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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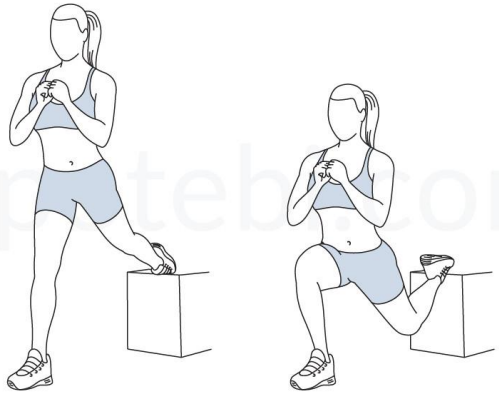
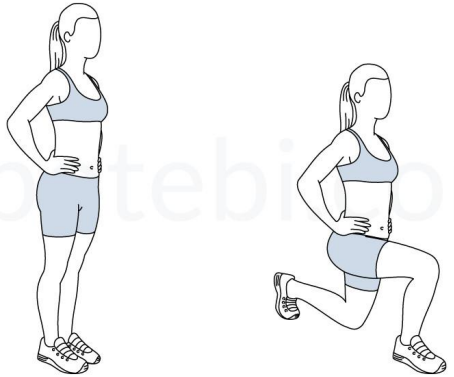
Introduction

- 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

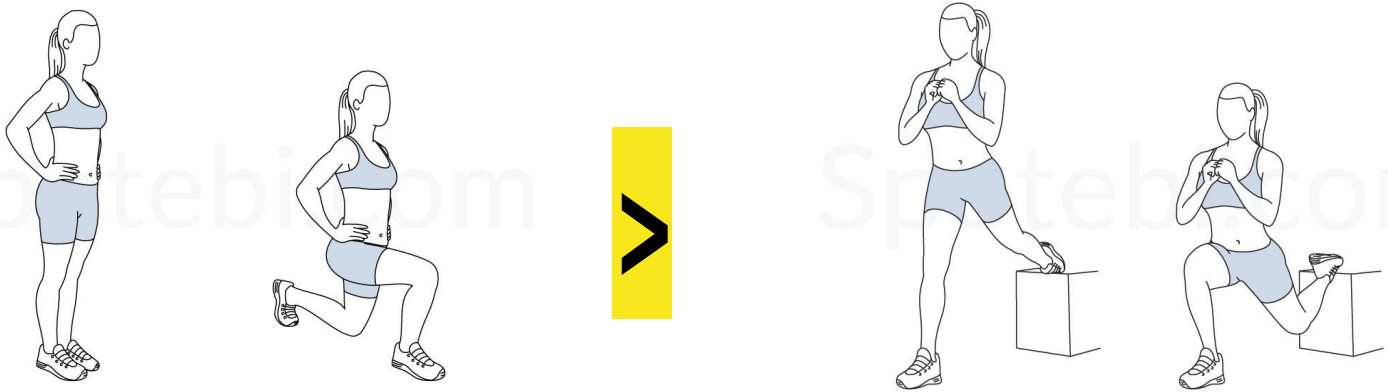
- To investigate the **hip, knee and ankle kinematics and kinetics** of a patient with movement coordination impairment (**MCI**) patellofemoral pain syndrome (**PFPS**) when performing a **bulgarian split squat** (BSS) compared to a **lunge**





Hypothesis

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



3. Nakagawa 2012
4. Willy 2019

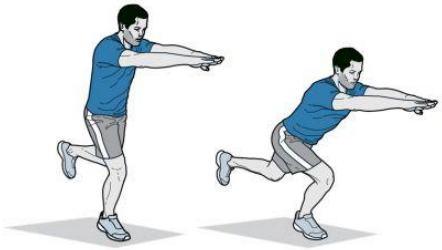
Rationale

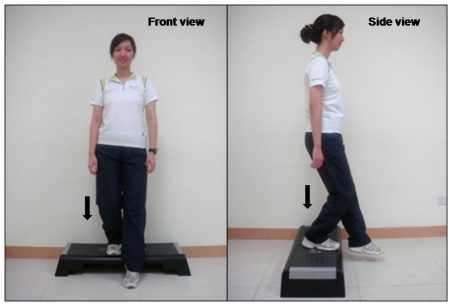
- In healthy populations, there is no significant difference in knee-valgus angle across exercises[3], but in patients with **MCI PFPS**, there is **dynamic knee valgus** throughout **all squatting** exercises[4]

