INDIVIDUALS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION DISPLAY ALTERED MECHANICS DURING SPLIT-BELT WALKING
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INTRODUCTION
Individuals with anterior cruciate ligament (ACL) injury have an increased risk of developing osteoarthritis (OA). Even after ACL reconstruction (ACL-R), the rate of OA incidence remains between 62% and 80% [1]. Researchers have suggested that altered gait patterns coupled with repetitive abnormal cartilage loading after ACL injury may have implications for the development of OA [2]. When compared to a healthy population, individuals with ACL injury exhibit abnormal sagittal, frontal, and transverse plane kinematics, as well as sagittal and frontal kinetic patterns during the stance phase of walking [3]. Researchers have demonstrated that knee-joint moments and angles are not fully restored following ACL-R [3]. Interestingly, when compared to a healthy population, both the involved and uninvolved limb exhibit abnormal movement patterns [4]. These kinetic asymmetries at the knee and hip are evident after ACL injury and remain after ACL-R. This would suggest that bilateral changes that occur after unilateral ACL injury and surgery may be related to changes in the neurological control of the locomotor system.

To date, no study has investigated strategies aimed towards reducing abnormal, asymmetric kinetic and kinematic patterns during walking in individuals with ACL injuries. Therefore, interventions that may reduce the alterations and asymmetries in gait associated with ACL injury could produce improved walking patterns bilaterally. Split-belt treadmills (SBT) consist of two independently-controlled belts (one under each leg) and have been shown to acutely restore or improve symmetry in spatiotemporal parameters such as step length, double-limb support time, and spatial patterns of each limb in populations post-stroke [5]. However, utilizing the SBT to restore normal kinematic (spatial) and kinetic patterns in populations with ACL injury at the knee has not been investigated.

Examining movement strategies (SBT) that may improve alterations and asymmetries during walking that may reduce the incidence of OA after ACL injury is needed. The aim of this study was to compare knee-joint moments and angles in the sagittal and frontal planes during normal treadmill walking and SBT walking in individuals with ACL injury and healthy young adults [3,4].

METHODS
Four ACL-R participants (3 female, 1 male; Age: 21 ± 1 yr; Height: 1.65 ± 0.11 m; Mass: 60.2 ± 11.2 kg; Time following ACL-R: 15.5 ± 12.2 mo) and four healthy controls (3 female, 1 male; Age: 21 ± 1 yr; Height: 1.65 ± 0.10 m; Mass: 63.6 ± 8.77 kg) walked on an instrumented SBT (960 Hz; Bertec Corporation, Columbus, OH) during two conditions: slow and split. Participants initially selected his/her fastest comfortable walking speed, then walked for three minutes with both belts moving at 50% of the fast speed (slow). The participants then walked for eight minutes with the ACL-R involved/nondominant leg moving at the fast speed and the ACL-R uninvolved/dominant leg moving at the slow speed (split).

Kinematic and kinetic data were recorded during the last 30 seconds of the slow, fast, split, and re-split conditions. Sixteen passive reflective markers were attached to the lower body in accordance with the Vicon Plug-in-Gait lower body marker system. Kinematic data were collected using a 7-camera motion capture system (120 Hz; Vicon Nexus, Oxford, UK).

Averages for three-dimensional knee joint-angles were calculated during the braking and propulsive phases of gait. Force recordings, marker position data and the individuals’ anthropometrics were used to calculate mean sagittal and frontal knee joint-moments during the propulsive and braking phases of gait via inverse dynamics. Sagittal and frontal plane joint moments and GRFs were normalized to body mass (kg) and temporally to 100% of the gait cycle. Braking phase was defined as the period from heel-strike to the first 50% of single-limb stance period. Propulsive phase
was defined as the period from second 50% of the single-limb stance to toe off [6]. Several 2x2 (group x condition) repeated measures MANOVAs with Bonferroni post-hocs for pairwise comparisons were used to analyze interactions of treadmill condition and group. Because this was a pilot study, a higher level of significance was used ($\alpha = 0.10$).

**RESULTS AND DISCUSSION**

A significant group x condition interaction ($p = 0.054$) indicated the uninvolved knee (ACL-R) displayed different mean sagittal angle, sagittal moments and frontal moments in slow and split walking. We did not observe any further significant group x condition interactions. Healthy controls showed no differences in knee angle, knee extensor/flexor moment, or knee abduction/adduction moment between slow and SBT walking. ACL-R individuals displayed larger uninvolved knee flexion angles ($p = 0.001$; Figure 1A) and smaller uninvolved knee flexor moments ($p = 0.032$; Figure 1B) during the propulsive phase in SBT walking compared to slow walking. ACL-R individuals also displayed larger uninvolved knee abduction moments ($p = 0.023$; Figure 1C) during the braking phase in SBT walking compared to slow walking (Figure 1).

We have demonstrated that the uninvolved knees of ACL-R individuals displays altered joint angles and moments during the braking and propulsive phase of gait when walking on the slow belt during the split condition. Changes in gait following ACL injury have been previously attributed to alterations in feedforward control to prevent anterior displacement of the tibia, and are present in both limbs. In addition to mechanical changes, these findings may provide further evidence of change in neurological control during walking after ACL-R. ACL-R may alter the mechanics of walking, particularly during a novel walking task (SBT). These alterations may lead to abnormal gait mechanics that could influence the individual’s likelihood for developing OA.

The incidence of OA diagnosis in the uninvolved limb is unlikely as it typically develops in the involved limb. However, it is possible that compensatory alterations in the uninvolved knee may influence overall gait. Because the human body is a kinetic chain, joints of the uninvolved side may have an important role in compensation and adaptation in steady walking. Finally, this information could be useful for developing therapies aimed towards preventing OA in populations with ACL injuries.

**REFERENCES**