Altered Knee Joint Loading Pattern Following ACL Injury and Reconstruction during Turns

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INTRODUCTION
ACL reconstruction is often performed in order to restore knee joint stability [1]. However, reports in the literature suggest that reconstruction of an injured ACL does not significantly reduce the risk of knee OA [2]. Previously reported motion pattern differences between ACL-reconstructed (ACL-R) knees and healthy knees indicate that current ACL reconstruction surgeries may not fully restore the joint function [3]. Changes in motion pattern of the knee joint may alter joint loading conditions of ACL-R knees during daily activity. Abnormal motion and joint loading patterns are risk factors of premature OA onset and progression. Greater bilateral differences of knee joint loading during level walking between ACL-R and healthy (ACL-I) knees were reported [4]. Changing direction is a common daily movement which, in average, occurs twice in every ten steps for human daily living. In this study, bilateral differences of knee joint loading during two types of turn were examined for patients with unilateral ACL-R knees. We hypothesized that there were no significant differences in the bilateral kinetic symmetry during turn for ACL-R group after surgery and rehabilitation when compared with ACL-I.

METHODS
Forty subjects (20 ACL-I subjects, 20 patients with unilateral ACL-R knees, 10 male and 10 female in both groups) were recruited and tested using an IRB approved protocol after obtaining signed consent forms. Twenty healthy subjects were recruited based on ages, genders, body weight and height of the ACL-R subjects. In the ACL-R group, there were 12 subjects with ACL-R in the right knees, and 8 subjects in the left knees. The ACL-R patients were from six months to two years after surgery or surgery at the time of test. Ninety-one 10 mm retro-reflective markers were attached to the major joint landmarks and lower extremity segments of the tested subjects [3]. A 10-camera motion analysis system (VICON, UK) was used to record the motion data at 60 Hz while the subject walked through the calibrated volume in normal speed. Two force platforms (AMTI, MA) mounted on the floor were synchronized with the motion capture system and used to record the ground reaction forces and torques at 1200 Hz. Five trials of step turn and five trials of spin turn of each leg from each subject during walking downstairs were recorded.

The movement of foot and shank during walking was determined using a rigid body optimization algorithm [5]. An inverse dynamics model was used to calculate knee joint forces and torques using previously reported anthropometric data [6]. Joint forces and torques of both knees were computed for each subject and expressed as three components in the tibial anatomical coordinate system. Joint forces and joint torques were normalized by the subject’s body weight. Bilateral differences of joint forces and torques were computed between left and right knees for all subjects. In order to avoid the influences of bilateral differences that may exist in ACL-I, ACL-R group were divided into two subgroups: ACL-R in the right knees (ACL-R-Rt) and ACL-R in the left knees (ACL-R-Lt). The obtained bilateral loading differences were compared during the stance of turns. Multivariate ANOVA was performed to test the difference between ACL-R groups, and ACL-I groups (SPSS, IL). Significance level was 0.05 in statistical analysis.

RESULTS
Subjects with unilateral ACL-R knee exhibited more significant bilateral differences in knee joint forces during both step turns and spin turns (Fig. 1). During spin turns, bilateral differences during step turns were greater than those during spin turns. In the healthy group, the anterior forces of the left knee were found greater during step turns and smaller during spin turns when compared with those of the right knee. During the bilateral differences in the anterior force of ACL-R-Rt were significantly greater than those of ACL-R-Lt and ACL-I at early stance (p<0.05). No such significant differences were found during spin turns. ACL-I had smaller lateral force in the left knee. Significantly greater bilateral differences in the lateral force during both step turns and spin turns were found in subjects with ACL-R-Lt than those in other two groups. At the early stance, the compressive force of the ACL-R knee was greater than their non-involved knee in both ACL-R groups with significantly greater bilateral differences than ACL-I.

Significant differences in knee joint extension and valgus torques were found during step turn (Fig. 2). A smaller extension torque was found in the knees with reconstructed ACL than the non-involved knee. There were significant difference in the bilateral differences between the ACL-R-Lt and ACL-R-Rt, and between ACL-R-Lt and ACL-I. No significant differences in knee joint torques during spin turn were found.

DISCUSSION
Significant differences in bilateral differences of knee joint forces and torques were found between ACL-R and ACL-I, and between the two subgroups of ACL-R. The hypothesis was disproved. Bilateral kinetic asymmetry was found in the ACL-I group during turns, especially during step turn. With unilateral ACL-R, bilateral kinetic asymmetry was either increased or decreased at the early stance of turns. Significant kinetic changes of the knee during step turn and spin turn were found in both ACL-R knees and noninvolved knees. Findings from this study shows that the peak bilateral differences in the knee joint forces and torques during turns, especially during step turn, were approximately 1 to 4 times greater than those during level walking reported early [4]. Loading at the knee at pivoting during daily activities is probably more harmful to the articular cartilage than those during level walking and stair climbing. During spin turn, the swing leg crosses over the planting leg, which shifts the line of body weight closer to the knee joint center than that during step turn. This may explain the relative smaller bilateral differences during spin turn. It is still not clear why the bilateral symmetry of knee joint loading during turns was not restored in the ACL-R knees, especially at the initial contact of the turn. Long-term effect of the altered knee joint loading during daily activities to knee osteoarthritis should be investigated. Further research is needed before recommendations can be made to patients with ACL-R knees in changing directions during daily activities.

REFERENCES: