Kinematic and Kinetic Analysis of the Single-Leg Triple Hop Test in Women With and Without Patellofemoral Pain

Biomechanical abnormalities of the lower extremities have been associated with a number of ankle, knee, hip, and lumbar/pelvic injuries. Women with patellofemoral pain (PFP) commonly exhibit a medial collapse of the knee, also called dynamic valgus. This dynamic valgus is characterized by a combination of excessive hip adduction and internal rotation and knee valgus during weight-bearing activities, such as ascending and descending stairs, running, or jumping. Mechanically, this misalignment decreases patellofemoral joint contact area, leading to increased articular stress and potentially PFP. However, Powers theorized that hip abductor weakness can alternately cause a contralateral pelvic drop during single-leg activities, shifting the center of mass medially away from the stance limb and leading to a knee external varus moment.

A number of kinetic and kinematic studies have described poor hip alignment, often associated with excessive trunk lean in the frontal plane, as well as altered knee and hip internal moments during low-impact activities in women with PFP. But few data exist on high-impact activities, which may add important information, such as the timing and sequencing in which peak angles of movement occur. The single-leg triple hop test (SLTHT), which includes landing and propulsion phases, is widely used in clinical practice to assess the dynamic stability of the knee. A number of authors have suggested that the hop test may be an important tool in identifying individuals who are at risk for knee injuries and to quantify improvements during the rehabilitation of individuals with PFP and those recovering from anterior cruciate ligament reconstruction.

The aim of the present study was to compare selected kinematics and kinetics of the trunk and lower extremities of women with and without PFP during the transition period between the first and second hops of the SLTHT. We also aimed to describe the time to peak joint
angle in both groups during this task. We hypothesized that, compared to the control group, women with PFP would exhibit greater ipsilateral trunk lean, contralateral pelvic drop, and hip adduction and internal rotation, as well as different timing and sequencing of peak joint angles. We also hypothesized that those with PFP would have higher hip and knee abductor internal moments.

**METHODS**

**Participants**

This cross-sectional study included 20 women with PFP (PFP group) and 20 age-matched pain-free women (control group). All volunteers were informed about the study procedures and signed informal consent in accordance with the Brazilian National Health Council Resolution Number 196/96. The protocol for this study was approved by the Universidade Nove de Julho Human Research Ethics Committee.

The sample size was calculated a priori, based on peak knee flexion angle reported in a previous study, which showed that maximal amplitudes of movement in the sagittal plane were related to changes in knee valgus kinetic and kinematic values. Calculations were performed using $\alpha = .05, \beta = .10$ (90% power), and a mean between-group difference of 11° for knee flexion, assuming a standard deviation of 10°. Based on these parameters, 17 participants per group were required to adequately power the study for this variable of interest.

All women in the study were between 18 and 35 years of age (Table 1), the age range within which women commonly have PFP. Women with PFP were included if they had anterior knee pain for at least 3 months and reported increased pain for 2 or more activities that commonly provoke PFP, as outlined by Thomeé et al. These activities included ascending and descending stairs, squatting, kneeling, jumping, long periods of sitting, resisted isometric knee extension at 60° of knee flexion, and pain on palpation of the medial and/or lateral facet of the patella.

The women in the PFP group were recruited from an outpatient rehabilitation program by a physical therapist with more than 10 years of clinical experience in knee rehabilitation. Women of similar demographic characteristics, who came to the clinic for treatment of upper extremity tendinopathies and did not have lower extremity involvement, were recruited from the same clinic at the time of discharge to serve as the control group. All participants were considered to be physically active, based on their weekly engagement in physical activity.

Potential participants were excluded if they exhibited any of the following: neurological disorder; injury to the hip, ankle, or lumbosacral region; rheumatoid arthritis; heart condition; previous surgery involving the lower extremities; or pregnancy. Women who had other knee pathologies, such as patellar instability, patellofemoral dysplasia, meniscal or ligament tears, osteoarthritis, or tendinopathies, were also excluded, as were those who exhibited a leg-length difference greater than 1 cm, when measured in supine, from the anterior superior iliac spine to the medial malleolus.

