Kinematics and Arthrokinematics in the Chronic ACL-Deficient Knee are Altered Even in the Absence of Instability Symptoms

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Introduction

Background

- Some patients cope with ACL-deficiency and return to sports and daily activities without symptoms of instability[1-3].
- The effect of chronic ACL-deficiency on knee kinematics remains unknown.

Purpose

- To analyze the in vivo kinematics and arthrokinematics of chronic ACL-deficient (ACL-D) and unaffected contralateral knees during level walking and downhill running using dynamic biplane radiography.

Hypotheses

- ACL-D knees would demonstrate increased anterior translation and internal rotation in comparison to the unaffected side.
- ACL-D knees would demonstrate altered tibiofemoral contact path location in comparison to the unaffected side.

Methods

Subjects

- Eight participants with unilateral chronic ACL-D (4 M, 4 F; average age 42±16 years; mean 67 months since ACL-injury).
- Inclusion: no instability, locking or catching sensations; able to participate in daily activities and some sports without symptoms of instability; positive Lachman and pivot-shift test; no other ligament injuries or meniscal tears requiring resection of more than one-third of the radial width of the meniscus; uninjured contralateral knee.

Data Collection and Data Processing

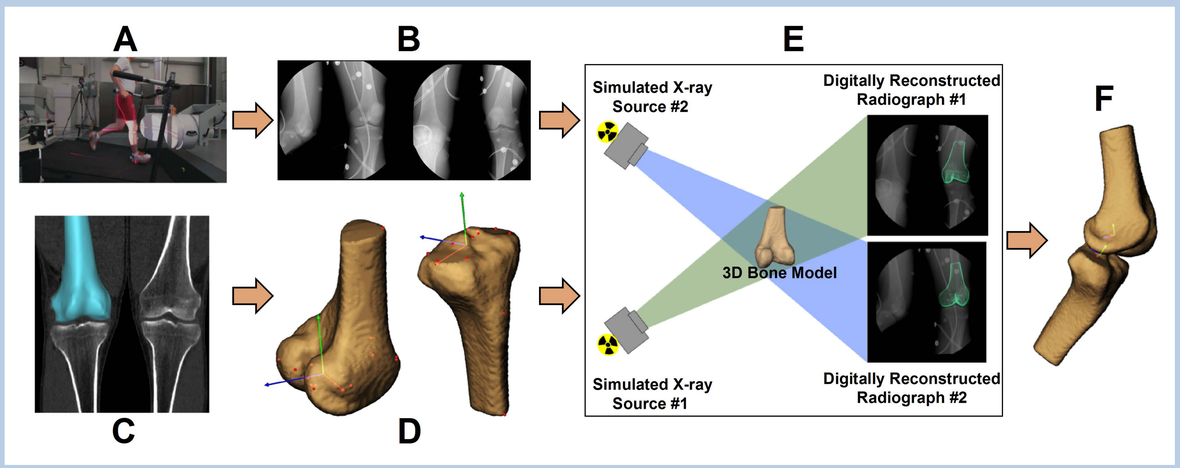

Figure 1: *A) Participants performed three trials of level walking at 1.2 m/s and three trials of downhill running at 2.5 m/s (10º slope) on an instrumented treadmill while B) synchronized biplane radiographs were collected at 100 and 150 images per second, respectively through the first 25% (walking) and 20% (running) of the gait cycle. C) Bilateral knee CT scans were collected and D) used to create 3D bone models. E) 3D knee kinematics were determined using a validated CT model-based tracking process[4]. F) Knee translations were calculated from femur origin to tibia origin and knee rotations were calculated using standard methods[5].*

Contact Path Calculation

- The path of the center of closest contact between the tibia and femur was determined using the distance-weighted centroid of the closest contact region on the femoral bone surface[6] (Figure 2).

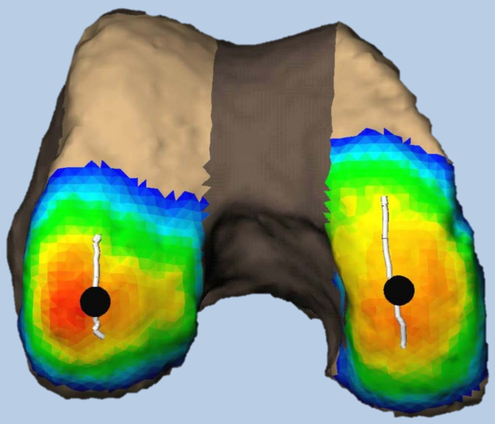

Figure 2: *Color mapped distance from the femur to tibia subchondral bone surface. The block dot identifies the center of closest contact at this instant. The white line represents the path of this center of contact over the first 20% of the running cycle.*

Methods

Statistical Analysis

- A 2-way repeated measures analysis of variance test (leg by gait cycle) compared anterior-posterior (AP) translation, internal/external (I/E) rotation, and contact point location between ACL-D and unaffected knees at each 5% interval of the gait cycle.