1. Almeida 2016
5. Willson 2008

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]





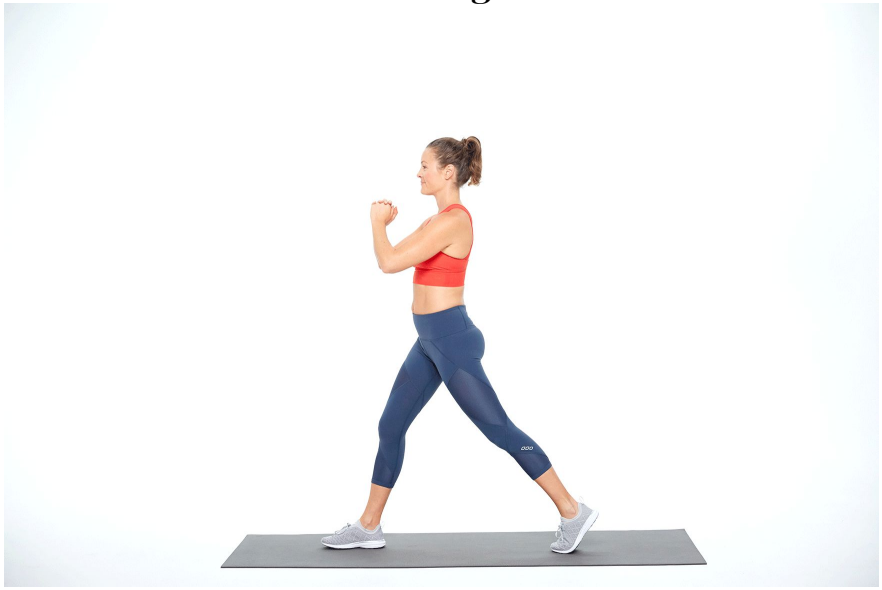
Loading progression for knee conditions[2] :
lunge to single-legged squat due to ↑ed BOS during lunges and greater knee joint moments

2. Comfort 2015

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**

Methods: Participant Characteristics

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

	1 subject performing typical squat mechanics (control)	**1 subject imitating squat with dynamic knee valgus (experimental)**
Participant characteristics	Female Height: 5’3” Weight: 125 lbs BMI: 22	Male Height: 5’10” Weight: 160 lbs BMI: 23

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.

