CONTRALATERAL LIMB DIFFERENCES IN KNEE KINETICS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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INTRODUCTION

The Anterior Cruciate Ligament (ACL) is the ligament that connects the anterior portion of the tibia to the posterior section of the femur, stabilizing the joint and limiting anterior translation of the tibia. Certain activities involving motions that suddenly strain the knee such as cutting or jumping in basketball or football, can result in an ACL tear. ACL reconstructions (ACLR) are common procedures used to restore joint function in the knee after an injury. Approximately 175,000 reconstructions are conducted annually [1]. Even though ACLR are routine, patients still often have kinematic and mechanical differences in their reconstructed joint compared to their joint pre-injury. These differences are thought to cause variations in joint surface interactions that result in abnormal loading patterns, increasing the risk of premature osteoarthritis (OA) [2]. In order to further improve ACL reconstruction surgeries and understand how these variations in joint surface interactions and loading patterns occur, it is essential to properly investigate the kinetics that occur at patients’ reconstructed and non-reconstructed contralateral knees. Kinetic data can then be used in addition to previously collected bone kinematics, joint surface data, and patient pain scores to further understand knee functionality post ACL reconstruction.

A common way to assess the differences in knee kinetics is to look at the knee moments that occur in the sagittal and coronal plane. A moment is defined as the tendency of a force to cause rotation about an axis. From previous studies, it has been thought that an increase in knee adduction moment in the coronal plane can increase the chance of OA development [3]. This is because increasing knee adduction moment results in increased loading of the medial compartment of the knee.

From the data observed in this study, the progression of knee joint inconsistencies in function can be measured after surgery. Significant differences between reconstructed and non-reconstructed knee moments are indicative of changes in gait and loading that patients may have due to their response to ACLR. The findings in this study will then be compared to other collected patient data such as the mentioned bone kinematics, joint surface, and pain score data, in order to further understand the degeneration of the knee joint and subsequent development of osteoarthritis.

OBJECTIVE

The goal of this project was to identify the kinetic differences between patient-specific reconstructed and non-reconstructed knees six months after surgery.

HYPOTHESIS

Significantly higher net knee moments in the sagittal plane were expected for non-reconstructed knees, while significantly higher net knee moments in the coronal plane of reconstructed knees were expected.

METHODS

Anatomic ACL reconstructions were carried out on 54 patients as part of an ongoing clinical trial. However, due to marker loss resulting in an inability to interpolate marker position in some patients, 33 patients (mean age 23±8.6 years, 33% female) had complete motion capture data for level walking trials (1.3 m/s), while 32 patients (mean age 23±8.5 years, 34% female) had complete data for downhill running trials (3 m/s, 10-degree slope) six months post-reconstruction.

In order to collect kinetic data, a dual force plate instrumented treadmill was placed within an 8-camera VICON system during walking and running. A Plug-in-Gait marker set was used in order to determine segment positions. Twelve trials in total were recorded for each patient, three for each knee, both for walking and running. Visual3D software made by C-Motion (Germantown, MD) was used to calculate the knee external moment data. The femur and tibia segments were modeled as frustums of right cones, while the foot and hip were modeled as right elliptical cylinders based on the acquired subject-specific measurements.

Understanding Visual3D and being able to decide on an effective way to process raw marker data was essential in order to make the analysis efficient and save time spent on this particular project. To do this, it was important to make use of the pipeline command system present in the program. The online Visual3D documentation was very helpful, even though the user interface was not intuitive. Using the pipeline, the moment curves of each trial were low-pass filtered at 10 Hz for walking and 15 Hz for running. These frequencies were selected because they were the sampling frequencies of the VICON video motion analysis cameras.

All moment data was normalized by patient mass. Peak moment values were recorded for each trial within 4% to 25% gait cycle using MATLAB and averaged for each knee. The moment data collected for the non- reconstructed contralateral knee for each subject was compared to that of the reconstructed knee, and the differences were analyzed using a paired t-test to observe significant kinetic differences between reconstructed and contralateral knees.
RESULTS
Patients exhibited a 43% decrease in peak external flexion moment in reconstructed knees compared to contralateral knees, which was found to be significantly (p<0.01) different (Figure 1A). In downhill running trials, there was a significant (p<0.01) 38% decrease in peak external flexion moment (Table 1B in reconstructed knees). External adduction moments were slightly higher in reconstructed knees in both running and walking trials, but the difference was not significant (Table 1C and 1D). As expected, moments in both planes experienced an increase in magnitude when subjects completed the more demanding task of running.

Figure 1. Mean net knee moments during running and walking trials in both the sagittal and coronal planes. Standard deviation bars are presented. *Indicates significance at p<0.01.

DISCUSSION
An opposing internal moment is required to balance the external moment found in a joint. Because the external flexion moment was found to be significantly lower in the reconstructed knee during both running and walking, less internal moment was required to be generated by the knee extensors, possibly straining the reconstructed ACL less. A phenomena known as quadriceps avoidance gait may be responsible for these findings [4]. Quadriceps avoidance gait is when patients limit the amount of force generated by the quadriceps muscles, the largest group of knee extensors, on the ACL-reconstructed knee in order to strain the graft less. Also, the deficit in extensor moment activity may be explained by the fact that the autograft is often harvested from the patellar tendon, which is connected to the quadriceps muscle. Kinetics that occur in the coronal plane are known to vary with gender, and the reason that no significant differences were found in the coronal plane moments could be due to the fact that this was a mixed-gender study.

The reason for the observed differences in the sagittal plane must be fully understood in order to fully understand the differences in joint mechanics between non-reconstructed and reconstructed knees. A better idea of what is happening inside the knee joint can be provided through the use of various other experimental techniques. In this study, electromyography (EMG) data was also collected and can either confirm or deny whether quadriceps avoidance gait is indeed responsible for the deficit in reconstructed knee sagittal net moment. Also, tibiofemoral bone kinematics were acquired for the same set of patients in the conducted trials, and will be analyzed in the context of knee kinetics. Cartilage thickness has also been calculated for these patients and may play a role in the kinetic differences as well. The same data two years after surgery has also been collected and must further be analyzed.

Understanding how all of the differences observed in ACLR patients and the resulting progression of OA over time can lead to better rehabilitation for ACLR patients, as well as the improvement of current surgery techniques.

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REFERENCES