Results

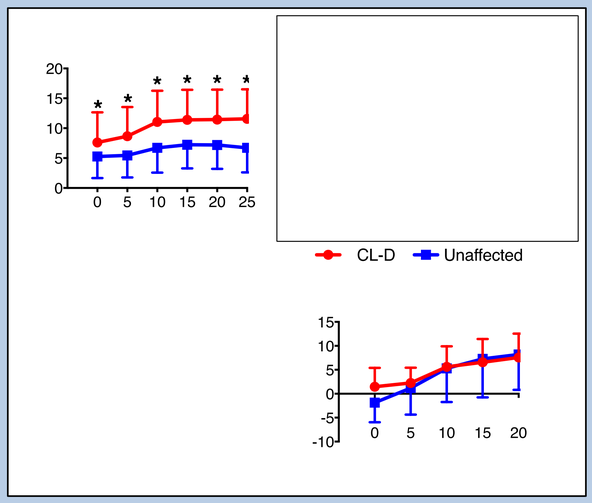

Figure 3: *Tibiofemoral AP translation and IE rotation during level walking and downhill running in ACL-D and unaffected knees. AP translations were larger in ACL-D knees during (A) level walking and (B) downhill running (* = p < 0.05). No differences were identified in IE rotation during (C) level walking and (D) downhill running. Error bars indicate inter-subject standard deviation.*

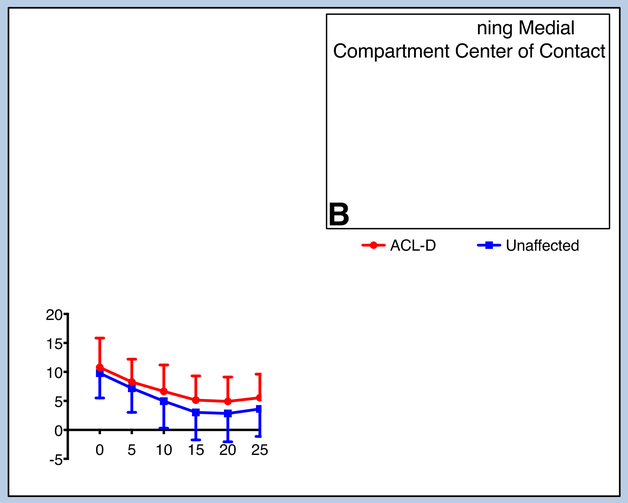

Figure 4: *Center of closest contact location in the AP direction on the medial and lateral condyle during walking and downhill running. No significant differences were identified in the medial condyle during walking (A) or running (C), as well as the lateral condyle during walking (B). Contact points were more anterior in the lateral femoral condyle at some instants of downhill running (D) (* = p < 0.05).*

Discussion

Main Findings

- In participants with chronic ACL-D without symptoms of instability, anterior translation of the tibia (ATT) was significantly larger during the early support phase of level walking and downhill running compared to the unaffected contralateral knee.
- Subchondral bone closest contact points were more anterior on the lateral femoral condyle in the ACL-D knee during the early support phase of downhill running.

Limitations

- Small sample size
- Wide range of age and time post-injury
- Only straight-ahead movements tested (no pivot movements)

Clinical Significance

- Chronic ACL-D knees, even in the absence of reported instability, appear to demonstrate subtle changes in tibiofemoral kinematics and arthrokinematics.
- Although some individuals with ACL-D knees are able to return to sports and daily activities without symptoms of instability, these individuals may still be susceptible to arthritic changes associated with abnormal joint kinematics and arthrokinematics.

References

1. Hurd WJ, et al. *AJSM,* 2008. **2.** Iliopoulos E, et al. *KSSTA,* 2017. **3.** Noyes, et al. *JBJS,* 1983. **4.** Anderst W, et al. *Med. Eng. Phys*., 2009. **5.** Grood ES and Suntay WJ. *J. Biomech. Eng.,* 1983. **6.** Anderst W and Tashman S. *J. Biomechanics,* 2003.

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