VALGUS LOADING CAUSES INCREASED *IN VITRO* ACL STRAIN IN SIMULATED JUMP LANDING

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INTRODUCTION

Anterior cruciate ligament (ACL) injury has been associated with abrupt deceleration while running, cutting or landing[3]. Videotape analyses of these injuries has implicated valgus configuration of the lower extremity as a potential injury risk factor.[5] The previous experimental studies that have examined this injury mechanism have done so using sub-physiologic loading magnitudes and rates[2,4]. In this study, we investigated the effect of valgus loading on ACL strain response in a dynamic loading configuration that better simulates landing from a jump with pre-activated knee muscles. We tested the null hypothesis that the addition of a valgus knee impact moment would not significantly increase peak relative strain in the anteromedial ACL bundle compared with a flexion impact moment loading of similar magnitude.

METHODS

Ten fresh cadaveric limbs were studied [mean (SD): 70.3 (15.4) years; 4 males; 6 females; ages 45 to 89]. Specimens were cut 15 cm proximal and distal to the knee joint and potted using polymethyl-methacrylate. A testing apparatus was constructed to simulate the position of a single extremity as it strikes the ground while landing from a jump or during a run/stop maneuver (Figure 1). Pre-impact muscle precontractions of the quadriceps, medial and lateral hamstrings, and medial and lateral gastrocnemius muscle-equivalents were achieved by pretensioning 7 kN/mm springs to maintain the initial angle of 25° knee flexion prior to impact. The impact force magnitude and its lever arm about the knee joint could be preset. The impact loading direction was standardized to either apply a flexion moment in the sagittal plane ("Flexion only" trial) or by additionally inclining the entire construct into 15 degrees of abduction a "Flexion + Valgus" moment trial.

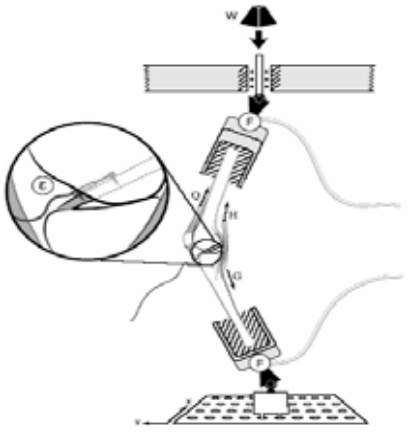

Figure 1. *Schematic of test set-up*

A 150 N weight was released from a fixed height to strike an impact rod in series with the proximal femur. This exerted an impulsive compressive force and flexion moment resulting in an increase in knee flexion angle. Two 3-axis load cells ("F") measured the 3-D forces and moments delivered to the knee construct, as well as the 3-D reaction forces and moments. A 3-mm DVRT (Microstrain, Burlington, VT) mounted on the ACL anteromedial bundle recorded its relative strain[1]. Impact forces, quadriceps muscle force, and ACL strain data were recorded at 2 kHz using a 16-bit A/D board, while tibiofemoral kinematics were tracked at 400 Hz using an Optotrak 3020 system to the nearest mm and degree. A repeated measures ('ABA') experimental design was run consisting of 10 'Flexion only', 10 'Valgus + Flexion', and 10 'Flexion only' trials were run. The last five trials under each condition were analyzed. The peak relative strains for individual specimens were normalized by dividing them by the mean peak relative ACL strain under both 'Flexion only' conditions. A paired Wilcoxon signed rank test was used to test the null hypothesis with a $p<0.05$ significance level.

RESULTS AND DISCUSSION

The mean (SD) peak impact force rose to 1,670 (390) N over a 30 ms time course, thus confirming the physiologic nature of the test. The impact forces did not differ between the 'Valgus + Flexion' and 'Flexion only' tests [1,620 (390) vs. 1,790 (380) N, respectively]. The mean (SD) relative strain during the 'Valgus + Flexion' loading was 4.3 (2.7)%, whereas the corresponding ACL strain measured 3.5 (2.8)% during the 'Flexion only' moment impact. Thus, we rejected the null hypothesis because the peak normalized relative ACL strain in the Valgus + Flexion' configuration was significantly higher than that in both the initial 'Flexion only' configuration ($p=0.04$) and final 'Flexion only' ($p=0.02$) conditions. Mean (SD) peak normalized ACL strain when the joint was loaded in 'Valgus + Flexion' was 1.28 (0.38) [non-dimensional units] across all specimens, while the mean (SD) ACL strain when loaded by a 'Flexion only' impact moment was 1.00 (0.32). The pretensioned muscle-equivalent springs gave an immediate rise in tension upon stretch, similar to a lengthening contraction condition *in vivo*. Any test order effect that may have been present was minimal because there was no significant difference in the peak strains measured under the two 'Flexion only' conditions.

CONCLUSIONS

In the slightly flexed knee, preloaded by quadriceps, hamstring and gastrocnemius muscle forces, relative ACL strain was significantly higher under a valgus + flexion impact loading than under a flexion-only impact loading.

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