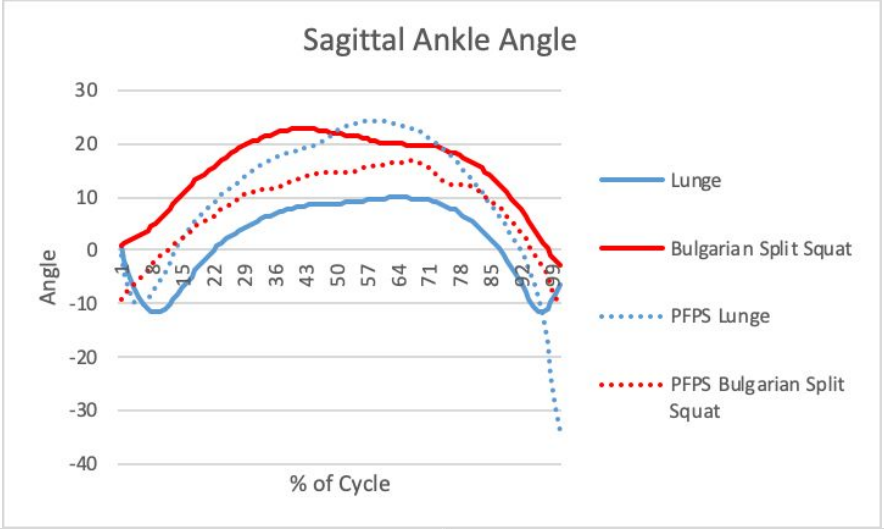
Methods

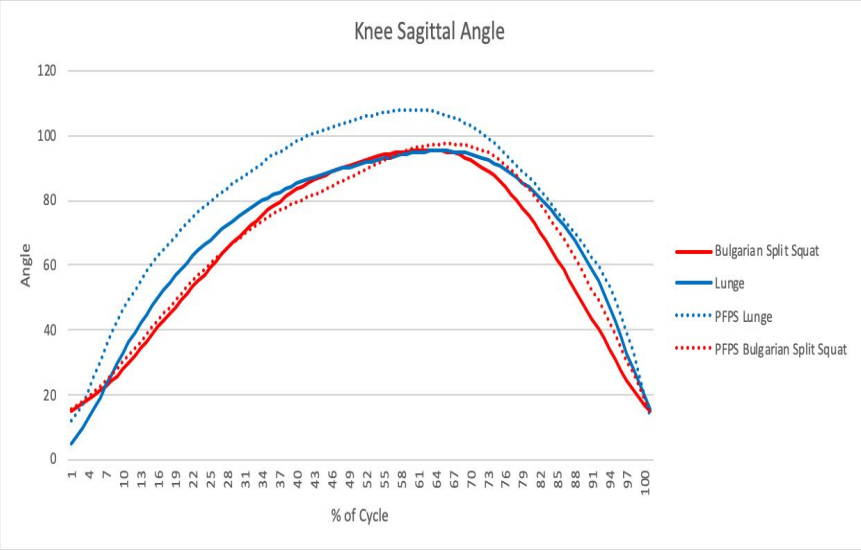
- Independent variable: exercises (BSS and lunge), 2 subjects (imitating pathological and healthy control)
- Dependent variables: frontal and sagittal angles and torque at hip, knee and ankle
- 3 repetitions of BSS (over 17” chair) and lunges with the left leg forward
- Data averaged over 3 trials and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

