Academy of PHYSICAL MEDICINE

Research Paper Review

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Trunk, pelvis, hip and knee kinematics, hip strength and gluteal muscle activation during a single-leg squat in males and females with and without patellofemoral pain syndrome

Journal of Orthopaedic & Sports Physical Therapy 2012; 42(6): 491-501

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ABSTRACT

Study Design

Controlled laboratory study using a cross-sectional design.

Objectives

To determine whether there are any differences between the sexes in trunk, pelvis, hip, and knee kinematics, hip strength, and gluteal muscle activation during the performance of a single-leg squat in individuals with patellofemoral pain syndrome (PFPS) and control participants.

Background

Though there is a greater incidence of PFPS in females, PFPS is also quite common in males. Trunk kinematics may affect hip and knee function; however, there is a lack of studies of the influence of the trunk in individuals with PFPS.

Methods

Eighty subjects were distributed into 4 groups: females with PFPS, female controls, males with PFPS, and male controls. Trunk, pelvis, hip, and knee kinematics and gluteal muscle activation were evaluated during a single-leg squat. Hip abduction and external rotation eccentric strength was measured on an isokinetic dynamometer. Group differences were assessed using a 2-way multivariate analysis of variance (sex by PFPS status).

Results

Compared to controls, subjects with PFPS had greater ipsilateral trunk lean (mean ± SD, 9.3° ± 5.3° versus 6.7° ± 3.0°; P = .012), contralateral pelvic drop (10.3° ± 4.7° versus 7.4° ± 3.8°; P = .003), hip adduction (14.8° ± 7.8° versus 10.8° ± 5.6°; P<.0001), and knee abduction (9.2° ± 5.0° versus 5.8° ± 3.4°; P<.0001) when performing a single-leg squat. Subjects with PFPS also had 18% less hip abduction and 17% less hip external rotation strength. Compared to female controls, females with PFPS had more hip internal rotation

(P<.05) and less muscle activation of the gluteus medius (P = .017) during the single-leg squat.

Conclusion

Despite many similarities in findings for males and females with PFPS, there may be specific sex differences that warrant consideration in future studies and when clinically evaluating and treating females with PFPS.

ANALYSIS

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Background Information

Patellofemoral pain syndrome (PFPS) accounts for approximately 25% of all knee injuries treated in sports medicine clinics. Previous studies have shown that females and males have differences in kinematics, strength and neuromuscular activation during functional and sports activities. There is however, little information in the literature on the biomechanical differences between females and males who present with or without PFPS. These differences become clinically important during weight-bearing activities, because both excessive hip adduction (which increases knee valgus) and hip internal rotation have been shown to directly affect patellofemoral joint kine¬matics and kinetics.

The purpose of this study was to compare trunk, pelvis, hip and knee kinematics, as well as gluteal muscle activation, between males and females with and without PFPS, while performing a single-leg squat. The single-leg squat is a common rehabilitation exercise that has been demonstrated to be useful in evaluating lower extremity alignment of patients with PFPS in an outpatient clinical setting. Some clinicians also utilize this movement in their clinical assessments.

PERTINENT RESULTS

Kinematics

Ipsilateral Trunk Lean

Females with and without PFPS demonstrated significantly greater ipsilateral trunk lean than males (mean difference 2.9°; 95% confidence interval [CI]: 1.6-5.2; P = .009). Subjects with PFPS showed sig¬nificantly greater ipsilateral trunk lean than the controls (mean difference 2.6°; 95% CI: 1.1-4.2; P = .012).

Contralateral Pelvic Drop

Subjects with PFPS had significantly greater contralateral pelvic drop than the controls (mean difference 2.9°; 95% CI: 1.2-5.2; P = .003).

Hip Adduction

Females presented significantly greater hip adduction compared to males (mean difference 6.9°; 95%

CI: 4.3-9.3; P < .0001), and subjects with PFPS demonstrated significantly greater hip adduction than the controls (mean dif¬ference 4.0°; 95% CI: 2.8-7.8; P < .0001).

Hip Internal Rotation
Post hoc analysis revealed that females with PFPS had significantly greater hip internal rotation than males with PFPS (mean difference 5.8°; 95% CI: 1.5-10.9; P = .02), control females (mean difference 5.9°; 95% CI: 1.7-11.0; P = .02), and control males (mean differ¬ence 6.1°; 95% CI: 1.6-10.9; P = .03).

Knee Abduction
Females showed significantly greater knee abduction than males (mean difference 3.9°; 95% CI: 2.1-5.3; P < .0001). Subjects with PFPS demonstrated significantly greater knee abduction than the controls (mean difference 3.4°; 95% CI: 1.8-5.2; P < .0001).

Eccentric Torque
Males generated significantly higher peak eccentric hip abduction torque (0.17 Nm/kg•m; 95% CI: 0.10-0.25; P < .0001) and peak eccentric hip external rotation torque (0.17 Nm/kg•m; 95% CI: 0.13-0.21; P < .0001) when compared to females. Subjects with PFPS generated less peak eccentric hip abduction torque (–0.15 Nm/kg•m; 95% CI: –0.23 - –0.10; P < .001) and peak eccentric hip external rotation torque (–0.10 Nm/kg•m; 95% CI: –0.13 - –0.06; P < .0001) when com¬pared to control subjects.

Electromyography
The post hoc analysis revealed diminished activation of the gluteus medius in females with PFPS when compared to the females in the control group (5.7% MVIC; 95% CI: 1.2-11.7; P = .035). However, there was no difference between males with and without PFPS (P = .95). Both female groups had great¬er MVIC values than both male groups (P < .01 for all 4 comparisons)

Females (PFPS and controls) demonstrated significantly greater activation of the gluteus maximus when compared to the male groups (4.7% MVIC; 95% CI: 1.8-7.5; P = .002).