**Procedures**

Individuals who met the inclusion and exclusion criteria and were willing to participate were scheduled for testing in the movement-analysis laboratory. Women who were symptomatic were first asked about the length of time they had experienced symptoms and the intensity of their pain, using a visual analog scale. Anthropometric assessment was subsequently performed and included measurements of body mass, height, distance between anterior superior iliac spines, leg length, knee and ankle width, and tibial torsion.

The volunteers walked on a treadmill for 10 minutes at a speed of 2 m/s. After this warm-up, they familiarized themselves with the SLTHT until they felt comfortable with the activity. During these practice hops, the distance reached with the first hop was measured, and this distance was used to determine the starting location of the participants so that they would land in the center of the force platform when performing the subsequent SLTHT.

Consistent with the conventional gait model, which has been used to assess hop tasks in the literature, reflective spherical markers were placed on the participants in the following locations: on the 2 anterior and posterior superior iliac spines, over the center of the patella, on the lateral femoral epicondyles, over the lower one third of the surface of the shanks, on the lateral malleoli, on the second metatarsals, on the calcanei, on the acromioclavicular joints, on the spinous process of the seventh cervical vertebra, on the spinous process of the 10th thoracic vertebra, on the jugular

**TABLE 1**

<table>
<thead>
<tr>
<th>Demographic Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control (n = 20)</strong></td>
</tr>
<tr>
<td>Age, y</td>
</tr>
<tr>
<td>Body mass, kg</td>
</tr>
<tr>
<td>Height, m</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
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<tr>
<td>VAS (0-10)†</td>
</tr>
</tbody>
</table>

*Abbreviations: BMI, body mass index; PFP, patellofemoral pain; VAS, visual analog scale.
†Values are mean ± SD.
Zero is no pain and 10 is the worst imaginable pain. The score is for the average pain intensity experienced during the last 2 weeks.
notch where the clavicles meet the sternum, on the xiphoid process of the sternum, and one offset anywhere over the right scapula. For the conventional gait model, the same markers are required during static and dynamic trials.

After all markers were attached, 1 static standing reference trial and 3 SLTHT trials were performed with the symptomatic limb for those with PFP or with the dominant limb for those in the control group. Two minutes of rest was provided between each trial. As it was not possible to standardize footwear, participants were barefoot during testing. In addition, to standardize the position of the participants and to avoid compensatory movements of the upper limbs, the participants were asked to cross their arms in front of the thorax while performing the task.

Instrumentation
An 8-camera BTS SMART-D (BTS SpA, Milan, Italy) system was used to capture the 3-D marker trajectories. The cameras were interfaced to a microcomputer and placed around a force plate embedded in the floor (model 9286; Kistler Holding AG, Winterthur, Switzerland). The force plate was interfaced to the same microcomputer that was used for kinematic data collection via an analog-to-digital converter, enabling the synchronization of kinematic and kinetic data.

Based on the results of the pilot study, sampling frequencies of 100 Hz (kinematic) and 400 Hz (kinetic) were used. These sampling rates have previously been used in a number of studies to assess the kinematics and kinetics of jump tasks.

Data Analysis
Kinematic data were converted to the C3D format using MATLAB software (The MathWorks, Inc, Natick, MA), applying the BTK 0.1.10 code (Biomechanical ToolKit), then labeled and processed in Vicon Nexus software (Oxford, UK) using the Plug in Gait model. As in previous studies assessing dynamic tasks, the kinematic data were filtered using a fourth-order, zero-lag, Butterworth, 12-Hz low-pass filter.

