Muscle Weakness after ACL Reconstruction is Correlated with Altered Knee Mechanics

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INTRODUCTION: Asymmetric muscle strength is commonly reported in anterior cruciate ligament reconstruction (ACLR) patients and we believe is a major contributor to altered dynamic knee function [1]. Asymmetries in dynamic ACLR knee function (knee kinematics, graft elongation, and cartilage contact) have been extensively demonstrated in multiple dynamic activities [2] and for multiple ACLR surgical techniques, including anatomical methods [3]. Asymmetric ACLR knee mechanics are thought to slow return to sport and contribute to post-traumatic osteoarthritis, thus restoring the ACLR knee to its intact function is the ultimate goal. To assess whether restoring muscle strength is critical to restore knee function, we investigated whether asymmetries in muscle strength are correlated with asymmetries in dynamic knee function at 6 and 12 months after ACLR.

METHODS: Forty-three patients (22 Female, Age = 29±7 years) who underwent unilateral, anatomical bone-patellar tendon-bone (BTB) ACLR were enrolled in an IRB-approved clinical trial investigating the use of platelet-rich plasma and bone marrow concentrate to accelerate healing (IRB# 2019-13, NCT04205656). The participants underwent a dynamic stereo x-ray (DSX) assessment of knee joint function, a CT scan, and muscle strength test at 6 and 12 months after surgery. DSX imaging was collected using 1ms pulsed exposures (90 kVp and 120mA) at 120 frames/s during downhill running (10º decline, 2.5 m/s) on an instrumented, dual-belt treadmill (Bertec), and single-leg stop jumps on a force plate (Bertec), with acquisitions triggered just before foot-strike. The CT scans were registered to the biplanar x-ray images to assess knee joint kinematics, reported using ISB standards. ACL strain was calculated based on the length between the tunnel centers and the ACL slack length was calculated from the knee posture in the CT scan. The asymmetry was calculated between the intact and ACLR knee at corresponding image frames and averaged over time. Due to the imaging field of view, running was analyzed from 0-30% of the stance phase and stop jump was analyzed from 10-90% of stance. Isokinetic knee flexion/extension strength tests (HUMAC) were performed and summarized by calculating the asymmetry in the peak torque and total work between the intact and ACLR limbs. Statistical Parametric Mapping (SPM) was used to perform a regression to assess the significance and correlation between the muscle strength and knee kinematics asymmetries across all participants.

RESULTS SECTION: At 6 months, 24/31 ACLR patients were able to perform downhill running and demonstrated average peak asymmetries (ACLR-intact) of -11º flexion, +2 mm anterior translation and -8º internal rotation. Participants demonstrated average extension and flexion peak torque asymmetries in the ACLR limb of -31% and -9%, respectively. In the stop jump at 6 months, the internal rotation was correlated with peak extension torque from 10-36% of stance ($p=0.01$, $R=0.47-0.57$), and negatively correlated with adduction asymmetry ($p=0.041$, $R=-0.51- -0.66$) from 10-36%. No significant correlations were found for running at 6 months. At 12 months, 28/29 participants were able to perform downhill running and demonstrated average peak asymmetries (ACLR-intact) of -8º flexion, 1 mm anterior translation and -5º internal rotation. Participants demonstrated average extension and flexion peak torque asymmetries in the ACLR limb of -19% and -6%, respectively. At 12 months, strong correlations were observed between the asymmetries in knee extension peak torque and flexion angle for 10-82% of stop jump ($R = 0.43-0.72$, $p < 0.0001$), and 11-30% of running (p-0.028, $R=0.42-0.72$). At 12 months, ACL strain was correlated with flexion peak torque asymmetry ($p=0.039$, $R=0.46 – 0.51$) from 65 – 80 % of stance.

DISCUSSION: This secondary analysis of our clinical trial revealed that muscle weakness after ACLR is correlated with altered dynamic knee function. The correlations found in downhill running between asymmetries in knee extension strength and flexion angle reflect the importance of quadriceps strength to load acceptance during running. The correlations between ACL graft strain and flexion peak torque asymmetry reflect the importance of the hamstrings for ACLR rehabilitation and their role in reducing the strain placed on the ACL through co-contraction. Consistent with previous studies, we also found the ACLR knee is externally rotated compared to the healthy contralateral knee, and this was partially explained by the correlation with extension strength asymmetry during load acceptance in the stop jump. This correlation reflects the angle of the patellar tendon in the coronal plane. Other factors such as pain may play a more important role in the early stages of healing as most of our correlations are only significant at 12 months, even though similar trends were observed at 6 months.

SIGNIFICANCE/CLINICAL RELEVANCE: ACLR patients with larger muscle strength asymmetries demonstrated larger asymmetries in knee kinematics during downhill running at 12 months after surgery and stop jump at 6 and 12 months after surgery. This suggests that targeted rehabilitation programs and orthobiologic treatments that accelerate healing to enable early loading may be critical to restore dynamic knee function as well as prevent reinjury and the development of post-traumatic osteoarthritis.

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