Comparison of Static and Dynamic Knee Kinematics during Squatting

1Mu, S; 1,2Moro-oka, T; 3Johal, P; 1,2Hamai, S; 4Freeman, MAR; +1Banks, SA
Senior author: banks@ufl.edu

Introduction Two important methods for in vivo kinematic study of the healthy human knee include static MRI examination and dynamic single- or bi-plane fluoroscopic examination. Static MR methods provide tremendous bone and soft-tissue detail, but they require the joint to be positioned statically for relatively long exposures. Fluoroscopic methods have the benefit of quantifying fully dynamic motions but, by themselves, do not provide the same level of articular surface interaction detail. In 2005, Johal et al. described detailed tibio-femoral kinematics during squatting using open MRI to acquire a series of static images every 10° of flexion.1 In 2008, Moro-oka et al. reported dynamic knee kinematics during 3 activities (squat, kneeling and stair climbing) based on single-plane fluoroscopy.2

Thus, two distinct methods and protocols have been used to quantify squatting kinematics in the healthy human knee. The obvious question arising from these reports is ‘Are the static and dynamic knee kinematics the same?’ The purpose of this investigation was to perform a detailed quantitative comparison of the findings from these two studies to determine if the results from static or dynamic protocols differ.

Material and Methods In the static study by Johal et al, the kinematics of ten male healthy knees were determined by a technique reported by Pinskerova et al., in which the centers of the posterior circular portions of the medial and lateral femoral condyles (termed the Flexion Facet Centers or FFCs) were tracked in mid-medial and mid-lateral compartment sagittal images. The FFC locations were then plotted relative to an average size tibia plateau. (Eckhoff et al. studied the morphology of human knees and confirmed that the femur flexion facets can be modeled as two co-axial cylinders,3 the FFCs now becoming 2 points on or very close to the axis of the cylinders.)

Moro-oka et al. used 3D-to-2D model-image registration methods and fluoroscopic images to obtain the 3D kinematics of six healthy male knees. Bone-embedded Cartesian coordinate systems for each femur and tibia were aligned with the cylindrical axis described by Eckhoff et al. By assuming the origin of the bone-embedded coordinate system lies on the midpoint between the medial and lateral FFCs, we can then calculate the movement of the FFCs relative to the tibia from the 3D knee kinematics. Projecting the FFCs onto the tibia plateau gives position values comparable to the results from Johal et al.

Linear interpolation was used on the dynamic data to get data from 0° to 120° flexion in 20° increments for direct comparison with the findings of Johal et al. Data at 0° and 20° flexion were adjusted in the same manner as Johal et al.1 to account for the transition from FFC to the more anterior extension facet center (EFC). The data were compared using a repeated-measures two-way ANOVA, with post hoc pair-wise comparisons performed using Tukey’s Honestly Significant Difference.

Results Comparison of the reformatted dynamic data with the static data reveal differences of less than 3mm for the medial condyle position and 2mm for the lateral condyle position over 0°-120° flexion (Figure 1). Statistical tests show significant difference at 0° and 120° flexion for the medial condyle. Plotting the average condylar locations on top of an average sized tibial plateau reveals clinically insignificant differences between the two data sets (Figures 2 and 3).

Discussion This quantitative comparison of healthy knee kinematics during squatting shows that essentially the same motions occur in both static and dynamic examinations. This finding provides the basis for informed comparison of data from static and dynamic studies in squatting-type motions, and provides cross-validation of these methods to produce results which are representative of the kinematics of the healthy knee.

References

Figure 1. Anteroposterior translation of medial and lateral femoral condyles.

Figure 2. Movements of medial and lateral femoral condyles relative to tibia from Johal’s data1.

Figure 3. Movements of medial and lateral femoral condyles relative to tibia from Moro-oka’s data2.