MEASUREMENTS OF *IN VIVO* PATELLOFEMORAL JOINT KINEMATICS WITH REAL-TIME MRI

Christine Draper [1], Thor Besier [1], Juan Santos [1], Garry Gold [1], Gary Beaupre [1,2], Scott Delp [1]

[1]Stanford University, Stanford, CA
[2]VA Rehabilitation Research and Development Center, Palo Alto, CA
email:cdraper@stanford.edu; website: http://nmbl.stanford.edu

INTRODUCTION

Accurate measurements of *in vivo* joint kinematics are needed to understand normal and pathological joint mechanics. Methods to quantitatively measure joint kinematics enable us to better identify abnormal motion and to evaluate treatments for certain musculoskeletal disorders.

Current methods of measuring *in vivo* joint motion include bi-plane radiography (Tashman, 2003) and cine-phase-contrast MRI (Sheehan, 1998). Recent advances in MRI technology have resulted in the implementation of real-time image acquisition (Kerr, 1997). Real-time MRI is non-ionizing and allows measurement of bone and soft tissue motion during dynamic, weight-bearing activities.

The purpose of this study was to determine the feasibility of measuring patellofemoral joint kinematics during upright, weight-bearing knee extension using real-time MRI.

METHODS

We examined the patellofemoral joints of six healthy control subjects. All subjects were female, between the ages of 20 and 30, and had no history of knee injuries. Real-time MR images of their knees were obtained using a 0.5T Signa SP open-MRI scanner (GE Healthcare) and the following scan parameters: field-of-view: 16cm, spatial resolution: 1.88mm, frame rate: 6 frames/s, 6 acquisitions/frame, 16ms readout trajectory. A custom-built backrest stabilized subjects in an upright, weight-bearing posture. Subjects performed continuous squatting movements in the scanner from 0° to 60° of knee flexion and back at a rate of 6°/s. An oblique-axial plane through the widest portion of the patella was imaged.

To evaluate whether the measurements obtained from real-time MRI are consistent with other methods of measuring joint alignment, we used quasi-static MRI (FOV: 20cm, matrix size: 128x128, slice thickness: 5mm, resolution: 1.6mm, TE: 5.6ms, flip angle: 70, # slices: 1) to obtain axial images at five knee flexion angles (0°, 15°, 30°, 45°, 60°). Subjects performed quasi-static knee flexion, holding each position for about 15 seconds.

Clinical measurements of patellar motion were estimated by manually identifying bony landmarks in each image frame. Bisect offset describes the medial/lateral position of the patella and is reported as the percentage of the patella lateral to the midline of the femur. Patellar tilt is a measure of the angle between the patella and the posterior femoral condyles (Figure 1).

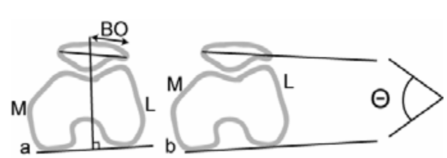

Figure 1: Diagram of bisect offset (BO) (a) and patellar tilt (Θ) (b) measurements.

For each subject, the measured kinematics from two real-time MRI trials were averaged and smoothed with a Hamming window filter.

To assess the precision of our estimates, we measured bisect offset and patellar tilt three times on the same set of real-time MR images and found the measurements to be repeatable (average RMS difference of 3.0% for bisect offset and 1.0° for patellar tilt).

RESULTS AND DISCUSSION

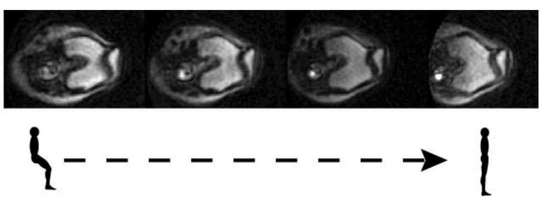

Figure 2: Sample real-time MRI frames during weight-bearing knee extension.

The measurements from the real-time MR images are within one standard deviation of the mean measurements obtained from the quasi-static images for most knee flexion angles (Figure 3). There are differences in the measurements of bisect offset at 45° and 60° and in patellar tilt at 30° of knee flexion. However, it is not known whether the kinematics occurring during a dynamic squat will necessarily equal those measured from quasi-static images. In future studies, we will analyze more subjects to identify whether the knee joint kinematics are different during a dynamic task.

Real-time MRI enables continuous measurements of joint kinematics to be obtained during dynamic, weight-bearing tasks. The techniques developed in this study may improve the diagnosis and treatment of subjects with patellofemoral pain. Abnormal motion of the patella relative to the femur is thought to be one cause of pain. However, it is unclear whether the clinical observation of altered patellar motion correlates with the kinematics occurring during the functional, weight-bearing activities that cause pain. We plan to use real-time imaging techniques to address this question. We will quantify the knee joint kinematics during dynamic, weight-bearing knee extension in subjects with patellofemoral pain and compare them to the measurements obtained in this study.

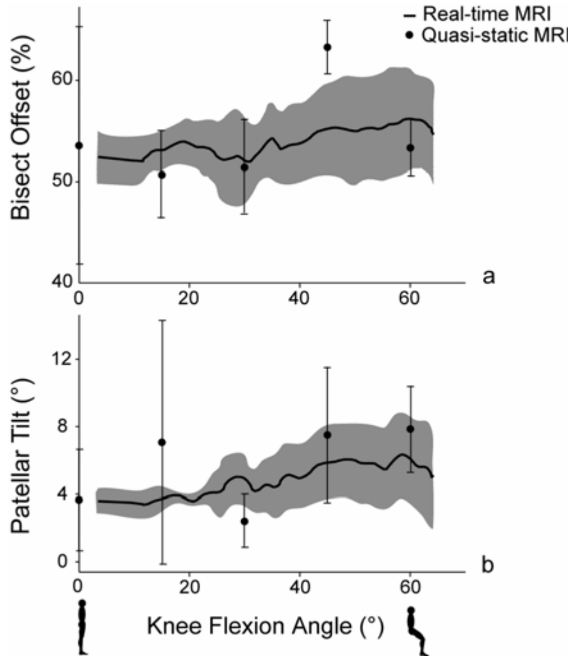

Figure 3: Relationship between knee flexion angle and (a) the percentage of the patella lateral to the midline of the femur (bisect offset) and (b) patellar tilt angle. The solid line is the mean ± SD of the measurements from real-time MRI. The circles are the mean ± SD of measurements from the quasi-static images.

REFERENCES

Tashman, S. and Anderst, W. (2003), *J Biomech Eng*, **125**, 238-245.
Sheehan,F.,et al.(1998),*J Biomech*,**31,**21-26.
Kerr, A., et al. (1997), *Magn Reson Med*, **38**, 355-367.

ACKNOWLEDGEMENTS

VA Rehabilitation R&D Service (#A2592R), the NIH (EB002524-01, EB005790-01), the NSF, and SGF.