### TABLE 2

<table>
<thead>
<tr>
<th>Joint</th>
<th>Control (n = 20)*</th>
<th>PFP (n = 20)*</th>
<th>Between-Group Differences</th>
<th>Effect Size</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior trunk lean</td>
<td>31.2 ± 6.0</td>
<td>35.9 ± 5.1</td>
<td>4.7 (11.8, 3.3)</td>
<td>0.8</td>
<td>0.038</td>
</tr>
<tr>
<td>Ipsilateral trunk lean</td>
<td>3.5 ± 2.4</td>
<td>9.2 ± 2.4</td>
<td>5.7 (4.2, 7.2)</td>
<td>2.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Ipsilateral trunk rotation</td>
<td>17.1 ± 5.3</td>
<td>11.5 ± 3.2</td>
<td>-5.6 (-8.4, -2.8)</td>
<td>1.2</td>
<td>0.003</td>
</tr>
<tr>
<td>Anterior pelvic tilt</td>
<td>35.0 ± 5.1</td>
<td>33.2 ± 3.3</td>
<td>-1.8 (-4.8, 1.2)</td>
<td>0.4</td>
<td>0.299</td>
</tr>
<tr>
<td>Contralateral pelvic drop</td>
<td>4.1 ± 1.6</td>
<td>7.3 ± 2.0</td>
<td>3.2 (2.0, 4.4)</td>
<td>1.7</td>
<td>0.001</td>
</tr>
<tr>
<td>Ipsilateral pelvic rotation</td>
<td>14.0 ± 3.0</td>
<td>10.9 ± 1.6</td>
<td>-3.1 (-4.6, -1.6)</td>
<td>1.2</td>
<td>0.001</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>58.6 ± 3.7</td>
<td>54.4 ± 5.4</td>
<td>-4.2 (-2.2, -1.2)</td>
<td>0.9</td>
<td>0.029</td>
</tr>
<tr>
<td>Hip adduction</td>
<td>6.9 ± 0.6</td>
<td>10.3 ± 0.6</td>
<td>3.4 (3.0, 3.8)</td>
<td>0.9</td>
<td>0.002</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>8.9 ± 0.9</td>
<td>12.5 ± 3.3</td>
<td>3.6 (21.5)</td>
<td>1.4</td>
<td>0.002</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>56.7 ± 4.9</td>
<td>47.8 ± 2.8</td>
<td>-8.9 (-11.5, -6.4)</td>
<td>1.4</td>
<td>0.001</td>
</tr>
<tr>
<td>Knee adduction</td>
<td>78 ± 3.0</td>
<td>84.2 ± 2.2</td>
<td>6.0 (-1.1, 2.3)</td>
<td>0.2</td>
<td>0.014</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td>32.5 ± 1.5</td>
<td>26.7 ± 0.8</td>
<td>-5.8 (-6.6, -5.0)</td>
<td>4.8</td>
<td>0.003</td>
</tr>
<tr>
<td>Ankle eversion</td>
<td>6.7 ± 2.2</td>
<td>10.6 ± 4.3</td>
<td>3.9 (12.6)</td>
<td>0.9</td>
<td>0.019</td>
</tr>
</tbody>
</table>

Abbreviation: PFP, patellofemoral pain.
*Values are mean ± SD degrees.
†Values in parentheses are 95% confidence interval.
‡Determined using Cohen d (0.0-0.2, trivial; 0.3-0.5, small; 0.6-0.8, medium; and 0.9 or higher, large).
Joint kinematics were calculated using a joint coordinate system approach and were reported relative to a static standing trial, to quantify the movement of one segment in relation to another or of one segment relative to the laboratory. Kinematics, ground reaction forces, and anthropometric data were used to calculate articular internal moments and power (scalar product of moment and angular velocity) of the hip, knee, and ankle, using inverse dynamic equations in Vicon Nexus software. Kinetic data were normalized to body mass.

Kinematic and kinetic data were obtained for the weight-bearing period between the first and second hops of the SLTHT. Therefore, the period of interest was from initial foot contact with the force plate (0%) to toe-off (100%) (FIGURE 1). Internal joint moment for the lower extremity was recorded at peak knee flexion angle and represented the end of the landing phase. The average power recorded during the landing phase was used to compare groups.

The peak joint angles, time to peak joint angles, and internal peak moments and power of each joint studied were imported into Excel (Microsoft Corporation, Redmond, WA) for statistical analysis.

The time-to-peak-joint-angle analysis was performed to understand the timing and sequencing with which the maximum amplitude of each joint was achieved during the transition period between the first and second hops of the SLTHT.

