

# EFFECT OF IMPULSIVE TRANSVERSE PLANE TIBIAL TORQUES AND FRONTAL PLANE MOMENTS ON IN VITRO ACL RELATIVE STRAIN DURING A SIMULATED JUMP LANDING

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## INTRODUCTION

Non-contact ACL injuries frequently occur under multi-plane dynamic knee loadings. Previous studies have examined ACL loading under relatively modest quasi-static knee loads [2, 3, 4]. Ahmed et al. [1] provided early insight into how transverse and frontal plane moments in the presence of the anterior tibial translation can strain the ACL. For example, the ACL would be more strained if the tibia rotates about a point on the medial aspect of the tibia than on the lateral aspect of the tibia. We tested the hypothesis *in vitro* that, under the large impulsive loads associated with a simulated jump landing, that neither the direction of the applied axial tibial torque (i.e., internal vs external tibial torque) nor the direction of the frontal plane moment (i.e., varus or valgus) would affect anteromedial bundle anterior cruciate ligament (AM-ACL) relative strain.

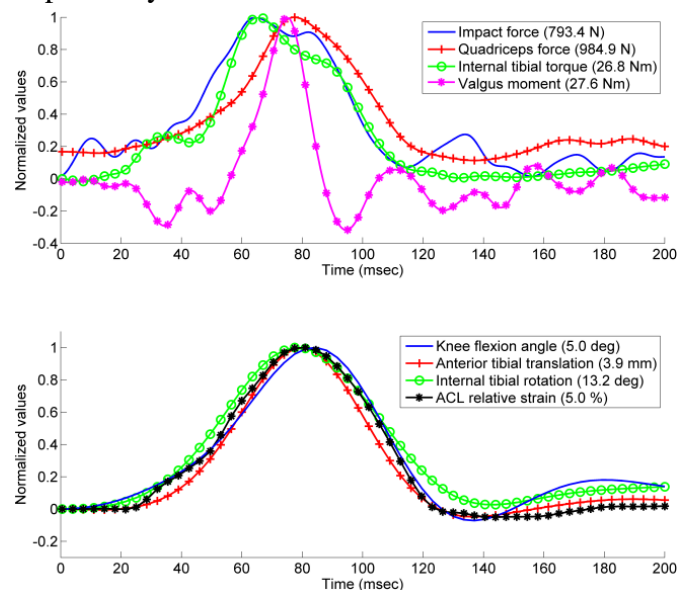
## METHODS

Nine fresh male cadaveric knees [mean (SD) age: 52.2 (16.0) years; five males] were mounted in a testing apparatus modified from Withrow et al. [4]. Under pre-impact quadriceps, hamstring and gastrocnemius muscle tensions, an impulsive force (~1 kN peaking at 50 ms) applied a peak flexion moment (~50 Nm peaking at 70 ms), varus or valgus moment (~±12 Nm peaking at 70 ms) and internal or external axial torque (~±25 Nm peaking at 70 ms) to the distal tibia with the knee initially in 15 deg of flexion. A 3-mm DVRT (Microstrain, Burlington, VT) was mounted on the AM-ACL to record relative strain. Tibiofemoral kinematics were recorded at 400 Hz, while 6-axis load cell, muscle forces and DVRT data were recorded at 2 kHz. After five pre-baseline (compression + flexion

moment) trials ('A1'), four blocks of six trials were run on each specimen in an 'A1-B-C-D-E-A2' design, where the post-baseline block is 'A2'. The first experimental block ('B') was randomized to be either varus or valgus moment combined with either internal or external tibial torque. Then the direction of the frontal plane moment was reversed on each block, while the axial tibial torque direction was reversed for blocks 'D' & 'E'. A repeated measures ANOVA was used to test the hypotheses ( $p < 0.05$  being considered significant).

