CHANGE IN KNEE CARTILAGE T2 IN RESPONSE TO MECHANICAL LOADING AT 3.0 T

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INTRODUCTION

The articular cartilage provides load-bearing function with its highly-organized collagen architecture and osmotic pressure via water flux, and disorder or degeneration of articular cartilage with collagen disorganization or abnormality of water content may result in failure in responding to normal load-bearing. Recent studies of MR imaging showed great potential of evaluation of T2 for quantitative assessment of the cartilage matrix and water content [1,2]. We have developed a loading apparatus to apply axial load to the knee joint during MR imaging in order to simulate physiological load-bearing condition while standing. The purpose of this study was to examine clinical feasibility of MR imaging under mechanical loading in normal volunteers, with respect to changes of T2 in the femoral and tibial cartilages of the knee joint.

METHODS

Thirteen volunteers with healthy knee joints were imaged on a 3.0 T MRI scanner (GE Healthcare, WI) using a transmit-receive birdcage coil. There were six men and seven women, and the mean age and body mass index (BMI) were 24 years (range; 21 to 35 years), and 22.0 (range; 18.9-29.7), respectively. All participants provided informed consent to participate in the study, which was approved by the Institutional Review Board. During MR imaging, the volunteer was laid on a custom-made loading apparatus, which had a pulley system linked to a sliding foot plate (Fig. 1). The shoulders of the volunteer were strapped tightly, and 50% of the body weight was applied via the foot plate, when loading.

On unloading and loading conditions, sagittal T2 maps of the medial and lateral femoro-tibial joints were obtained from multi-echo spin echo sequence with fat-suppression (TR=1500 ms, 8 TEs between 15-120 ms, 3-mm section thickness, NEX=2, FOV=12 cm, in-plane resolution=0.23 mm). T2 value was calculated on a pixel-by-pixel basis by fitting the echo time data and the corresponding signal intensity to a mono-exponential equation. On a color-coded T2 map, low T2 value was represented with red color and high T2 value with green or blue color. On each of medial and lateral sagittal image, three regions of interest (ROIs) in the femoral and tibial cartilages at the weight-bearing portion were manually defined for each subject (Fig. 2). ROIs of the femoral cartilage included Z1: covered by the anterior meniscus, Z2: direct contact to the opposing tibial cartilage, and Z3: covered by the posterior meniscus. ROIs of the tibial cartilage included Z4: covered by the anterior meniscus, Z5: direct contact to the opposing femoral cartilage, and Z6: covered by the posterior meniscus. T2 values on unloading and loading conditions in each ROI were compared using a paired t-test. The relationship between change of T2 values by loading and age or BMI of volunteers were evaluated using the Spearman correlation coefficient. A p value of less than 0.05 indicated significance.

RESULTS

Between the images on unloading and loading conditions, apparent changes of cartilage thickness or meniscus shape were not seen, however, relative changes of T2 value distribution were observed, especially at the surface of the cartilage (Fig. 3).

By application of loading, there was a significant decrease of T2 value at Zone 2, 5, and 6 ($p<0.05$) on the medial femoro-tibial joint (Table 1). By application of loading, there was also a significant decrease of T2 time at Zone 2, 4, and 5 ($p<0.05$) on the lateral femoro-tibial joint. There was no significant relation between change of T2 values by loading and age or BMI of volunteers.

DISCUSSION

The present findings indicated clinical feasibility of MR imaging on loading, with respect to yielding significant changes of T2 values on the weight-bearing portion of the femoral and tibial cartilages. From previous studies that change of T2 values are related with disruption of cartilage architecture and water content [1,2], decrease of T2 values associated with loading may reflect efflux of water content or change of collagen fiber orientation in response to applied compression or shear force. Interestingly, change of T2 values by loading was only observed in the zone uncovered by the meniscus on the femoral cartilage, while changes of T2 values were widely seen, at the similar magnitude, in the zones both covered and uncovered by the meniscus on the tibial cartilage. This finding may represent a significant biomechanical role of intact meniscus to disperse load-transmission and to prevent stress concentration on the tibial cartilage [3]. From responsiveness of loading, T2 evaluation under loading will be expected to allow detection of early degenerative changes of the cartilage and meniscus with high sensitivity before morphological changes appear, and to provide biomechanical assessment of ill-condition with respect to localized stress concentration in the cartilage, due to abnormal knee alignment such as varus/ valgus deformity or flexion contracture.

REFERENCES

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Fig.1: Loading apparatus

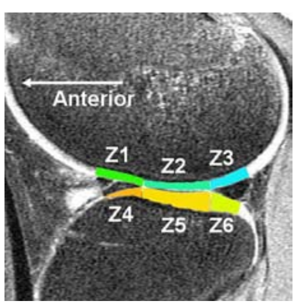

Fig. 2: Definition of ROIs

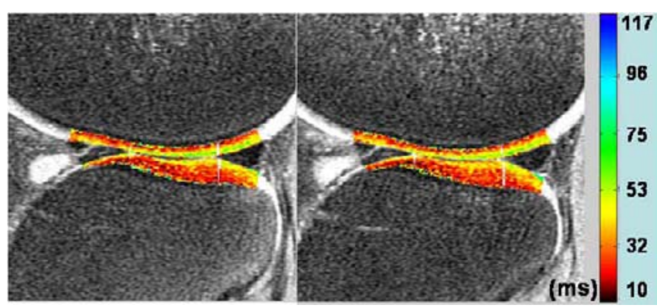

Fig. 3: T2 maps on unloading (left) and loading (right) conditions

Table 1: T2 values of each ROI (mean ± SD) under unloading and loading conditions on the medial and lateral femoro-tibia joints

	Medial femoro-tibial joints					Lateral femoro-tibial joints			
Zones	Unloading (ms)	Loading (ms)	Changes (%)*	P value		Unloading (ms)	Loading (ms)	Changes (%)*	P value
Z1	35.4 ± 3.0	35.1 ± 3.7	-0.3 ± 11.6	0.83		36.7 ± 2.5	35.5 ± 3.0	-3.0 ± 8.7	0.215
Z2	35.8 ± 2.5	34.2 ± 2.7	-4.4 ± 5.6	0.017		38.4 ± 3.5	36.6± 3.5	-4.6 ± 5.2	0.010
Z3	36.8 ± 2.3	36.9 ± 2.2	0.3 ± 4.4	0.88		40.5 ± 4.0	40.3 ± 3.0	-0.3 ± 5.2	0.711
Z4	33.9 ± 2.4	32.5 ± 3.8	-4.2 ± 7.2	0.07		36.8 ± 5.3	33.5 ± 4.3	-8.3 ± 8.8	0.007
Z5	35.1 ± 3.2	32.9 ± 2.2	-6.1 ± 6.1	0.005		35.2 ± 4.0	33.3 ± 2.9	-4.8 ± 7.7	0.034
Z6	35.6 ± 3.0	33.7 ± 2.3	-5.0 ± 6.3	0.011		36.9 ± 4.1	34.7 ± 3.4	-5.5 ± 9.1	0.057

* Changes were calculated as (T2 value on loading condition - T2 value on unloading condition) / T2 value on unloading condition *100