**Statistical Analysis**
The Kolmogorov-Smirnov test (with the Lilliefors correction factor) was used to test the normality of the kinematic and kinetic data. Descriptive statistics, means, and standard deviations were calculated for all variables. The average of 3 trials was used for all statistical analyses of the kinematic and kinetic data. The kinematic and kinetic variables were compared between groups using 2 separate multivariate analyses of variance (ANOVAs). If there were significant multivariate effects, univariate effects were tested for all relevant variables. The significance level was set at $P < .05$. Cohen's $d$ effect sizes were calculated and defined as trivial if the value was between 0.0 and 0.2, small if between 0.3 and 0.5, medium if between 0.6 and 0.8, and large if 0.9 or higher. All statistical comparisons were performed with SPSS Version 15.0 (SPSS Inc, Chicago, IL).

**RESULTS**

The multivariate ANOVAs indicated significant differences for kinematic variables ($P < .001$), joint internal moments ($P < .001$), and joint powers ($P < .001$).

**Performance**
The mean ± SD distance for the first jump of the SLTHT for the women in the control group was 1.05 ± 0.17 m, compared to 0.96 ± 0.11 m for the women in the PFP group ($P = .091$).

**Kinematics**

**TABLE 2** provides the descriptive peak joint angle data, as well as the results of statistical analysis for between-group comparisons.

**Trunk** When compared to the control group, the women in the PFP group exhibited greater anterior ($P = .038$) and ipsilateral ($P = .001$) trunk lean, but less ipsilateral trunk rotation ($P = .003$).

**Pelvis** When compared to the control group, the women in the PFP group exhibited greater contralateral pelvic drop ($P = .001$) and less ipsilateral rotation ($P = .001$). There was no significant difference between groups for anterior pelvic tilt ($P = .299$).
Hip  Women in the PFP group exhibited greater hip adduction ($P = .002$) and internal rotation ($P = .002$). However, they exhibited less hip flexion ($P = .029$).

Knee  When compared to the control group, the women in the PFP group exhibited less knee flexion ($P = .001$). No significant difference was found for knee adduction ($P = .614$).

Ankle  Women with PFP exhibited greater ankle eversion ($P = .019$) and less dorsiflexion ($P = .003$) than those in the control group.

Time to Peak  Data on the time to peak joint angle as a percentage of contact time are provided in Figure 2 and Table 3. The women in the PFP group exhibited a significantly ($P < .05$) faster time to peak joint angle for the following variables: ipsilateral trunk rotation, hip internal rotation, knee flexion, knee adduction, ankle dorsiflexion, and ankle eversion. They conversely exhibited a significantly ($P < .05$) slower time to peak joint angle for the following variables: anterior trunk lean, ipsilateral trunk lean, contralateral pelvic drop, and hip adduction. There were no significant between-group differences ($P > .05$) for time to peak joint angle for hip flexion and anterior pelvic tilt.

**Kineti**cs  Table 4 provides the descriptive statistics for all kinetic variables as well as the results of the between-group comparisons.

**Hip**  Women with PFP exhibited a greater internal hip abductor moment than those in the control group ($P = .017$), but less hip power absorption in the frontal plane ($P = .006$). No statistically significant differences were found between groups for internal hip extensor moments ($P = .679$) and hip power absorption in the sagittal plane ($P = .931$).

**Knee**  Women with PFP exhibited a greater internal knee abductor moment than those in the control group ($P = .001$) and greater knee power absorption in the frontal plane ($P = .001$). Conversely, they exhibited a lower internal knee extensor moment ($P = .001$) and less knee power absorption in the sagittal plane ($P = .006$).

**Ankle**  Women with PFP exhibited a lower internal ankle plantar flexor moment than those in the control group ($P = .035$) and less ankle power absorption in the sagittal plane ($P = .018$). No significant differences were found between groups for the internal ankle invertor moment ($P = .051$) and ankle power absorption in the frontal plane ($P = .420$).

**DISCUSSION**

This study compared selected trunk and lower extremity kinematic and kinetic variables between women with and without PFP for the weight-bearing period between the first and second hops of the SLTHT. In comparison to women in the control group, those with anterior knee pain exhibited greater anterior and ipsilateral trunk lean, contralateral pelvic drop, hip adduction and internal rotation, and ankle eversion, but less ipsilateral trunk and pelvic rotation, hip and knee flexion, and ankle dorsiflexion. Furthermore, women with PFP exhibited greater hip and knee internal abductor moment, less hip power absorption and greater knee power absorption in the frontal plane, but less knee extensor and ankle plantar flexor internal moments with less knee and ankle power absorption in the sagittal plane.

