# GENDER DIMORPHISM IN KNEE JOINT MECHANICS AFFECTS ACL LOADING

[1]Kiyonori Mizuno, [2]Jack Andrish and [2]Ton van den Bogert and [1]Scott McLean,
[1]Department of Biomedical Engineering, The Cleveland Clinic Foundation, Cleveland OH
[2] The Orthopaedic Research Center, The Cleveland Clinic Foundation, Cleveland OH; email: mcleans@ccf.org

## INTRODUCTION

Anterior cruciate ligament (ACL) injury is a common and potentially traumatic knee joint injury. Women suffer ACL injuries more frequently than men (Arendt and Dick, 1995), with this disparity commonly attributed to a combination of neuromuscular, anatomical and hormonal factors. The potential for gender differences in ACL loading, and hence injury risk, stemming from a gender dimorphism in knee joint mechanics however, has not been addressed. The current study examined whether the ACL in the female knee experiences larger strain than its male counterpart, under application of the same three-dimensional (3D) knee joint loading state.

## METHODS

Methods for data collection have been described previously (Mizuno et al., 2004). Joint loads (forces and torques) were applied to 5 male (57 ± 13.4 yrs) and 5 female (58.3 ± 11.5 yrs) cadaveric specimens via a custom-designed loading device and were recorded with a 6 DOF load cell fixed to the tibia. Synchronous knee flexion data were recorded via an electro-goniometer secured across the joint. ACL strain was recorded via a microminiature differential variance reluctance transducer (DVRT, Microstrain, Burlington, VT) attached to the anterior-medial bundle (AMB). Data were collected at 10 Hz while flexion angle and loads were varied continuously for about 25 minutes. Regression analysis was applied to determine how ACL strain depended on seven independent variables: anterior-posterior, medial-lateral and compression force, flexion-extension, varus-valgus and internal-external rotation torques and knee flexion angle. Specifically, single specimen data were fit to the following model:

$$\varepsilon = a_0 + \sum_{i=1}^{7} b_i x_i + \sum_{i=1}^{7}\sum_{j=1}^{i} c_{ij} x_i x_j \qquad (1)$$

where, ε corresponds to AMB strain and $x_i$ is the $i^{th}$ independent loading variable. Specimen-specific regression coefficients were obtained via least-squares fitting, following which model strain predictions were validated. A clinically relevant 3D knee joint loading state, comprising combined valgus (10 Nm) and internal rotation torque (10 Nm) was then input to each specimen-specific regression model, at flexion angles of 0, 15, 30, 60, and 90 degrees (Kanamori et al., 2000). Resulting ACL strains were submitted to a 2-way ANOVA to test for gender and flexion angle effects ($P<0.05$).

## RESULTS AND DISCUSSION

Male and female specimen specific regression models could predict ACL strain within 0.51% ± 0.10% and 0.52% ± 0.07% of the measured data respectively, and in each case explained more than 75% of the associated variance (Figure 1). Predicted strains in each model were also consistent with that obtained experimentally for the same loading and knee flexion conditions. Significant increases ($p<0.05$) in mean peak ACL strains were observed in female compared to male models under the same load application (Figure 2). It is not clear which aspect of gender-dimorphic joint mechanics is responsible for this ACL strain increase. It is possible that the female ACL experiences the same force as the male ACL, but is more compliant and undergoes larger strains. It is equally plausible that female knee geometry is such that the ACL experiences a larger force than in the male knee when subjected to combined valgus and internal rotation loads. Further study is needed to quantify the contributions of these two potential mechanisms.

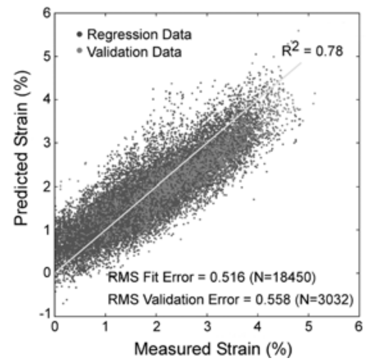


**Figure 1:** Model predicted versus measured ACL strain.

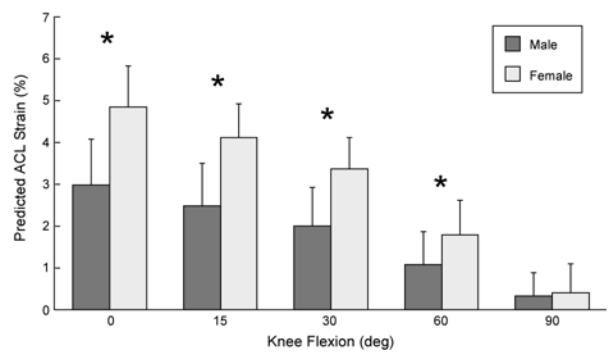


**Figure 2:** Gender comparisons of predicted strains.

## CONCLUSIONS

A gender dimorphism in knee joint mechanics exists, which may play an important role in ACL injury risk during dynamic sports postures. The ultimate success of current injury prevention strategies, typically teaching females to adopt "male" neuromuscular patterns, may thus be severely compromised. Elucidation of the underlying causes of this gender dimorphic behavior would facilitate more effective screening and prevention of ACL injury in the future.

## REFERENCES

1. Arendt et al., (1995) *Am J Sports Med* **23**: 694-701.
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## ACKNOWLEDGEMENTS

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