Isometric Strength Ratios of the Hip Musculature in Females With Patellofemoral Pain: A Comparison to Pain-Free Controls

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The purpose of the study was to compare hip agonist-antagonist isometric strength ratios between females with patellofemoral pain (PFP) syndrome and pain-free control group. One hundred and twenty females between 15 and 40 years of age (control group: n = 60; PFP group: n = 60) participated in the study. Hip adductor, abductor, medial rotator, lateral rotator, flexor, and extensor isometric strength were measured using a hand-held dynamometer. Comparisons in the hip adductor/abductor and medial/lateral rotator and flexor/extensor strength ratios were made between groups using independent t-tests. Group comparisons also were made between the anteromedial hip complex (adductor, medial rotator, and flexor musculature) and posterolateral hip complex (abductor, lateral rotator, and extensor musculature). On average, the hip adductor/abductor isometric strength ratio in the PFP group was 23% higher when compared with the control group (p = 0.01). The anteromedial/posterolateral complex ratio also was significantly higher in the PFP group (average 8%; p = 0.04). No significant group differences were found for the medial/lateral rotator ratio and flexor/extensor strength ratios. The results of this study demonstrate that females with PFP have altered hip strength ratios when compared with asymptomatic controls. These strength imbalances may explain the tendency of females with PFP to demonstrate kinematic tendencies that increase loading on the patellofemoral joint (i.e., dynamic knee valgus).

Key Words: knee, chondromalacia, patella, patellofemoral pain syndrome

Introduction

Recent literature suggests that impaired hip strength may contribute to altered lower limb mechanics and the development of patellofemoral pain (PFP) (9,12,19,24,25). For example, Powers et al. (26) reported that internal rotation of the femur (as opposed to patella motion) was responsible for lateral patella displacement and tilt in females with PFP. It also has been suggested that dynamic valgus of the knee during weight-bearing tasks will increase the dynamic quadriceps angle and the lateral forces acting on the patella (25).

Impaired strength of the hip musculature is thought to underlie the kinematic tendencies that increase loading on the patellofemoral joint in females with PFP. Several authors have quantified hip strength in persons with PFP using a hand-held dynamometer and have reported decreased strength of the hip abductors, lateral rotators, and extensors (10,15,19). Studies also suggest that strength imbalances between the hip agonists and antagonists could be responsible for PFP (3) overuse injuries in general (2). For example, Baldon et al. (3) have reported that persons with PFP exhibit greater eccentric hip abduction strength relative to eccentric hip abductor strength. To date, no studies have investigated the hip strength ratios for the sagittal or transverse plane muscle groups.

Recent studies have demonstrated that focused hip muscle strengthening can result in improved clinical outcomes in females with PFP (13,21). As such, there is a need to better understand strength deficits in this population to better guide clinical decision making. Importantly, a more comprehensive assessment of hip agonist-antagonist strength ratios needs to be undertaken. The purpose of the current study was to compare...
hip strength ratios between females with PFP and pain-free controls. Based on the previous literature in this area, we hypothesized that when compared with pain-free control group, females with PFP would exhibit strength ratios that favor the hip flexors, adductors and medial rotators over the hip extensors, abductors, and lateral rotators, respectively.

METHODS

Experimental Approach to the Problem

We used a cross-sectional design to examine whether females with anterior knee pain presented hip strength imbalances when compared to asymptomatic population. All subjects performed a maximal isometric contraction of all hip muscle groups and the strength values were obtained using a handheld dynamometer, according to previous studies. (19,23) Between-group comparison was analyzed in relation to hip agonist-antagonist strength ratios.

Subjects

Sixty females aged between 15 and 40 years (mean ± SD, age, 25.0 ± 7.0 years) were recruited. A total of 60 subjects were divided into two groups: the control group (n = 60, pain-free) and the PFPS group (n = 60, PFP). The inclusion criteria for the PFPS group were as follows: lower extremity pain present for at least 4 weeks, pain intensity of at least 3 on a 10-cm Visual Analog Scale (VAS), and the absence of contraindications for participation in the study.