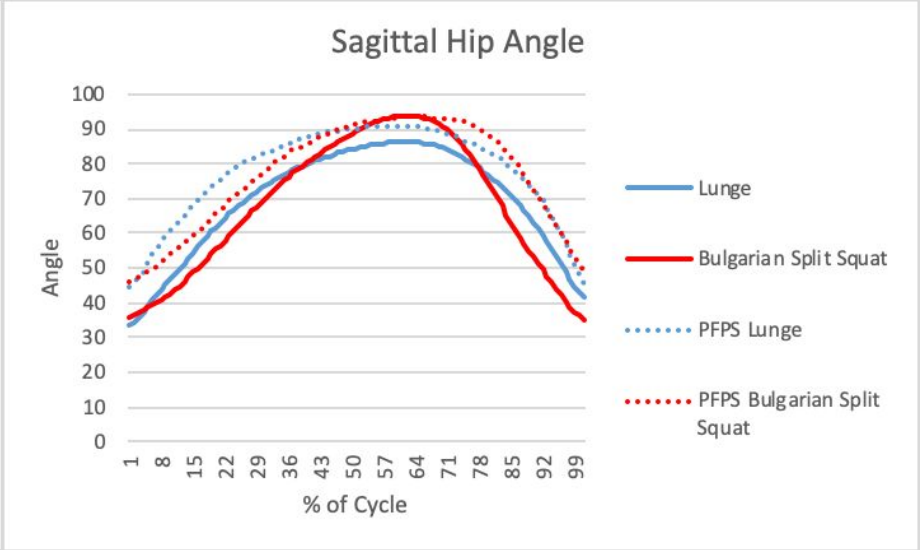
Lunge: Frontal

Bulgarian Split Squat: Frontal

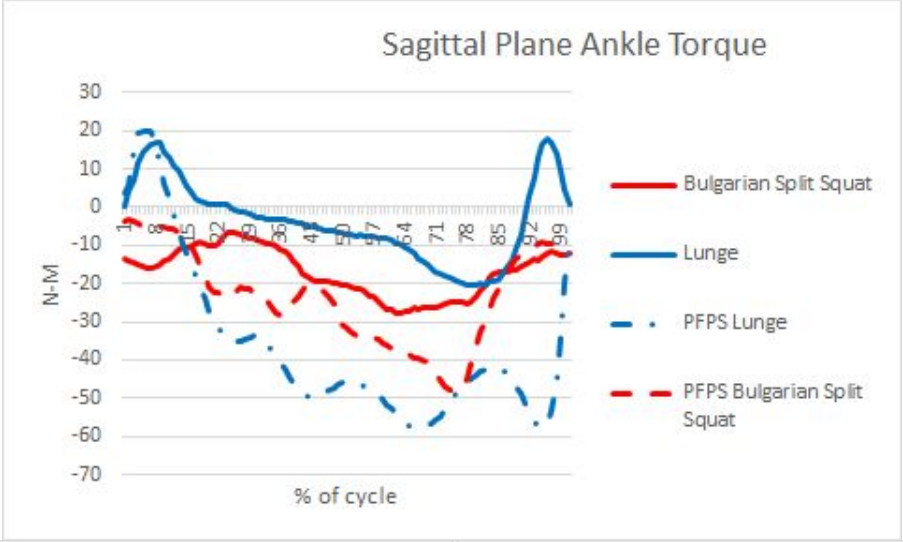
+: flexion
-: extension

