THE EFFECTS OF COMPRESSIVE LOAD AND MUSCLE FUNCTION ON ANTERIOR CRUCIATE LIGAMENT STRAIN DURING REHABILITATION EXERCISES

+*Fleming, B (A-NFL Charities); **Ohlen, G; *Abate, J; **Renstrom, P; *Peura, G; *Beynnon, B
+*University of Vermont, Burlington, VT. (802) 656-4254, Fax: (802) 656-4247, Braden.Fleming@uvm.edu

Introduction:
The optimal means of rehabilitating a patient following ACL reconstruction remains controversial since little is known about the effects of the loads produced by muscle contraction and bodyweight on knee biomechanics. Closed kinetic chain exercises (CKC), such as squatting, are thought to protect the ACL, or healing ACL graft, since they involve co-contraction of the quadriceps and hamstring muscles that "stiffen" the tibiofemoral joint and reduce anterior tibial translation. CKC activities also produce substantial compressive loads across the knee due to bodyweight that are thought to interlock the articular surfaces of the tibiofemoral joint, hence reduce anterior shear loading. In contrast, open kinetic chain exercises, such as leg extension exercises, are thought to be deleterious to graft healing since they involve isolated contractions of the quadriceps muscles that cause anterior displacement of the tibia. However, recent evidence suggests that the compressive load produced by bodyweight may shift the tibia anterior relative to the femur, which in turn would strain the ACL (1, 2). There is also evidence to suggest that the peak ACL strain values produced during OKC and CKC exercises are similar in magnitude (3). However, the loading conditions for OKC and CKC exercises have not been systematically evaluated. The objective of this study was to compare knee extensor (concentric quadriceps) and knee flexor (concentric hamstrings) exercises when performed against different resistances, both with and without a compressive load across the tibiofemoral joint to represent the CKC and OKC conditions, respectively. The hypotheses were: 1) Peak ACL strain values produced by the extensor exercises increase with an increase in the resistance, 2) Peak ACL strain values for the flexor exercises decrease with an increase in resistance, and 3) Peak ACL strain values for either extensor or flexor exercises will decrease with an increase in joint compressive load.

Methods:
Ten patients (7 males, 3 females; mean age 33) who were candidates for arthroscopic partial meniscectomy, or chondral debridement, under local anesthesia participated in the study. All patients presented with normal ligament function at the pre-operative visit. The Institutional Review Board approved the study and the subjects granted their informed consent.

Following the routine surgical procedure, a Differential Variable Reluctance Transducer (DVRT; MicroStrain, Inc., Burlington VT) was implanted in the anteromedial band of the ACL. The displacement measurements of the ACL mid-substance were converted to strain using the engineering strain formulation [ε = (L - L0)/L0*100]. The transducer length corresponding to the slack-taut transition length of the ACL served as the reference length, L0, for the calculation (4).

Following implantation of the DVRT, the subjects were seated on a custom designed test bench that enabled them to perform extensor and flexor exercises against constant resistances. The subjects were seated such that the flexion-extension axes of the knee and test bench were aligned. The knee flexion angle was measured by a potentiometer mounted to the flexion-extension pivot of test bench. Pulleys with weights were used to apply, or remove, the compressive load equal to 40% of body weight to the foot and oriented along the tibia axis.

The extensor and flexor exercises were performed against resistance torques of 0, 12, and 24Nm. The exercises were performed with and without the compressive load applied. A blocked randomization procedure (exercise type; compressive load; resistance torque) was employed to establish the test order. A comparison of the peak ACL strain values of the different test conditions using a 3-way repeated measures analysis of variance tested the hypotheses. The three factors were exercise type (concentric extensor versus concentric flexor), compressive load (0% versus 40% bodyweight), and resistance torque (0, +/-12, and +/-24 Nm). Pair wise comparisons were then performed between conditions using Fisher’s LSD Procedure.

Results:
The mean peak ACL strain values were dependent on exercise type (p=0.006). Leg extensor exercises both with and without a compressive load across the joint produced higher strain values than the corresponding flexor exercises (Fig. 1). No significant increases in ACL strain values were produced due to the compressive joint load (0=0.79). The effects of torque on the peak ACL strain values were dependent on exercise type (p<0.001), and this interaction was compressive load dependent (p=0.009). For the extensor exercises, an increase in the resistance torque produced an increase in ACL strain values both with and without a compressive load. The opposite occurred for the flexor exercises without compressive loading where a decrease in ACL strain values was found with an increase in resistance torque. When a compressive load was applied during the flexor exercises, there was no decrease in ACL strain with an increase in resistance.

Fig. 1: Mean Peak ACL strain values for the extensor and flexor exercises with and without a compressive load applied to the foot. The error bars represent 1 standard error.

Discussion:
The peak ACL strain values for the extensor exercises were greater than that of the flexor exercises. This would be expected since the quadriceps muscles, which are antagonistic to the ACL, are dominant. Although the concentric flexor exercises produced strains that were less than the concentric extensor exercises, the ACL was still strained. This result was most likely due to co-contraction of the extensor and flexor muscles (5). This study verifies that the strains produced during OKC and CKC exercises are similar in magnitude as previously reported (3). The OKC condition was represented by the extensor and flexor exercises without the compressive load while the CKC condition was represented by the same exercises with the compressive load applied. Both exercises exhibited changes in ACL strain values with a corresponding increase in resistance torque. Although the strain magnitudes were similar between the OKC and CKC conditions, the compressive loading condition (CKC) for the flexor dominant exercises did not exhibit the reduction in ACL strain values that was shown for the OKC condition.

References:

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**Karolinska Hospital, Stockholm, Sweden.