BIPLANE FLUOROSCOPY ANALYSIS OF KNEE KINEMATICS DURING GAIT

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INTRODUCTION

Optical marker camera systems and electromagnetic sensors are commonly used to measure lower limb kinematics with the important goal of attempting to identify gait adaptations after injury, surgery, or rehabilitation. There are inherent errors in these systems, such as inconsistent marker placement on anatomical landmarks and soft tissue movement artifact during dynamic trials [1]. It is important to accurately measure tibio-femoral translations and rotations to understand and estimate stresses being placed on ligaments serving to stabilize the knee [2].

Biplane fluoroscopy is a novel and potentially more accurate way of understanding 6DOF tibio-femoral kinematics. Despite increasing use of this device, there is a paucity of normative data. The purpose of this study was to describe knee rotations and translations during gait using biplane fluoroscopy. We hypothesized that while knee rotation angles would be similar to what had previously been reported in the literature, translations would have less total excursion during stance phase.

METHODS

Five healthy male subjects (29.8 ± 7.5yrs, 1.8 ± 0.1m, 84.0 ± 8.1kg) completed a walking trial at 2.75 mph while biplane fluoroscopic images were collected at 100 Hz (Figure 1) by two high-speed cameras (Phantom V5.1, Vision Research, Wayne, NJ) interfaced with two fluoroscopy systems (Philips Medical Systems, Best, Holland). Fluoroscopy images were collected during the loading portion of stance phase.

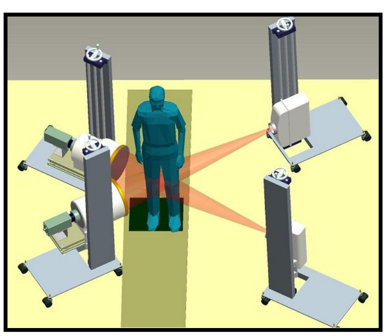

Figure 1: Biplane fluoroscopy collection area

A CT scan was acquired using an Aquilion 64 (Toshiba America Medical Systems, Tustin, CA). Three dimensional models of the femur and tibia were reconstructed from the CT images (0.5mm slices with a 512x512 pixel resolution) in Mimics software (Materialise, Inc, Ann Arbor, MI). Fluoroscopy images were tracked in Model-Based RSA software (Medis Specials, Leiden, Netherlands) by selecting manually selecting automatically detected bone contours. An 6DOF optimization algorithm calculated the 3D pose and orientation of the models in space (Figure 2).

Coordinate systems were applied to the femur and tibia models as follows: The origin of the femoral coordinate system was placed between the medial and lateral femoral condyles on the center line of a cylinder fitted to the medial and lateral posterior condyles (Figure 2). The tibial coordinate system was placed at the tibial spine and aligned with the femoral coordinate system. Using these coordinate systems, translations and rotations of the tibia with respect to the femur were determined by methods described by Grood and Sunday [3].