TABLE 1. Baseline characteristics (mean ± SD) and data normalized to body weight [mean ± SD (95% confidence interval)] of the female subjects in each group for the isometric hip adductor/abductor, medial/lateral rotator, and flexor/extensor strength ratios.*

<table>
<thead>
<tr>
<th>Demographics/Measures</th>
<th>Control (n = 60)</th>
<th>PFPS (n = 60)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>25.0 ± 7.0</td>
<td>24.0 ± 6.0</td>
<td>0.84</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.3 ± 11.5</td>
<td>58.5 ± 11.0</td>
<td>0.78</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.8 ± 7.1</td>
<td>161.0 ± 6.5</td>
<td>0.86</td>
</tr>
<tr>
<td>Duration of symptoms (mo)†</td>
<td>0</td>
<td>43.0 ± 42.0</td>
<td>0.0001</td>
</tr>
<tr>
<td>VAS (0–10)†</td>
<td>5.8 ± 1.7</td>
<td>0</td>
<td>0.0001</td>
</tr>
<tr>
<td>ADLS (0–100)†</td>
<td>99.8 ± 0.8</td>
<td>73.2 ± 17.1</td>
<td>0.0001</td>
</tr>
<tr>
<td>Ratio‡ Adductor/abductor</td>
<td>1.03 ± 0.18</td>
<td>1.33 ± 0.66</td>
<td>0.01</td>
</tr>
<tr>
<td>Medial/lateral rotator</td>
<td>0.97 ± 0.25</td>
<td>1.11 ± 0.41</td>
<td>0.07</td>
</tr>
<tr>
<td>Flexor/extensor</td>
<td>1.00 ± 0.27</td>
<td>1.00 ± 0.34</td>
<td>0.81</td>
</tr>
</tbody>
</table>

*PFPS = patellofemoral pain syndrome; VAS = Visual Analog Scale; ADLS = Activity of Daily Living Scale.
†Statistically significant difference (p < 0.05).
‡Mean ± SD (95% confidence interval).
Twenty-six of these subjects had unilateral pain and 34 had bilateral symptoms. Sixty pain-free subjects of similar physical characteristics (24.0 ± 6.0 years; height, 161.2 ± 5.9 cm; body mass, 57.9 ± 8.3 kg) served as the control group.

The inclusion criteria for the PFP group were the same as described by Thomee et al. (29). To be admitted to the PFP group, subjects had to have an insidious onset of pain (non-traumatic) for at least 3 months during any of the following activities: squatting, climbing up or down stairs, kneeling, sitting for long periods, performing resisted isometric knee extension at 60 degrees of knee flexion, pain upon palpation of the medial or lateral aspects of the patella. A standard clinical examination was performed to rule out concomitant pathology of the lower extremity.

Hip strength of persons in the PFP group was obtained from the painful limb of subjects with unilateral PFP and the more symptomatic limb of subjects with bilateral PFP. The exclusion criteria for both groups were as follows: patellar instability, previous knee surgery, meniscal or ligament injuries, tendon or cartilage injury, neurological disease, hip or ankle injuries, muscle pain, lumbar or sacroiliac joint pain, rheumatoid arthritis, or pregnancy. All volunteers were informed about the procedures for the study and provide informed written consent in accordance with National Health Council Resolution CNS-196-96. This study was approved by the University Research Ethics Committee.

We used a clinically significant strength difference of 15% between groups and estimates of variability from the previous literature (15) to perform an a priori power analysis. This analysis suggested that 50 subjects would provide adequate protection from type I and II errors using an alpha level of 0.05 and a beta level of 0.20.

### Procedures

A calibrated Nicholas hand-held dynamometer (Lafayette Instrument Company, Lafayette, IN, USA) was used to measure hip strength (4–6). Furthermore, measurements with this instrument have been shown to have good to excellent interrater and intrarater reliability with respect to measuring hip strength in persons with PFP (1,23).

Hip abductor strength was evaluated with the subjects positioned in sidelying on their non-tested lower limb (19,27). To evaluate the hip rotators, the subject was positioned in a seated position on the examination table with the hips and knees flexed to 90 degrees. To evaluate the lateral rotators, the hip was
Strength Ratio of the Hip Musculature

![Figure 2. Comparison of the strength ratio of the anteromedial/posterolateral hip complex in the subjects of the control and PFP groups. PFP = patellofemoral pain.](image)

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 (11,19,27). The medial rotators were evaluated in neutral hip rotation with resistance to movement applied just above the lateral malleolus (Figure 1) (6,10,19).

The hip flexors were assessed with the subjects sitting on the table with the hips and knees flexed to 90 degrees. The examiner positioned the dynamometer 3 cm above the superior pole of the patella, on the anterior aspect of the thigh (10,19). Hip extensor strength was evaluated with the subjects positioned in the prone position, with the knee flexed to 90 degrees and hip in slight lateral rotation. Resistance was applied to the distal posterior thigh (Figure 1) (10,19).

