THE EFFECT OF WEIGHT BEARING ON ANTERIOR CRUCIATE LIGAMENT (ACL) STRAIN

Braden C. Fleming ¹, Bruce D. Beynnon ¹, Per A. Renstrom ², Bjorn Engstrom ² and Glenn D. Peura ¹

¹ Dept of Orthopaedics & Rehabilitation, University of Vermont, Burlington, VT
² Section of Sports Medicine, Karolinska Institute, Stockholm, Sweden
Email: fleming@salus.med.uvm.edu Web: www.vtmednet.org/~g136911/

INTRODUCTION

Knee joint stability is maintained by a force balance between the ligaments, muscles, articulating surfaces, and body weight. One of the most important ligaments to knee stability, and yet most frequently ruptured is the ACL. To gain insight into ACL function and its interaction with other factors that maintain joint stability, its strain response should be evaluated under both non-weight bearing and weight bearing conditions. The objective of this study was to evaluate the ACL strain response during non-weight bearing and weight bearing in combination with three clinically relevant externally applied loadings; 1) anterior-posterior (A-P) shear, 2) internal-external (I-E) torques, and 3) varus-valgus (V-V) moments.

PROCEDURES

Eleven subjects who were candidates for arthroscopic meniscectomy under local anesthesia participated in the study. Following the routine surgical procedure, a Differential Variable Reluctance Transducer (DVRT; MicroStrain, Inc. Burlington VT) was implanted in the anteromedial bundle of the ACL. The wounds were closed and the subject’s foot was positioned in a custom designed loading fixture that allowed independent application of A-P shear forces, I-E torques, and V-V moments to the knee.

The subject was placed in a position similar to that of a squat, with their knee flexed at 20° and the trunk flexed to 10°. The magnitude of the applied loads were measured using a 6 DOF load cell (SRMC3A-6-250; AMTI, Watertown MA) at the foot in combination with a custom designed load cell at the tibiofemoral joint. For the weight bearing condition, the compressive force was applied to the foot and directed along the axis defined by the center of the ankle and hip joints. A compressive load equal to 40% of body weight was applied simulating the weight of the torso and upper leg. The external loading conditions were then applied in a random order. A 2 x 3 factorial ANOVA was employed where each subject served as their own control. The independent variables were the external loading regimes (A-P, I-E, & V-V) and the dependent variable was ACL strain. The two factors investigated were the weight bearing status and selected externally applied load levels (A-P forces: 0, 90 & 130 N; I-E torques: -9, 0, and 9 Nm; and V-V moments: -10, 0, and 10 Nm).

RESULTS AND DISCUSSION

For all three loading conditions, there were significant changes in ACL strain values due to weight bearing status (p<0.01) and the externally applied load levels (p<0.01). Significant interactions were found between
weight bearing status and ACL load (p<0.01). An increase in ACL strain values was produced by an increase in anterior shear load for both weight bearing and non-weight bearing conditions (Fig. 1). With no shear force applied to the tibia, application of body weight alone produced a significant increase in ACL strain. At high anterior shear loads (130 N), ACL strain values during weight bearing became similar to the non-weight bearing condition (Fig. 1). An internal torque of −10 Nm strained the ACL with the knee non-weight bearing while an external torque of 10 Nm did not (Figure 2). Weight bearing significantly increased ACL strain values with the application of external torques and low internal torque values. At −10 Nm of internal torque, no difference was found between weight bearing and non-weight bearing conditions. For V-V loading, the ACL was not strain when the knee was non-weight bearing. Weight bearing increased ACL strain values significantly across the range of V-V moments tested.

**SUMMARY**

This investigation provides new insight into the function of the ACL, *in vivo*, during two clinically relevant conditions. The first condition included evaluation of ACL strain without body weight and muscle contraction. The non-weight bearing data is clinically relevant for the evaluation of ligament integrity. The second was the response of the ACL in the presence of body weight and associated muscle activity, and provides insight into ACL function during activities of daily living and rehabilitation. In the absence of body weight, ACL strain values were increased only in response to externally applied anterior shear loads and internal torques of the tibia. In contrast, weight bearing, even in the absence of externally applied loads, increased ACL strain values. Similar findings were observed with the addition of the externally applied loads in combination with weight bearing. The observed increase in ACL strain is important from a clinical perspective. Previous cadaveric studies have suggested that the compressive load produced by body weight reduced the A-P displacement response of the tibia with respect to the femur as well as ACL load. Our in vivo study contradicts the decrease in ACL load observed in cadavers and emphasizes the need to quantify ACL function in the presence of body weight.

**ACKNOWLEDGEMENTS**

The authors thank Dan Plaster, Anders Valentin, and Dan Ramsey for help on the project. Support was provided by Smith & Nephew Donjoy, Vista CA.

**FIG. 1**: ACL strain vs A-P shear loading.

**FIG. 2**: ACL strain vs I-E torque.