CLINICAL APPLICATION & CONCLUSIONS
The current study demonstrated that males and females with PFPS presented increased ipsilateral trunk lean, contralateral pelvic drop, hip adduction and knee abduction when compared to pain-free controls, while performing a single-leg squat. Individu¬als with PFPS also showed diminished hip abduction and hip external rota¬tion strength as measured eccentrically. Overall, the noted differences were more evident in females than in males. Interestingly, females with PFPS had greater hip internal rotation than males with PFPS and both control groups.

The present results revealed that males and females with PFPS presented very similar patterns of kinematic and strength alterations compared to their respective control groups; however, al-terations in hip internal rotation and gluteus medius activation were only found in females with PFPS.

The findings of a combination of hip abductor weakness and increased ipsilateral trunk lean are consistent with the concept that increased ipsilateral trunk lean may act as a compensatory mecha¬nism for hip abductor weakness.

It has been reported that increased ipsilateral trunk lean may increase the valgus moment of the knee joint. In the present study, the subjects with PFPS showed greater ipsilateral trunk lean, hip adduction, and knee abduction than the controls during the single-leg squat. The increased knee valgus presented by subjects with PFPS may have detrimental consequences, because it may increase the lateral forces acting on the patella. This may result in increased contact pressure between the lateral femoral condyle and the lateral facet of the patella, which may lead to PFPS. Therefore, although it has been proposed that increased ipsilateral trunk lean could compensate for hip abductor weakness, it has the potential to promote detrimental effects on the tibiofemoral and patello¬femoral joints.

CLINICAL APPLICATION

Compared to controls, males and females with PFPS showed increased ipsilateral trunk lean, contralateral pelvic drop, hip adduction, and knee abduction during a single-leg squat. These altered kinematics were ac¬companied by decreased strength of the hip abductors and external rotators, as measured eccentrically on an isokinetic dynamometer. Additionally, in contrast to males, females with PFPS showed increased hip internal rotation and decreased gluteus medius activation during the single-leg squat. Therefore, despite many similarities in findings for males and females with PFPS, there are specific sex differences that may warrant consideration in future studies, and when evaluating and treating females with PFPS.

In addition to previously described pelvis, hip, and knee bio¬mechanical differences, altered trunk kinematics was found during the performance of a single-leg squat in males and females with PFPS compared to male and female control participants. Sex-specific hip kinematic and muscular activation differences exist and should be addressed when treating patients with PFPS.

STUDY METHODS

This cross-sectional study included 80 subjects divided into 4 groups, with 20 subjects per group: females with PFPS (female PFPS), age-matched pain-free females serving as a control group (female controls), males with PFPS (male PFPS), and age-matched pain-free males serving as a control group (male controls). Subjects were between 18 and 35 years of age.

Inclusion Criteria:

- Insidious onset of symptoms unrelated to a traumatic event
- Retropatellar or peripatellar knee pain with at least 2 of the following functional activities: stair ascent or descent, running, kneeling, squatting, prolonged sitting, jumping, isometric quadriceps contraction, and palpation of the medial and/or lateral facet of the patella
- Pain of more than 3 months in duration

Exclusion Criteria:

- Previous history of knee surgery
- History of back, hip, or ankle joint injury or pain
- Patellar instability
- Pain on palpation of the patellar tendon, iliotibial band, or pes anserinus tendons

- Signs or symptoms of meniscal or knee ligament involvement
- Any neurological involvement that would affect gait

The subjects reported to the Musculo-skeletal Laboratory for 2 testing sessions. The kinematic and EMG evaluations were performed during the first session, and the eccentric hip torque tests were evaluated during the second session on a separate day. There was a 1-week interval between the 2 sessions to prevent any possible influence of fatigue on the evaluations.

Three-dimensional trunk, pelvis, hip, and knee joint kinematics were measured using a Flock of Birds tracking device (miniBIRD; Ascension Technology Corporation, Burlington, VT) in conjunction with MotionMonitor software (Innova¬tive Sports Training, Inc, Chicago, IL).

The electromyographic (EMG) signals of the gluteus medius and gluteus maximus were recorded at 2000 Hz, using double-differential surface electrode DE- 3.1 sensors (Delsys Inc, Boston, MA), with three 1 × 10-mm bars, 99.9%-Ag conductors, and an interelectrode distance of 10 mm, amplified by a Bagnoli 8-channel system (Delsys Inc, Boston, MA). Maximum voluntary isometric contractions (MVIC) were recorded for the gluteus maximus and gluteus medius muscles. The subjects were given the opportunity to practice the single-leg squat. They were instructed to squat to an angle greater than 60° of knee flexion during a 2-second period, then to return to the initial single-leg-stance position over another 2-second period. Thus, it took 4 seconds, as monitored by a digital metronome, to perform a single-leg squat. A trial was considered valid if the subject had performed the single-leg squat to at least 60° of knee flexion, within a 4-second period, without losing his/her balance.

Statistics:
Results were compared between males and females with and without PFPS, using a 2-way multivariate analysis of variance (sex by PFPS status). If there were significant multivariate effects, univariate effects were examined. For all univariate F tests, significant main effects were reported if there were no significant interactions. Scheffé post hoc tests were used to determine significant pairwise differences when there was a significant interaction.

STUDY STRENGTHS / WEAKNESSES

The authors meticulously describe their testing methods, which were very thorough and specific. Cohort matching was performed satisfactorily and the statistical analysis was complete. Although the sample sizes were relatively small, the authors did justify their choice of sample size in the methods section. Overall, this study provides important clinical information regarding the treatment of PFPS, especially the differences between genders. The results should be taken into account when prescribing exercise for PFPS patients.