## RESULTS AND DISCUSSION

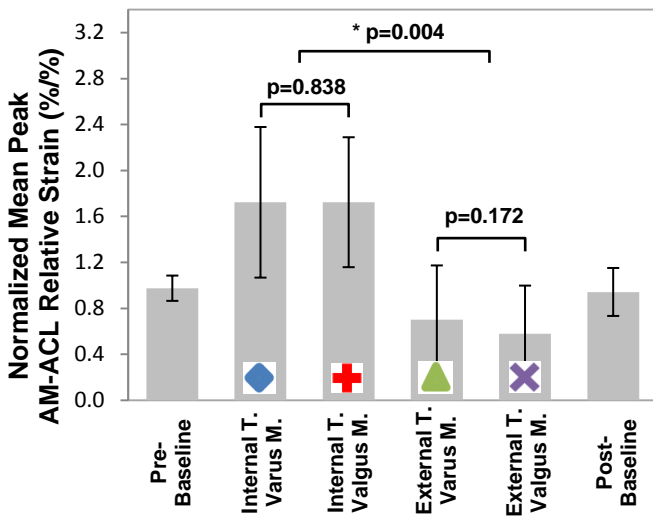
The mean peak AM-ACL relative strain was  $7.2 \pm 4.4$  % and  $7.6 \pm 5.1$  % under internal tibial torque combined with varus and valgus moment, respectively. The corresponding values were  $2.6 \pm 2.7$  % and  $2.4 \pm 3.0$  % under external tibial torque combined with varus and valgus moment, respectively.



**Figure 1:** Sample temporal behavior of the applied impact force, resulting quadriceps force, internal

tibial torque, valgus moment, knee flexion moment, anterior tibial translation, internal tibial rotation, and AM-ACL relative strain. Measurements have been normalized to their peak values (see legends).

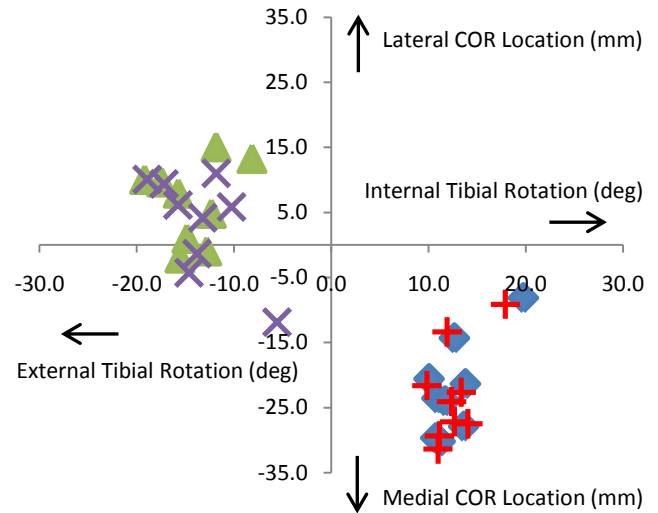
In a test of the hypothesis, the normalized mean peak AM-ACL relative strain was significantly greater under the internal than external tibial torque ( $p=0.004$ ), regardless of the direction of the frontal plane moments (varus or valgus) (Fig. 2). This result corroborates, but extends the finding by Fleming et al. [3]. Their in-vivo quasi-static study suggested that the AM-ACL is not a restraint to varus-valgus moment.



**Figure 2:** Normalized mean (SD) peak AM-ACL relative strain values under the frontal plane moments (M) and the axial tibial torques (T). Error bars represent  $\pm 1$  standard deviation. The asterisk indicates a significant difference.

Under the internal tibial torque the tibia rotated about a medial center of rotation (COR), whereas under the external tibial torque it rotated about a lateral COR, regardless of whether a varus or valgus moment acted (Fig 3.). Ahmed et al. [1] suggested that the internal tibial torque would increase the ACL strain more when the tibia rotates about a medial COR than a lateral COR, and vice versa. Initially, we speculated that a varus and valgus moment would increase the compression on the medial and lateral aspects of the tibia, respectively, thereby guiding the location of the COR (i.e., a medial COR under a varus moment and a lateral COR under a valgus moment). However, because of the posterior translation of the femur relative to the tibia due to the large quadriceps force, the COR actually tends to occur on the medial and lateral

aspects of the tibia for the internal and external tibial torque, respectively.



**Figure 3:** Axial tibial rotation angle vs. Center of rotation (COR) location under each compound impact loading (meaning of symbols shown in Fig. 2).

## CONCLUSIONS

In the presence of muscle forces, the AM-ACL was strained the most under an impulsive internal tibial torque in the presence of compression and flexion moment, regardless of whether an impulsive varus or valgus moment acts during the simulated jump landing.

## REFERENCES

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2. Durselen et al. AJSM 1995;23(1)
3. Fleming et al., J Biomech 2001;34(2):163-170
4. Kanamori et al. Arthroscopy 2002;18(4):394-398
5. Withrow et al. AJSM 2006;34(2):269-274.

## ACKNOWLEDGEMENTS

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