Compared to the control group, time to peak joint angle for women with PFP occurred earlier for ipsilateral trunk and pelvic rotation, hip internal rotation, knee adduction, knee flexion, and ankle dorsiflexion and eversion, whereas it occurred later for anterior and ipsilateral trunk lean, contralateral pelvic drop, and hip adduction.

Some of these findings, especially the greater ipsilateral trunk lean,33 contralateral pelvic drop,33 hip adduction,15,31,33 and hip internal rotation,32,33 are consistent with what has previously been reported in the literature when comparing individuals with PFP to a control group free of pathology. The novel finding of this study is related to the knee frontal absorption in the sagittal plane (P = .018). No significant differences were found between groups for the internal ankle invertor moment (P = .051) and ankle power absorption in the frontal plane (P = .420).

**TABLE 3**

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 20)*</th>
<th>PFP (n = 20)*</th>
<th>Between-Group Differences†</th>
<th>Effect Size‡</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior trunk lean</td>
<td>61 ± 3</td>
<td>69 ± 3</td>
<td>8 (6, 10)</td>
<td>2.3</td>
<td>.001</td>
</tr>
<tr>
<td>Ipsilateral trunk lean</td>
<td>28 ± 2</td>
<td>38 ± 1</td>
<td>10 (9, 11)</td>
<td>5.9</td>
<td>.001</td>
</tr>
<tr>
<td>Ipsilateral trunk rotation</td>
<td>17 ± 5</td>
<td>12 ± 1</td>
<td>-5 (-8, -2)</td>
<td>1.2</td>
<td>.003</td>
</tr>
<tr>
<td>Anterior pelvic tilt</td>
<td>37 ± 2</td>
<td>38 ± 2</td>
<td>1 (0, 2)</td>
<td>0.5</td>
<td>.100</td>
</tr>
<tr>
<td>Contralateral pelvic drop</td>
<td>28 ± 1</td>
<td>38 ± 1</td>
<td>10 (9, 11)</td>
<td>7.3</td>
<td>.001</td>
</tr>
<tr>
<td>Ipsilateral pelvic rotation</td>
<td>24 ± 2</td>
<td>14 ± 1</td>
<td>-10 (-11, -9)</td>
<td>5.3</td>
<td>.001</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>35 ± 3</td>
<td>36 ± 3</td>
<td>1 (1, 3)</td>
<td>0.3</td>
<td>.540</td>
</tr>
<tr>
<td>Hip adduction</td>
<td>23 ± 3</td>
<td>33 ± 3</td>
<td>10 (8, 12)</td>
<td>3.3</td>
<td>.001</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>22 ± 1</td>
<td>12 ± 2</td>
<td>-10 (-11, -10)</td>
<td>7.4</td>
<td>.001</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>62 ± 3</td>
<td>60 ± 3</td>
<td>-2 (-4, 0)</td>
<td>0.6</td>
<td>.032</td>
</tr>
<tr>
<td>Knee adduction</td>
<td>15 ± 2</td>
<td>12 ± 3</td>
<td>-3 (-5, -1)</td>
<td>1.1</td>
<td>.003</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td>62 ± 4</td>
<td>58 ± 3</td>
<td>-4 (-6, -2)</td>
<td>1.1</td>
<td>.032</td>
</tr>
<tr>
<td>Ankle eversion</td>
<td>62 ± 4</td>
<td>58 ± 3</td>
<td>-4 (-6, -2)</td>
<td>1.1</td>
<td>.019</td>
</tr>
</tbody>
</table>

Abbreviation: PFP, patellofemoral pain.

*Values are mean ± SD percent.

†Values in parentheses are 95% confidence interval.

‡Determined using Cohen d (0.0-0.2, trivial; 0.3-0.5, small; 0.6-0.8, medium; and 0.9 or higher, large).
plane data, which, though not previously reported in the literature, have previously been described by Powers\(^9\) as an alternate model of frontal plane deviations.

