Individual joint loading type affects human cartilage composition as measured by biochemical MRI

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INTRODUCTION

Human locomotion is a complex, interactive process where body mass, muscle forces, ground reaction force (GRF) and joint motion affect the load-bearing cartilage thousands of times a day during activities of daily living. Biochemical MRI techniques provide indirect information on the structure and composition of cartilage. T2 relaxation time is sensitive to the properties of the collagen network and tissue hydration [1,2] while delayed Gadolinium Enhanced MRI of Cartilage (dGEMRIC) is sensitive to the proteoglycan content of cartilage [3]. The aim of this study was to investigate the effect of individual, biomechanically measured joint loading type on biochemical properties of load bearing articular cartilage, as measured by biochemical MRI.

MATERIALS AND METHODS

Thirty-seven healthy, asymptomatic male volunteers (24-46 years) were enrolled to the study and informed consent was obtained. Loading type was determined from biomechanical measurements performed on a 50-m long indoor runway. These included the measurement of loading rate, ground reaction force (GRF) and aerobic threshold for 29 subjects. Weight and BMI were determined for all participants.

Biochemical MRI measurements including T2 relaxation time and dGEMRIC measurements were conducted on 37 subjects. T2 relaxation time measurements were conducted using a multi-echo spin-echo sequence (with TR/TE=1500ms/15, 30, 45, 60ms; 5-mm slice thickness; 0.27x0.27mm in-plane resolution) in the sagittal plane covering the central weight-bearing area of lateral and medial femoral condyles. This was followed by the dGEMRIC-experiment involving an intravenous injection of 0.2mM per kilogram of weight (i.e. "double dose") of gadopentetate dimeglumine (Magnevist, Schering, Berlin, Germany) followed by 5 minutes of knee bending exercises and 5 minutes of walking. After a 90-minute delay, T1 relaxation time was measured using a single-slice inversion recovery fast spin echo sequence (TR/TE/TI=1800ms/16ms/50, 100, 200, 400, 800, 1600ms; 5-mm slice thickness; 0.27x0.27mm in-plane resolution). For cartilage segmentation, the load bearing areas of the femur and tibia were divided into various segments of load bearing cartilage, separately assessing the superficial and deep halves of the articular cartilages (Fig 1). For statistical analyses, linear correlation analysis was applied between MRI and biomechanical parameters. To further investigate these associations, the subjects were divided into two groups based on the median values of T2 or dGEMRIC for each ROI. The biomechanical parameters between groups were compared using the non-parametric Mann-Whitney test and two-way t-test.

RESULTS

Significant correlations were observed between MRI and biomechanical parameters. T2 and dGEMRIC were negatively correlated with BMI and body weight at tibia. Aerobic threshold correlated positively with T2 at central/posterior tibial regions of interest, while dGEMRIC in the deep cartilage of the posterolateral femur showed a positive correlation with level of the aerobic threshold (Table 1). dGEMRIC was negatively correlated with vertical GRF at one region of interest in the medial compartment of the femur and tibia. After dividing MRI parameters in each ROI into two groups based on the median values of T2 and dGEMRIC, a higher aerobic threshold was related with a longer T2 relaxation time at posterolateral tibia and lower dGEMRIC index at medial tibia and at lateral femur (Table 2). A lower dGEMRIC index at medial femur was related with a higher GRF.

DISCUSSION

Our results from the present study demonstrate how biomechanically controlled individual joint loading type affects the macromolecular status of articular cartilage as measured by biochemical MRI. Both MRI techniques are reported to reflect the mechanical properties of cartilage, demonstrating the connection between tissue integrity and matrix constituents [4]. The biochemical composition of cartilage is related to the characteristic loading type of individual subjects while the cartilage constituents may vary with physical performance. Cartilage constituents can be altered with exercise and adapt to individual loading conditions in daily-life activities or joint-loading exercise [5-7].

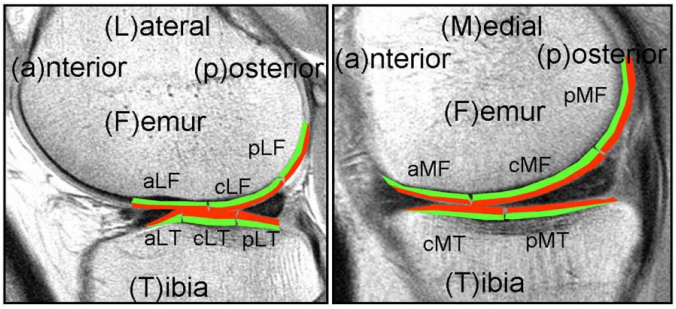

Fig. 1: The division and nomenclature of the cartilage segments.

Table 2: Comparison of biomechanical parameters between groups as divided by the median value of MRI parameters in each compartment. Only statistically significant differences are shown.

	< Median		≥ Median		
	N	Mean±SD	N	Mean±SD	P-value
T2					
Aerobic threshold					
pLTs	12	8.4±1.2	13	9.85±1.68	0.026[1]
dGemric					
GRF					
aMFs	14	2060±294	15	1835±182	0.019[2]
aMFd	13	2091±289	16	1823±171	0.004[2]
cMFd	13	2056±327	16	1852±157	0.055[2]
Aerobic threshold					
aLFs	14	9.5±0.94	10	8.8±2.30	0.045[1]
cMTs	14	10.0±1.62	11	8.1±0.83	0.002[1]

[1]Significance from Mann-Whitney's test. [2]Significance from t-test.

Table 1. Significant correlations between biomechanical measurements and MRI parameters.

	N	Pearson's r	P-value
T2			
BMI			
cMTs	37	-0.371	0.026
Weight			
pLTs	37	-0.413	0.011
Aerobic threshold			
aLTs	25	-0.498	0.011
pLTs	25	0.446	0.025
cMTs	25	0.478	0.016
pMTd	25	0.427	0.033
dGemric			
BMI			
aMFs	37	-0.381	0.020
cMTs	37	-0.327	0.048
cMTd	37	-0.346	0.036
Weight			
cMTs	37	-0.360	0.029
cMTd	37	-0.386	0.018
GRF			
aMFd	28	-0.431	0.019
pMTs	28	-0.373	0.046
Aerobic threshold			
pLFd	24	0.442	0.027

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