Two submaximal trials were used to familiarize the subject with each test position. This was followed by 2 maximal isometric effort trials for each muscle group. The examiner applied just enough resistance to match the patient muscle force. Data from the 2 maximum effort trials were averaged and used for the statistical analyses. Each contraction was held for 5 seconds, and a 30-second rest period was given between trials. A 1-minute rest period was provided between the testing of each muscle group. The order of muscle testing was randomized. Strength values were measured in kilograms and were normalized by body mass using the following formula: (kg strength/kg body mass) × 100 (27).

Apart from quantifying agonist/antagonist hip strength ratios, we also evaluated the combined strength of the "hip anteromedial complex" that included the summed strength values of the adductors, medial rotators, and flexors. The combined strength of the "hip posterolateral complex" that included the summed strength of the abductors, lateral rotators, and extensors was also evaluated. Finally, the hip strength ratio taking into account the anteromedial/posterolateral complex musculature was assessed.

All data were collected by a single examiner who had 8 years of clinical experience. This person was not blinded to group assignment. To assess reliability, the strength of all 6 muscle groups was assessed in 15 subjects (7 with PFP and 8 without pain) on 2 separate occasions. Reliability was determined to be good to excellent for all measures (intraclass correlation coefficients ranging between 0.76 and 0.92) (19).

**Pain and Function Assessment**

All subjects completed the Knee Outcome Survey–Activity of Daily Living Scale (ADLS) to measure function. The ADLS contains 14 items, each 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 persons diagnosed for PFP (16,20). Patients rated their worst level of PFP during the last week using an 11-point Visual Analog Scale (VAS) where 0 corresponded to no pain and 10 corresponded to “worst imaginable pain” (23).

**Statistical Analyses**

Independent *t*-tests were used to compare subject characteristics, function, pain, and duration of symptoms between groups. Independent *t*-tests also were used to compare the hip adductor/abductor, medial/lateral rotator, and flexor/extensor isometric strength ratios between groups. Strength ratios were described using mean values, SDs, and 95% confidence interval. Graph Pad Instat was used for statistical analyses. The alpha level was set at 0.05.

**Results**

Subject characteristics are provided in Table 1. The PFP and control groups were similar in terms of age, weight, and height (*p* > 0.05). The duration of symptoms, VAS, and ADLS score were statistically different (*p* = 0.0001) between groups.

The hip adductor/abductor, medial/lateral rotator, and flexor/extensor strength ratios of both groups are presented in Table 1. The PFP group demonstrated a significantly greater hip adductor/abductor isometric strength ratio when compared with the control group (average difference 23%; *p* = 0.01). Within the PFP group, the hip adductors were 33% stronger than the abductors. No statistical differences were found between groups for the hip medial/lateral rotator isometric strength ratio (*p* = 0.07) and hip flexor/extensor strength ratio (*p* = 0.81). With respect to the anteromedial/posterolateral hip complex strength, the ratio was significantly
higher in the PFP group compared with the control group (average difference 8%; \( p = 0.04 \)).

**DISCUSSION**

The relationship between hip strength and PFP has been widely investigated in recent years (3,10,14,27). It has been hypothesized that weakness of the hip extensors, abductors, and lateral rotators (13,19), leads to abnormal hip mechanics and increased loading of the patellofemoral joint (13,21,24,27). However, altered hip kinematics also may be associated to the hip strength imbalances in the frontal, sagittal, and transverse planes (3,25,28). The current study partially supports this assumption in that the PFP group exhibited a higher hip adductor/abductor isometric strength ratio compared with the control group. However, no group differences were found between the hip medial/lateral rotator and flexors/extensor isometric strength ratios. Based on our findings, females with PFP seem to be more prone to hip muscle imbalance in the frontal plane.

Baldon et al. (3) first investigated the hip agonist/antagonist strength ratios in persons with PFP. Their study showed higher eccentric ratio of hip adductors to abductors in symptomatic subjects compared with control group. Our results collaborate these findings and other investigations that also have found differences in the hip adductor/abductor strength ratio in volunteers or healthy athletes (2,3,6,8,30) (Table 2).