These findings are consistent with the high demands placed on the hip abductors during the SLTHT, which leads to the contralateral pelvic drop and ipsilateral trunk lean, potentially reflecting hip abductor weakness.\(^7,9,33,41,45\) Specifically, the contralateral pelvic drop moves the center of mass of the body medially away from the knee joint, increasing knee internal valgus moment.\(^39\) Moreover, the contralateral pelvic drop explains the uncommon combination of hip adduction and knee adduction presented in our study. While both groups that participated in this study exhibited a similar movement pattern, the pattern was more pronounced in those with PFP.

In the transverse plane, women with anterior knee pain exhibited a greater amount of hip internal rotation and reached peak hip internal rotation earlier. Theoretically, this excessive and early internal rotation could be attributed to weakness or a deficit of activation of the hip external rotators.\(^22,31,33,43\)

In the frontal plane, women with PFP exhibited a greater amount of hip adduction, which was reached later during the movement. Furthermore, those with PFP exhibited greater ipsilateral trunk lean and contralateral pelvic drop, associated with greater hip internal abductor moment and less hip power absorption than individuals in the control group (FIGURE 3).

Similar to hip adduction, both contralateral pelvic drop and ipsilateral trunk lean occurred later in the PFP group than in the control group. Consistent with the findings of others, these findings may be explained by a deficit in torque produced by the hip abductor muscles.\(^33,46\) In our opinion, weak hip abductors may initially be able to control the pelvis, but they cannot sustain this position during the entire movement. Because contralateral pelvic drop occurs in association with an internal hip abductor moment and power absorption in the hip joint, ipsilateral trunk lean is expected as a compensatory adjustment to promote lateral displacement of the ground reaction forces.\(^37,40,49\)

In the sagittal plane, women from the symptomatic group exhibited less hip and knee flexion, less ankle dorsiflexion, less internal knee extensor and ankle plantar flexor moment, as well as less knee and ankle power absorption. A greater knee flexion angle and greater internal knee extensor moment and power absorption lead to increased compressive force on the patellofemoral joint.\(^16,17,32\) We believe that women in the PFP group limited their sagittal plane movement during the SLTHT in an attempt to reduce the demand on the quadriceps and, consequently, to decrease patellofemoral joint stress. The symptomatic women also exhibited exaggerated movements in terms of anterior trunk lean, which peaked later than it did in the control group. This may have occurred as a compensatory mechanism of the trunk, moving the center of mass of the trunk more directly above the knee joint, to reduce load-absorption demands on the lower extremity.\(^47\)

A number of studies have assessed the biomechanical behavior of patients with PFP while performing less demanding tasks.\(^7,8,25,31,43\) The present study used 3-D analysis of proximal (trunk, pelvis, and hip), local (knee), and distal joints (ankle) to study a more challenging task (SLTHT), requiring greater neuromuscular control. We believe that this knowledge can play an important role in clinical decision making aimed at interventions to prevent abnormal movements in lower limbs during functional activities.

The present study has a number of potential limitations. First, the study only assessed the transition between the first and second jumps, based on data from a pilot study that showed greater kinetic and kinematic peak values oc-
CONCLUSION

Compared to the control group, women with PFP exhibited altered kinematics and kinetics of the trunk, hip, knee, and ankle in all 3 planes of motion during the weight-bearing transition period between the first and second hops of the SLTHT.

KEY POINTS

FINDINGS: Compared to the control group, women with PFP exhibited altered kinematics and kinetics of the trunk, hip, knee, and ankle in all 3 planes of motion during the weight-bearing transition period between the first and second hops of the SLTHT.

IMPLICATIONS: These biomechanical alterations are different from those identified during other weight-bearing functional movements in this population. Therefore, incorporating higher-demand tasks in the clinical evaluation may provide additional information useful for intervention.

CAUTION: These data are limited to young women during a specific high-impact activity (SLTHT) and do not establish cause and effect.

The primary clinical implication of these findings is that it may be beneficial to consider highly challenging activities when assessing patients with PFP. Future studies should consider incorporating electromyographic assessment of the trunk, hip, and knee musculature.

REFERENCES

5. Bizzini M, Childs JD, Piva SR, Delitto A. System-


