INTRODUCTION

Patellofemoral joint pain (PFP) is a condition affecting up to 30% of active individuals. Although the etiology of this condition is still not well understood, a number of contributing factors have been identified. The natural history of this condition appears to involve abnormal patellofemoral joint kinematics, condromalacia, and ultimately osteoarthritis. Early detection of cartilage wear is an important component of diagnosis and early treatment for this relatively young group of patients. However, standard morphological MR imaging is not sensitive to early changes in cartilage wear. More recently, MR pulse sequences have been developed to quantify physiological features of cartilage (e.g. water and proteoglycan contents). However, they too, lack sensitivity to early changes in cartilage health. To address this problem, we have proposed a novel method to capture these physiologic properties under known patellofemoral joint loads.

METHODS

A custom, non-ferromagnetic device was fabricated from a fiberglass-epoxy composite and nylon screws and fitted to a standard knee-foot stack coil (Fig. 1). The device consists of a frame for a PVC pneumatic cylinder and a locking mechanism for the coil. This allows the calibrated cylinder to compress the patella during imaging by controlling air pressure input from the MRI control room. Engineering tests demonstrated that the device could reliably compress a substrate in the range of 5–18 kg with a drift of < 4% over 10 minutes.

10 adult subjects (6 control subjects and 4 subjects with PFP) were recruited under a UCSD approved protocol. After obtaining informed consent, subjects were placed in a 3T MR system (GE MR750) and the orientation of the compression device plunger was aligned with the anterior surface of the patella.

Figure 1: Compression device outside and inside a knee-foot stack coil.

Figure 2 A-D. Axial T2 maps of control and PFP patients under unloaded and loaded conditions.
A standard T2 mapping sequence (TR 800ms, TE 10ms, 8 echos) was obtained to quantify regional PFJ cartilage water content with the joint 1) unloaded and 2) under a load of 15% body weight (Fig 2). Note that the knee was axially loaded for 5 minutes prior to the scan and during the scan time of less than 4 minutes.

To quantify T2 values, non-overlapping regions of interest (ROIs) were analyzed on the medial and lateral facets of the patella; the slope of the T2 decay curve (using echos 2-8) was extracted using ImageJ and the MRIAnalysisPak plugin.[1] T2 values were compared using a 2-way repeated measures ANOVA.

RESULTS AND DISCUSSION

At 15% body weight, the T2 value of the medial facet increased by 19% (p<0.05, Fig. 3) and the lateral facet increased by 12% (p=0.13, Fig. 4). This indicates that water concentrations in the ROIs were elevated under loading. There were no significant differences between control and PFP subjects at this load and no interactions between group and loading condition. We also found that the cartilage T2 value recovered to its unloaded T2 values within 4 minutes of load removal (data not shown).

These data are directed towards a “proof-of-concept” approach for the device. In our preliminary experience, all but one subject was able to tolerate a load of 15% body weight, and this patient did not tolerate the load because of apprehension about PFJ dislocation, not pain. Furthermore, the device components did not produce any MR artifacts or induce motion-related artifact in the tissues of interest, ensured high spatial resolution and contrast.

Future work with this device is aimed at identifying a critical load for detection of early osteoarthritis by manipulating the load magnitude and load time in a group of patients who have early OA confirmed arthroscopically. Correlating increases in T2 with specific morphological or mechanical measurements of OA will allow for a more precise testing method and the development of a “threshold” between normal cartilage wear and true early OA.

Obviously, this will require a larger group of subjects.

Potential uses for this device are not restricted to those shown in this study. It could also be used to quantify changes in cartilage thickness at a given load in normal and pathological patients. With its wide range of load fidelity, one could envision using it to apply very specific axial loads to other joints or tissues. This device allows us to combine the power of MRI and mechanical loading to analyze the behavior of human tissues in non-resting states.

REFERENCES