Previous investigations have evaluated the relationship between hip abductor and lateral rotator isometric strength and abnormal hip kinematics during stair descent in females with PFP (7,32). The authors reported decreased hip lateral rotator and abductor strength in subjects with PFP but no differences between groups in the lower extremities kinematics in the transverse and frontal planes (7). In contrast, Wilson and Davis (32) evaluated the lower extremity during weight-bearing activities and found changes in the frontal and transversal planes in symptomatic subjects (32).

To date, no study has investigated sagittal plane hip strength ratios in persons with PFP. According to Powers (25), weakness of the posterior rotators of the pelvis, such as the gluteus maximus, could result in excessive anterior tilting of the pelvis leading in compensatory lumbar lordosis. Although an imbalance between hip flexor and extensor could potentially cause anterior pelvic tilting, a difference between the PFP and control group in sagittal plane was not identified in this study.

Recent literature has consistently demonstrated decreased hip strength of specific muscles in females with PFP. Many studies reported decreased hip lateral rotators strength in subjects with PFP (18,19,27). This specific weakness could not be enough to cause a hip strength imbalance and consequently an altered kinematics of the lower extremities in the frontal and transverse planes. Abnormal hip mechanics during functional activities may be the result of hip agonist/antagonist strength imbalances and not only a specific hip muscle group weakness. Our clinical hypothesis is supported by kinematic studies, which questioned a direct relationship between specific weakness in isolated hip muscles and abnormal lower extremities kinematics (7,32). The results of the present study demonstrate that adductors are 33% stronger than abductors in the PFP group. This is consistent with the study by Thorborg et al. (30).

According to Crossley et al. (11), an ADLS score of 70 and a VAS of 6 are indicative of moderate pain and functional disability. Females of the PFP group in the present study showed a mild level of pain and disability, which may be one explanation for the lack of differences between groups for the hip muscle in sagittal and transversal plane. However, a recent clinical commentary conducted by Neuman (22) noted that most of the major muscular groups control movements in 2 or more planes. We agree with this statement because important proximal muscles, such as gluteus maximus and medius, for example, can be synergist for the hip abduction, extension, and lateral rotation. For this reason, we performed a comparison of the strength ratio between the anteromedial/posterolateral complex hip muscles (Figure 2). Taken together, the abductor, lateral rotator, and extensor musculature was weaker than the adductor, medial rotator, and flexor musculature in the PFP group. We believe that a strengthening protocol focusing all muscle groups of the posterolateral hip complex should be performed aiming a balance in relation to their antagonists in patients with PFP.

These data may influence treatment of lower limb injuries, helping the therapist not focus on absolute hip abductor strength but also normalizing the strength so that it is close to a 1:1 ratio with hip adductors. The same can be done between the muscles of the hip posterolateral complex in relation to the anteromedial complex. Clinically, we also believe that these correlations might be valuable in screening for injuries, including other disorders in the lower extremity (hip, knee, and ankle) as iliotibial band syndrome, adductor strains, knee ligament injuries, tendinopathies, plantar fasciitis, ankle sprains, and so on.

The current study has several limitations. The first is that the examiner was not blinded to subjects with PFP or control group. Lack of blinding may have produced unintentional bias during physical examination. To minimize this bias, a single examiner who was experienced with the procedures performed all testing (10,23). We used manual stabilization of the dynamometer during testing; whereas previous studies have shown that examiner resistance affects the measurements (7,31). We also did not control the gravity effect during tests. However, our own reliability data showed repeatability of the measurements, which is consistent with the data of previous studies (23,27). Also, we did not measure limb length, but this bias was minimized by using females of similar anthropometric values, including height.

The current study demonstrated that females with PFP have a significant imbalance between hip adductors and abductors muscle groups when compared with asymptomatic females. In contrast, there was no difference between hip lateral rotators and medial rotators and between flexors and extensors in both control and PFP groups, despite
a tendency of higher rotator medial/lateral strength ratio in the PFP group. Therefore, future studies are needed to better understand the relationship between hip muscles strength ratio and patellofemoral contact area and the possible influence of trunk muscles weakness on abnormal alignment of lower extremities during functional activities.

**Practical Applications**

Based on the results of this study, we believe that these correlations might be valuable in screening for injuries in lower limbs, because the normalized strength ratio between abductor and adductor muscle groups should be close to 1:1. We should not focus only in absolute or single muscular group strength because the imbalance could be caused by a “muscular complex,” such as the imbalance between anteromedial/posterolateral complex in PFP.

**References**