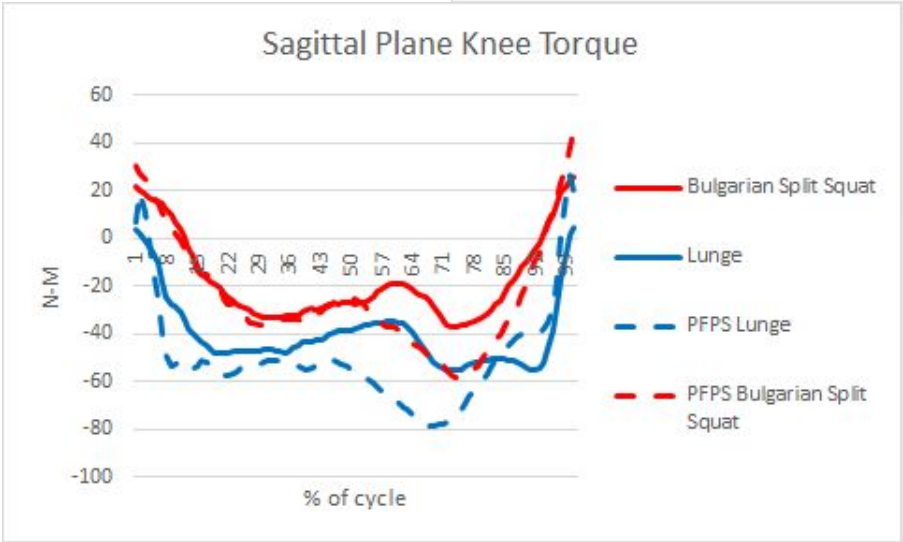


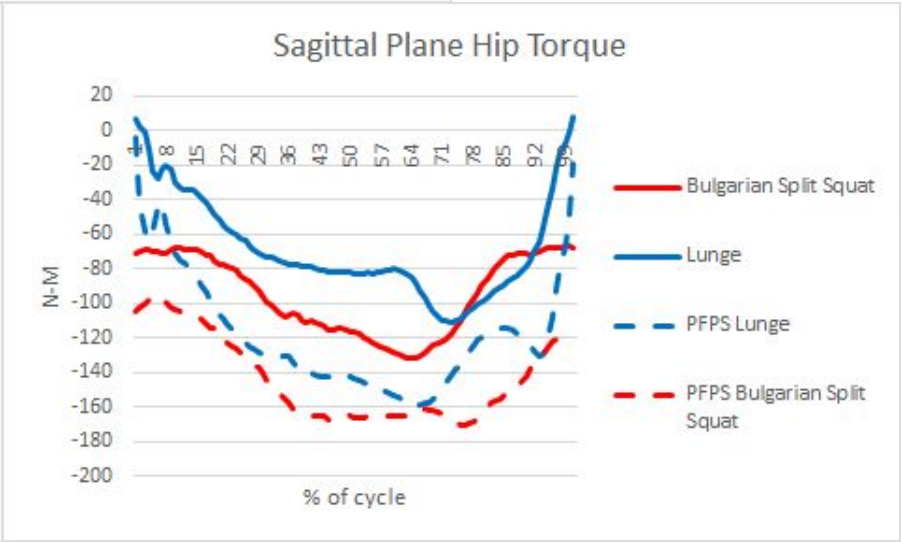




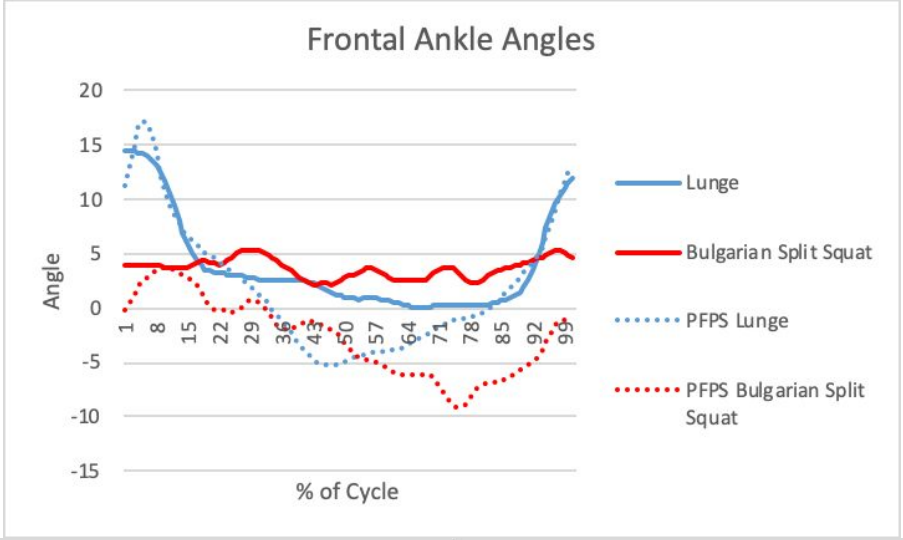
+: flexion
-: extension