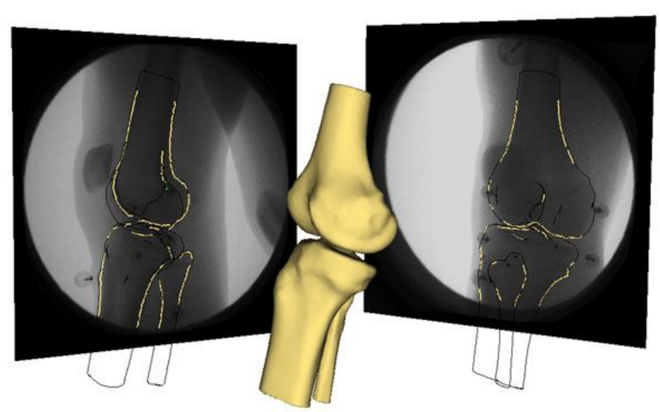

Figure 2: 3D models of the femur and tibia were matched to fluoroscopy images

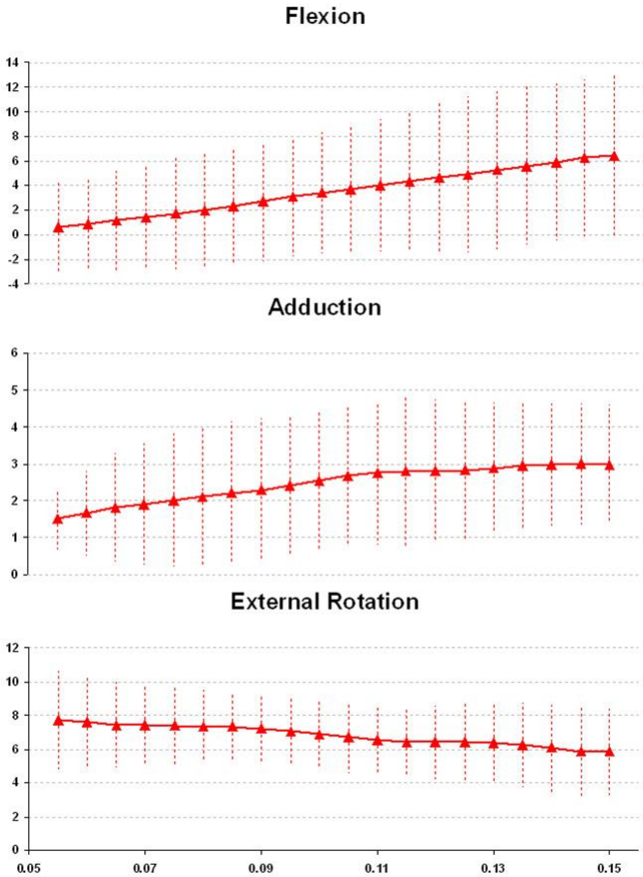

Figure 2: Knee rotations (degrees) and standard deviations. The x-axis represents time after heel strike (seconds).

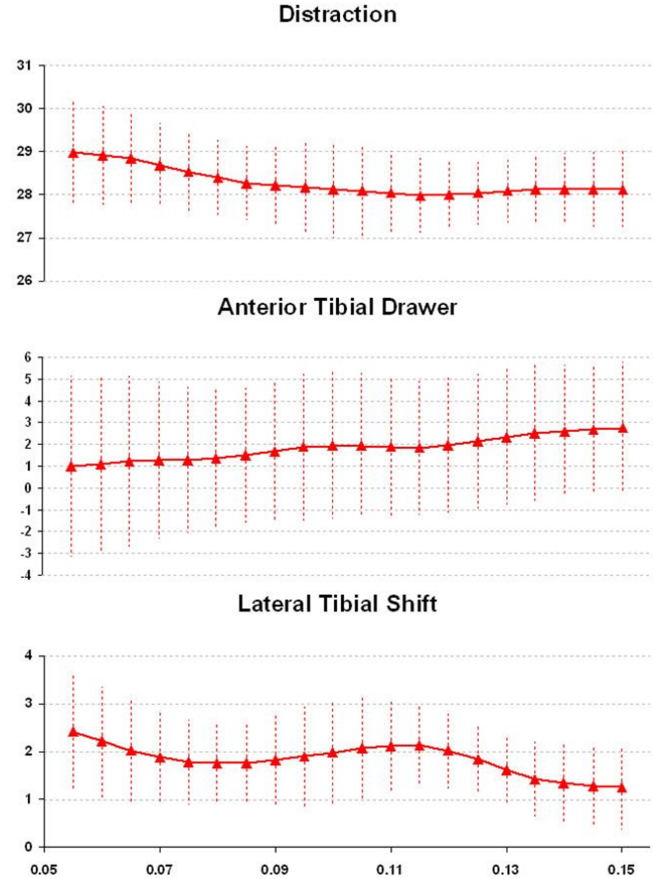

Figure 3: Knee translations (mm) and standard deviations. The x-axis represents time after heel strike (seconds).

RESULTS AND DISCUSSION

During the loading portion of stance phase, the tibio-femoral joint became more flexed, the tibia was adducted between 1.5º and 3º, and the tibia was initially externally rotated, but began to internally rotate by about 2 º (Figure 2). As the knee was flexing, the tibia moved anterior to the femur by 2mm and medial to the femur by 1mm (Figure 3).

The magnitudes of translations are lower than what has been reported in bone pin studies and using marker-based systems such as the point cluster techniques [4]. In those studies, translational excursions during loading phase were on the order of a centimeter, while our results show excursions of a few millimeters. Our results also compare favorably to other biplane fluoroscopy studies analyzing gait [5].

CONCLUSIONS

Tibiofemoral rotations in biplane fluoroscopy are similar to what has been previously reported in bone pin studies. The advantage of fluoroscopy is that it is less painful for the subject. Lower translational displacements indicate that optical techniques may overestimate the strain being placed on knee ligaments during dynamic trials. Biplane fluoroscopy is a useful and highly accurate method for identifying gait pathologies.

REFERENCES

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