

A STATISTICAL MODEL FOR PROXIMAL TIBIOFIBULAR JOINT MOTION

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INTRODUCTION

The proximal tibiofibular joint (PTFJ) and its relationship to overall knee joint mechanics has been largely unexplored. The proximal fibula serves as the insertion for several anatomic structures integral to knee stability – the lateral collateral ligament (LCL), arcuate ligament, posterolateral capsular complex, and biceps tendon all insert onto the proximal fibula.

Our group is working on elucidating this joint's functional role in overall knee joint mechanics. We have previously presented data on maximum translation of the PTFJ during discrete loading conditions (Scott et al., 2005). Here we present data on three additional specimens and general conclusions obtained with help of a mathematical modeling technique.

METHODS

Four fresh-frozen cadaveric knee specimens were tested with the knee joint fully intact. The tibia was mounted vertically on a six degree of freedom force/torque sensor (SI-2500-400, ATI Industrial Automation, Apex NC) mounted to the floor. Two reflective markers were mounted on pins driven into the tibial plateau and the head of the fibula at the proximal tibiofibular joint, respectively. Motion was recorded by a digital video camera at 10 frames per second. Load cell data was synchronized to the video data and recorded at 10 Hz. Specimens were subjected to manual loading conditions in each of four flexion

angles (0, 30, 60, 90 degrees as established by a manual goniometer). Varying loads were applied manually to a “handlebar” on the femur, in combination with a static compressive load of 40 lb to simulate weight bearing (Mizuno et al., 2004). At each flexion angle, the operator loaded the joint in varus, valgus, internal tibial rotation, and external tibial rotation. Peak moments were approximately 20 Nm for internal-external rotation and 50 Nm for varus-valgus.

Video images were digitized using custom Matlab software. The displacement of the fibula marker relative to the tibia marker was computed to quantify PTFJ motion in the sagittal plane. Each specimen's data were entered into custom MATLAB software to obtain a second order regression model for PTFJ motion as a function of the tibiofemoral joint loading state:

$$y = a_0 + \sum_{i=1}^7 b_i x_i + \sum_{i=1}^7 \sum_{j=1}^i c_{ij} x_i x_j \quad ,$$

where y is the dependent variable (anterior-posterior or inferior-superior PTFJ motion) and x_{1-7} are the independent variables: flexion angle, 3-D tibiofemoral force vector, and 3-D tibiofemoral moment vector. After a model was created for each specimen, it was used to predict PTFJ motion in nine specific physiological loading conditions: combinations of varus and internal tibial rotation torques (10, 0 and -10 Nm), combined with 250 N compression. The model outputs were then compared across specimens.

RESULTS AND DISCUSSION

PTFJ joint motion was largest in the anterior-posterior direction. In all specimens, the regression model was able to fit the measured data well. In the anterior/posterior axis, which will be reported here, the RMS fit error ranged from 0.17 mm-0.35 mm, and the correlations of the models ranged from 0.941-0.971.

In all specimens, anterior fibula motion was seen during external tibial rotation. This is consistent with previous observations that LCL force is greatest in this loading condition (LaPrade et al., 2004). We also found anterior fibula translations during varus loading, and combined varus and external rotation (Fig. 1). There was more variation between specimens in pure varus loading. When in pure varus, even small variations in orientation of the articular surface of the PTFJ could drastically affect the motion.

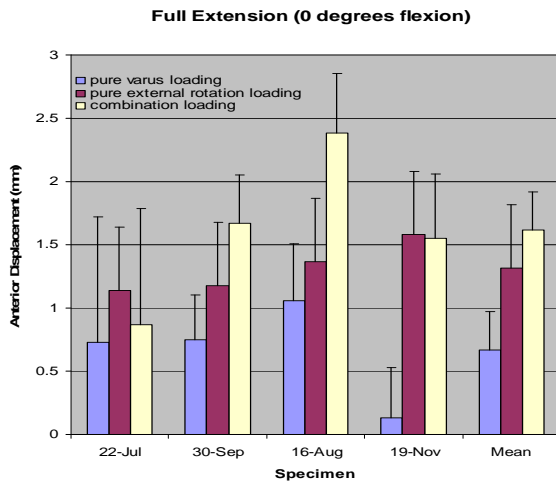


Fig 1: Anterior fibula translation in four specimens and three loading conditions.

Results were consistent across specimens at full extension, with increasing variability as the flexion angle increased. This effect is possibly due to changes in knee joint geometry from changing angle of

ligamentous forces as the femur rolls back on the tibial plateau.

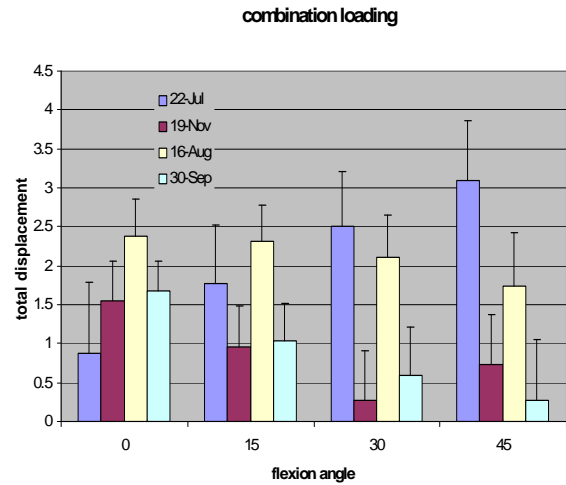


Fig. 2: Inter-specimen variability increases with flexion angle.

We present a statistical method of analysis for complex joint loading scenarios. Our model allowed us to interpolate the data within the seven-dimensional space of tibiofemoral joint loading states, such that hypothetical loading conditions could be simulated and compared between specimens. This has allowed us a deeper understanding of the complex behavior of the PTFJ.

REFERENCES

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