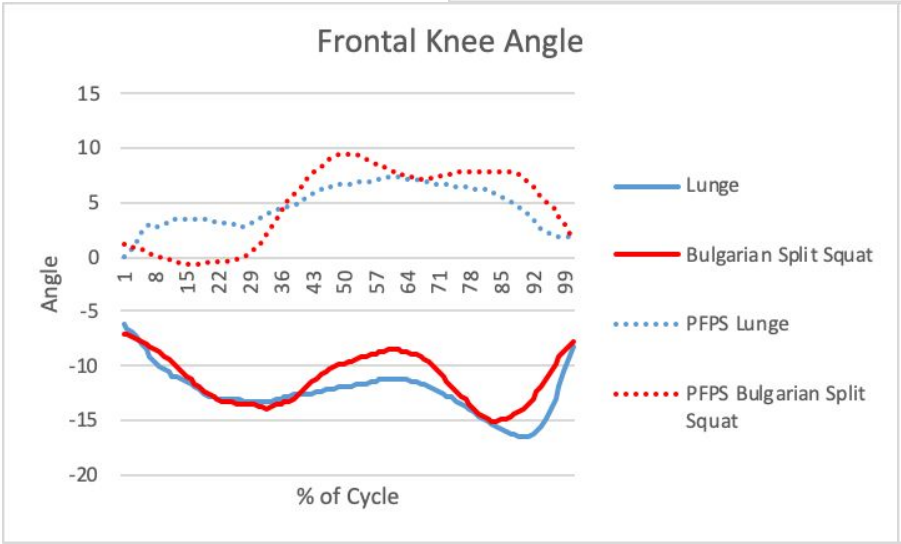


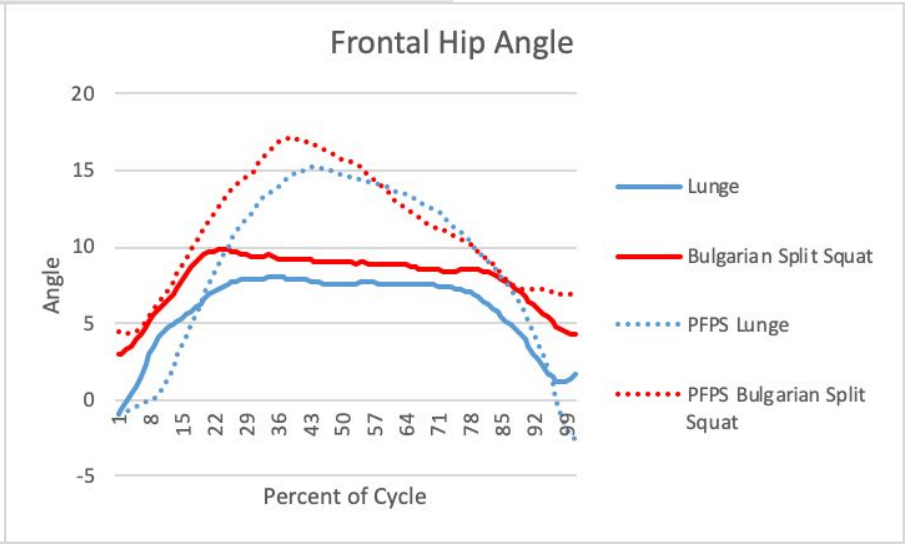




+: adduction
-: abduction







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