Comparison of Lunge and Bulgarian Split Squat Kinematics and Kinetics between a Subject with Patellofemoral Pain Syndrome and a Non-pathological Control

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Introduction

- **Prevalence:**
  - PFPS prevalence ranges from 3-85%
  - Most commonly in the literature reported as 25%
    - 1.5-7.3% of all patients seeking medical care

- **Demographic information:**
  - Occurs across the lifetime, from young children to older sedentary adults
  - Depends on activity level and environmental context
    - High prevalence between 12 and 19 y/o or 50 and 59 y/o
  - 55% are women

- **Recurrence: 70-90%**
  - 50-56% of adolescents report persistent knee pain after 2 yrs
Purpose

- To investigate the **hip, knee and ankle kinematics and kinetics** of a patient with movement coordination impairment (MCI) patellofemoral pain syndrome (PFPS) when performing a **bulgarian split squat (BSS)** compared to a **lunge**.
Hypothesis

For patients with MCI PFPS, **lunge**s will have **less frontal plane movement and torque in the hip, knee, and ankle** than Bulgarian split squats.
Rationale

- In healthy populations, there is no significant difference in knee-valgus angle across exercises\(^3\), but in patients with MCI PFPS, there is **dynamic knee valgus** throughout all squatting exercises\(^4\)
Rationale

- Patients with MCI PFPS in comparison to controls without PFPS
  - ↑’ed medial knee displacement AND ↑ed hip adduction and knee external rotation during single-leg squats\(^5\)
  - ↑’ed frontal plane projection angle AND muscle weakness in hip abductors, extensors and external rotators during step-down\(^1\)
- Given the above exercise’s similarity to a single-loaded leg during BSS, medial displacement and the resulting valgus forces will most likely be similar in BSS\(^1,\,^5\)

1. Almeida 2016
5. Willson 2008
Rationale

For PSFS patients:

**Forward Lunge**

More stable on the front-loaded leg (both legs on the ground and less of an anterior weight shift)

**Bulgarian Split Squat**

*Need to stabilize more* on the front-loading leg since the majority of weight is shifted over that leg*

=> Greater external varus/valgus forces requiring greater internal stabilization forces at knee, increasing potential for dynamic valgus collapse

Loading progression for knee conditions²:
lunge to single-legged squat due to ↑ed BOS during lunges and greater knee joint moments

2. Comfort 2015
Methods: Participant Characteristics

- Participant characteristics of both subjects:
  - Healthy participants (no pathology or pain)
  - 23 year olds
  - Caucasian

<table>
<thead>
<tr>
<th>Participant characteristics</th>
<th>1 subject performing typical squat mechanics (control)</th>
<th>1 subject imitating squat with dynamic knee valgus (experimental)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Height: 5’3” Weight: 125 lbs BMI: 22</td>
<td>Male Height: 5’10” Weight: 160 lbs BMI: 23</td>
</tr>
</tbody>
</table>
Methods: Motion Capture

- 3D motion capture reflective markers were attached at points on the hip, knee and ankle for data collection in the frontal and sagittal planes.
- The motion capturing system is not able to directly measure rotation angles.
- Joint angles and moments around the hip, knee, and ankle were automatically calculated.

*This is an example of the marker locations used, but is not an actual image of markers used in this study.*
Methods

- Independent variable: exercises (BSS and lunge), 2 subjects (imitating pathological and healthy control)
- Dependent variables: frontal and sagittal angles and torque at hip, knee and ankle
- 3 repetitions of BSS (over 17” chair) and lunges with the left leg forward
- Data averaged over 3 trials and 2 individuals
  - Recorded angles and torques at hip, knee and ankle in frontal and sagittal planes
Lunge: Frontal
Bulgarian Split Squat: Frontal
+: flexion
-: extension
+: flexion
-: extension
+: adduction
-: abduction
+: adduction
-: abduction
Results

- Greater hip and knee adduction angles in the PFPS lunge and BSS.

- Greater hip and knee adduction torques in the PFPS conditions
  - Peak adduction torque at hip and knee: greater with bulgarian split squats than lunges across conditions

- Greater extension moments were seen in the PFPS subject in lunges and BSS
Discussion: Our results compared to the literature

- Women with PFPS in step-down exercise present with greater dynamic knee valgus (increased frontal projection angle) and decreased hip torque:
  - Our results: BSS similar to step-down, BSS showed increased knee valgus (agreed) but not decreased hip muscle torque (possibly due to using a healthy participant who is able to compensate with increased strength at the hip)

<table>
<thead>
<tr>
<th>FPPA, hip and trunk strength in the patellofemoral pain (PPG) and control groups (CG)</th>
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<tbody>
<tr>
<td><strong>PPG</strong></td>
</tr>
<tr>
<td>FPPA Initial (degrees)</td>
</tr>
<tr>
<td>FPPA Peak (degrees)</td>
</tr>
<tr>
<td>Abduction (N.m/kg)</td>
</tr>
<tr>
<td>Extension (N.m/kg)</td>
</tr>
<tr>
<td>External rotation (N.m/kg)</td>
</tr>
<tr>
<td>Posterolateral (N.m/kg)</td>
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<tr>
<td>Lateral core (N.m/kg)</td>
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</tbody>
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Abbreviations: FPPA, Frontal Plane Projection Angle.
Discussion: Our results compared to the literature

- When patients with PFPS perform single-leg squats, there is increased medial displacement of hip and FPPA compared to healthy control.
  - Consistent with our results: BSS similar to SLS, BSS had increased medial displacement of hip (agree)

![Graph showing hip adduction angle during squats](image1)

**FIGURE 8.** Frontal plane projection angles of the knee during single-leg stance and single-leg squats for females with patellofemoral pain syndrome (PFPS) and a healthy female control group. Error bars represent standard errors of the mean. *P<.05.
Limitations

- Experimental PFPS conditions were mimicked by a healthy subject
- Only 2 subjects were used
- Each type of lunge was only performed 3 times by each subject
- Recovery times were not specific
- Subjects did not fatigue during exercise and therefore, did not need significant recovery break
- Data Outliers (ankle data)
Take-Aways

- Greater stress is placed on the medial knee joint when performing squat-like exercises with similar mechanics to those seen in someone with MCI PFPS.
- Bulgarian split squats and lunges had larger hip and knee adduction torques in the PFPS condition.
- Bulgarian split squats had larger hip and knee adduction torques compared to lunges.
Clinical implications

- Lesser hip adduction torques in the PFPS conditions likely indicates a lack of hip abductor strength\(^1\)
  - Rehab for PFPS should focus on hip abductor strengthening
- Patients should be educated on proper technique for any squat variation
  - Often, knee valgus can be reduced to some degree by focusing on preventing it.
  - “Don’t let your knees cave in”
- Lunges may be better to use at first with PFPS patients
- Bulgarian split squats might be useful as a “pre-hab” exercise in healthy athletic populations
  - Help to simulate the forces at the knee present in cutting motions in sports.
  - Used to train for stability at the knee

\(^1\) Almeida 2016


