al[9], who also compared uninjured and injured sides of females with PFPS, also found weakness of the hip abductors and lateral rotators.

The hip extensors have been suggested to be the most important muscle group to provide 3-dimensional control of the lower limb during functional activities.[28,31] In our study, females with unilateral PFPS, when compared to the control group, showed hip extensor weakness, a finding consistent with those of previous studies reporting decreased isometric hip extensors strength in females with PFPS.[35,39] However, these findings contrast with those of Boling et al,[6] who used an isokinetic device to assess concentric-eccentric strength of the hip muscles.

Females with bilateral PFPS in our study demonstrated weakness of the hip abductors, lateral rotators, extensors, and flexors, which is consistent with data previously reported in other studies. Despite our findings of weakness for all 6 hip muscle groups, we do not agree with Chichanowski et al[9] that females with PFPS demonstrate overall hip weakness due to withdrawal from training, because the females with bilateral PFPS in the current study, similar to our control group, were sedentary.

Although there is growing evidence that altered hip mechanics may influence the patellofemoral joint, biomechanical studies have questioned an absolute direct relationship between specific hip weakness and altered lower extremity kinematics during dynamic tasks.[14,25,38] Souza and Powers[39] showed that females with PFPS demonstrated significantly greater peak hip internal rotation than that of the control group during 3 different tasks (running, stepping down, and landing from a jump). Nevertheless, no group difference in hip adduction was observed in their study. In contrast, Willson and Davis[43] demonstrated a significantly greater average adduction compared to asymptomatic subjects during hopping, running, and single-limb squatting. Bolgla et al[5] reported no difference in hip adduction or internal rotation between females with and without PFPS while descending stairs. Recently, Boling et al[7] published a prospective study of biomechanical risk factors for PFPS that reported increased hip internal rotation as a predictor of knee symptoms in subjects; however, hip adduction was not a factor in the predictive model.

The authors of a recent systematic review of 6 studies comparing hip muscle strength between females with and without PFPS concluded that there is strong evidence that females with PFPS exhibit impaired strength of the hip abductors, lateral rotators, and extensors.[34] Recently, Long-Rossi and Salsich[21] reported that diminished hip lateral rotation strength is a predictor of self-reported functional status in females with PFPS. In addition, several studies have reported improved hip kinematics after weight-bearing hip-strengthening programs.[24,26,27,30] Although specific hip weakness was a common finding in sedentary females with PFPS in the present study, additional research is needed to better understand the relationship between hip weakness, hip and knee kinematics, and patellofemoral joint pressure. In addition to hip abductor, lateral rotator, and extensor strength, future studies should include strength measures of other proximal muscle groups, including the trunk musculature, which further contributes to proximal stability.[10,45,46]

LIMITATIONS

One potential limitation of the study is that the examiner was not blinded to subjects having PFPS or being in the control group. Lack of blinding might have produced unintentional bias during physical examination.[9,29] But, the examiner was blinded to the side of pain for the patients with PFPS and their status as having unilateral or bilateral pain. To minimize potential bias, a single examiner, who had experience with handheld dynamometry, performed all muscle testing.

We used manual stabilization during testing. While previous studies have shown that examiner resistance affects the measurements,[5,42] our own reliability data showing repeatability of the measurements are consistent with the data of previous studies.[29,35] We did not measure limb length, and this may be a confounding variable affecting strength measurement.[16] However, this bias was minimized by using females of similar anthropometric values, including height.

Factors other than hip strength, such as of lower-extremity alignment (ie, Q angle and femoral anteversion), anterior pelvic tilt, foot type, and flexibility could be involved with PFPS of sedentary females. Future studies specifically designed to assess a combination of these variables in the etiology of PFPS are needed.

Future studies are also needed to determine if interventions aimed at strengthening the hip musculature would reduce pain and improve function in this population with long-term duration of symptoms.[9,21] It is unclear if patients with a shorter-term duration of symptoms would present similar hip weakness. Therefore, additional research is needed to better understand the relationship between duration of symptoms and hip weakness, including prospective studies that could help determine any causal relationships.

CONCLUSION

This study showed that, compared to a matched control group, females with bilateral PFPS have significant weakness of all 6 hip muscle groups. In contrast, those with unilateral PFPS had weakness of the hip extensors, lateral rotators, abductors, and flexors. ◉

KEY POINTS

FINDINGS: The sedentary females with unilateral PFPS in our study showed muscle weakness of the hip extensors, lateral rotators, abductors, and flexors, when compared to the control group. Those with bilateral PFPS had weakness of all 6 hip muscle groups.

IMPLICATION: These results suggest that hip strength, possibly of all muscle groups, may need to be addressed to improve pain and function in this population.

CAUTION: The retrospective nature of the study precludes cause-and-effect relationship to be established. Studies are needed to determine if addressing the hip strength deficits would lead to decreased pain and improved function.

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