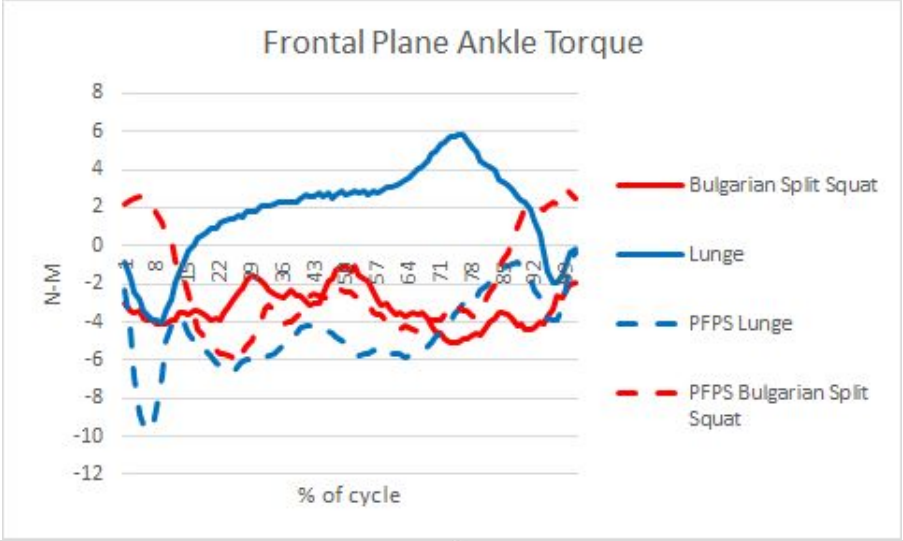
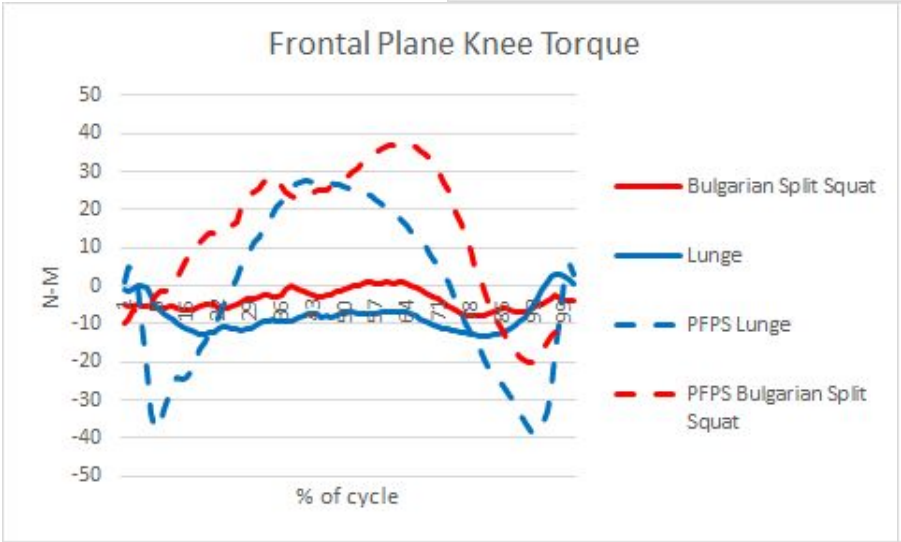
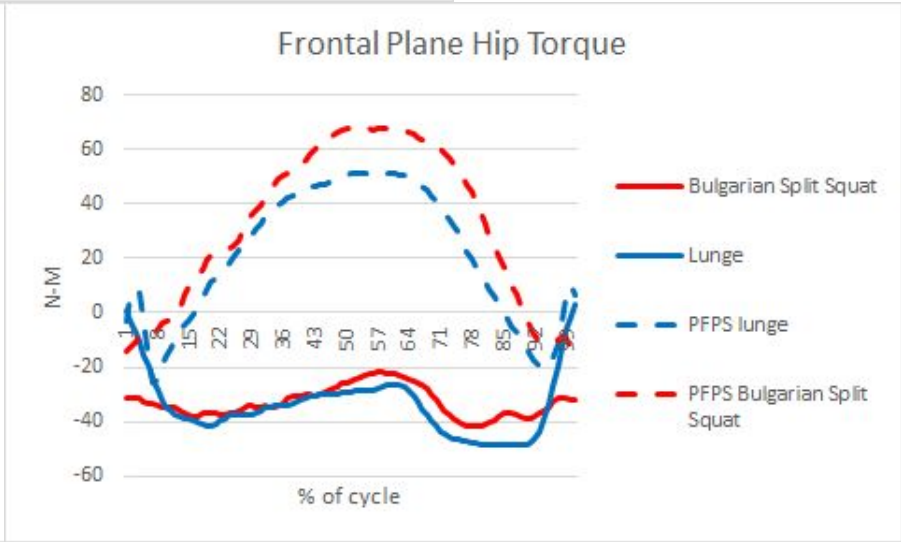
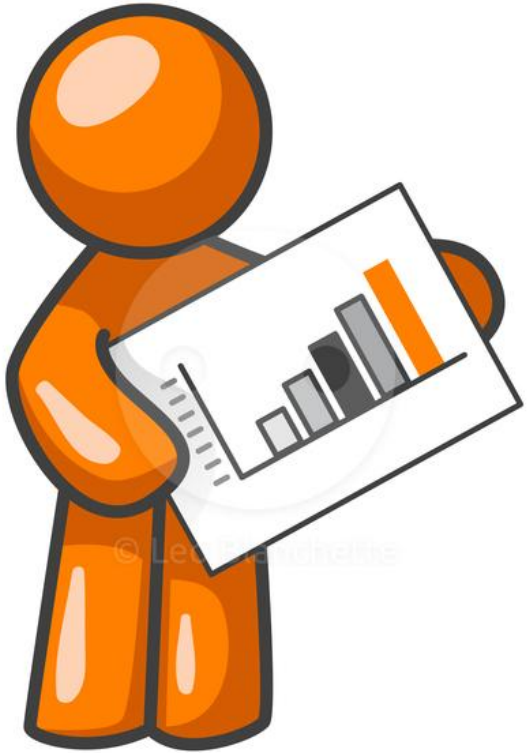






Results

- **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



1. Almeida 2016

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**[1]
  - 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)

FPPA, hip and trunk strength in the patellofemoral pain (PPG) and control groups (CG)

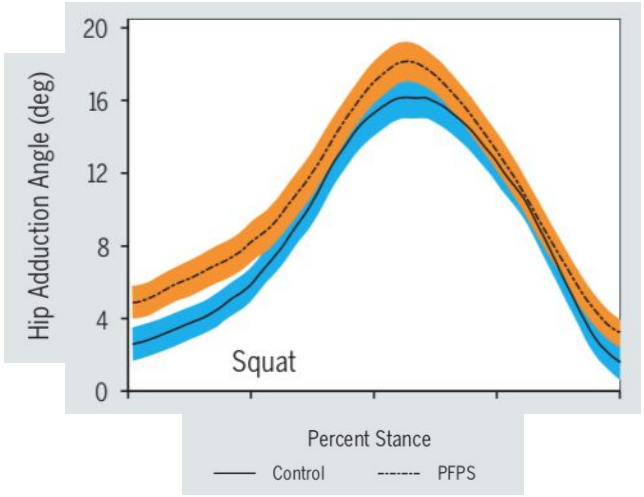
	PPG	CG
FPPA Initial (degrees)	−7.02 ± 2.9	−7.05 ± 2.3
FPPA Peak (degrees)	−11.9 ± 5.9	−6.7 ± 7.1
Abduction (N.m/kg)	75.5 ± 24.6	92.3 ± 19.3
Extension (N.m/kg)	43.9 ± 22.3	60.9 ± 20.1
External rotation (N.m/kg)	35.1 ± 9.3	41.6 ± 8.4
Posterolateral (N.m/kg)	51.5 ± 15.8	64.9 ± 11.9
Lateral core (N.m/kg)	181.9 ± 89.2	186.7 ± 44.8

Abbreviations: FPPA, Frontal Plane Projection Angle.

5. Wilson 2008

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[5].
  - Consistent with our results: BSS similar to SLS, BSS had **increased medial displacement of hip (agree)**



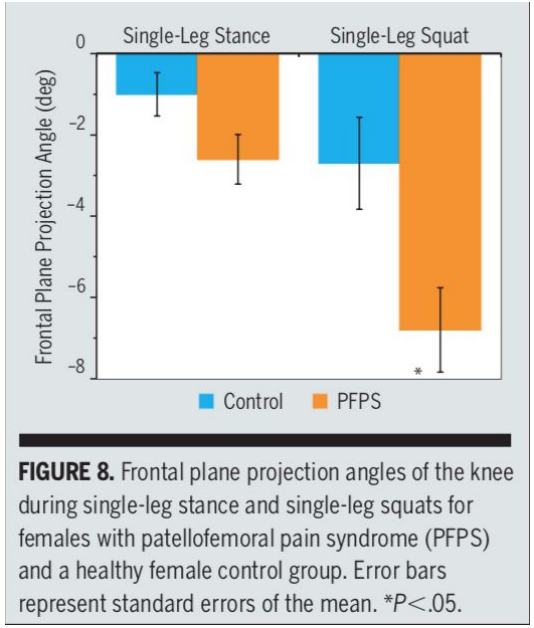


FIGURE 8. Frontal plane projection angles of the knee during single-leg stance and single-leg squats for females with patellofemoral pain syndrome (PFPS) and a healthy female control group. Error bars represent standard errors of the mean. *$P<.05$.

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

1. Almeida 2016

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

This is considered IRB exempt (IRB 151).

References

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