Are sports good for your knees? An MRI evaluation of the effects of basketball on knee health in Division I collegiate athletes

M. A. Vogelsong[1,2], G. Pappas[3], E. Staroswiecki[1,4], N. K. Bangerter[5], E. Han[6], B. A. Hargreaves[1], H. J. Braun[1], M. R. Safran[3], and G. E. Gold[1]

[1]Radiology, Stanford University, Stanford, CA, United States, [2]UCSF School of Medicine, San Francisco, CA, United States, [3]Orthopaedic Surgery, Stanford University, [4]Electrical Engineering, Stanford University, [5]Electrical Engineering, Brigham Young University, [6]GE Global Applied Sciences Laboratory, Menlo Park, CA

Introduction

Previous work has suggested that exercise may have protective effects on articular cartilage, particularly in subjects with an increased risk of osteoarthritis [1, 2]. Advances in imaging of the biochemical properties of cartilage have permitted a more nuanced look at the early changes elicited by exercise before later morphological changes seen on traditional proton MRI become apparent. Specifically, T_2 relaxation time mapping has been shown to reflect collagen structure and water content, while $T_{1\rho}$ has shown correlations to proteoglycan (PG) content [3,4]. Similarly, sodium MRI measures PG content directly, taking advantage of the attraction between positively charged sodium ions and negatively charged glycosaminoglycans [5]. This study aimed to evaluate the effects of an extended period of high intensity activity on knee health of collegiate basketball players using both conventional proton MRI as well as T_2, $T_{1\rho}$ and sodium imaging.

Methods

21 previously asymptomatic knees of 21 collegiate Division I basketball players (age 18-22; 10 male, 11 female) were imaged in the sagittal plane using a GE Signa Excite 3.0T MRI scanner (GE Healthcare, Milwaukee, WI) and an 8-channel proton (T_2 & $T_{1\rho}$) or custom sodium quadrature coil. Athletes were imaged prior to and within 1 month following the end of their 5 month competitive season. T_2 images were obtained using a 2D-FSE with TR/TE 2000/8.8, 16.5, 26.3, 35, 43.8, 52.5, 61.3, and 70 ms, 320x160 matrix size, 3 mm slice thickness, 16 cm FOV, and receiver bandwidth ± 41 kHz with a 10 min imaging time. $T_{1\rho}$ images were acquired using a prototype magnetization-prepared spoiled gradient echo sequence with a 500 Hz spin-lock pulse (TR/TSL 5.1/0, 10, 30, and 70 ms, 256 x 192 matrix size, 3 mm slice thickness, 16 cm FOV, 70-degree flip angle, receiver bandwidth ±62 kHz, 10 min imaging time) [6]. A fast gradient-spoiled sequence using the 3D cones *k*-space trajectory was used to obtain sodium images (TR/TE 35/0.6 ms, flip angle 70 degrees, 28 signal averages, resolution 1.25 x 1.25 x 4 mm, 21 minute imaging time) [7]. A test tube containing 100 mM saline was placed within the coil for normalization. Routine 2D-FSE images with fat suppression using axial and sagittal proton density weighting and sagittal T_2 weighting were also obtained.

An experienced musculoskeletal radiologist and orthopaedic surgeon evaluated the 2D-FSE images for patellar and quadriceps tendinopathy, ligament and meniscal injury, articular cartilage health and bone marrow edema. T_2 and $T_{1\rho}$ maps were generated and relaxation times as well as sodium signals were measured by two independent observers using OsiriX from the following 2D ROIs: medial/lateral anterior, central, and posterior femoral condyle, medial/lateral anterior and posterior tibia, and medial/lateral superior and inferior patellar cartilage (Figure 1). Student's paired t tests were used to compare T_2, $T_{1\rho}$ and sodium measures before and after the season while Pearson's correlation coefficient was used to assess interobserver reliability.

Results

Pathologies were frequently seen in the patellar region, with signal changes or defects in patellar articular cartilage seen in 10 and 13 subjects pre- and post-season and patellar bone marrow edema in 10 and 16 subjects pre- and post-season. Subjects also tended to have mild patellar and quadriceps tendinopathy, mild edema surrounding ligaments, and either no or mild intra-substance meniscal signal both before and after the season, with little change over the course of the season. Subjects showed significant increases in T_2 relaxation times in the lateral femur, medial femur, and medial tibia, as well as significant decreases in $T_{1\rho}$ relaxation times in all regions. Significant decreases were seen in sodium signal intensity in the patella (Table 1, Figure 2). Interobserver reliability was found to be strong for all imaging techniques (R=0.83, 0.87 & 0.90 for T_2, $T_{1\rho}$ & Na^+ respectively).

Table 1. Average Relaxation Times & Sodium Signal Intensities Pre- and Post-Season

Location		Pre-Season	Post-Season	*P*
Lateral Femur	T_2	39.47	40.99	***<0.001***
	$T_{1\rho}$	44.78	42.45	***<0.001***
	Na^+	1.0003	0.9996	*0.970*
Lateral Tibia	T_2	34.35	34.36	*0.994*
	$T_{1\rho}$	39.15	37.01	***<0.001***
	Na^+	0.9938	0.9691	*0.381*
Medial Femur	T_2	40.05	41.96	***<0.001***
	$T_{1\rho}$	42.91	41.21	***0.002***
	Na^+	1.0357	0.9972	*0.170*
Medial Tibia	T_2	38.06	40.82	***<0.001***
	$T_{1\rho}$	43.42	41.79	***0.022***
	Na^+	1.0257	1.0224	*0.922*
Patella	T_2	35.92	36.35	*0.322*
	$T_{1\rho}$	42.69	40.72	***<0.001***
	Na^+	0.9665	0.8903	***<0.001***

Discussion

These results suggest that in a young population of asymptomatic athletes, high intensity basketball may have beneficial effects on tibiofemoral and potentially damaging effects on patellofemoral articular cartilage. While conventional MRI showed few morphological changes in the tibiofemoral region, the decrease in $T_{1\rho}$ relaxation times may indicate increased deposition of proteoglycans (PGs) within the articular cartilage, which may then draw more water into the cartilage leading to an increase in T_2. However, the decrease seen in sodium signal intensity in the patella conflicts with the decrease in $T_{1\rho}$, as it indicates a loss of PGs. It is possible that in this region, the structural damage in the patella seen on proton scans may have had a greater influence on T_2 and $T_{1\rho}$ than the decrease in PG content. Meanwhile, the sodium results may have been affected by measurement errors from partial volume effects, most notably in the thinner tibiofemoral ROIs. Additionally, there were likely slight variations in the amount of activity in which each subject engaged over the season, potentially confounding the results. However overall, these findings indicate that basketball may have varying effects on different cartilage regions and that new quantitative imaging techniques may be useful for detecting subtle cartilage changes.

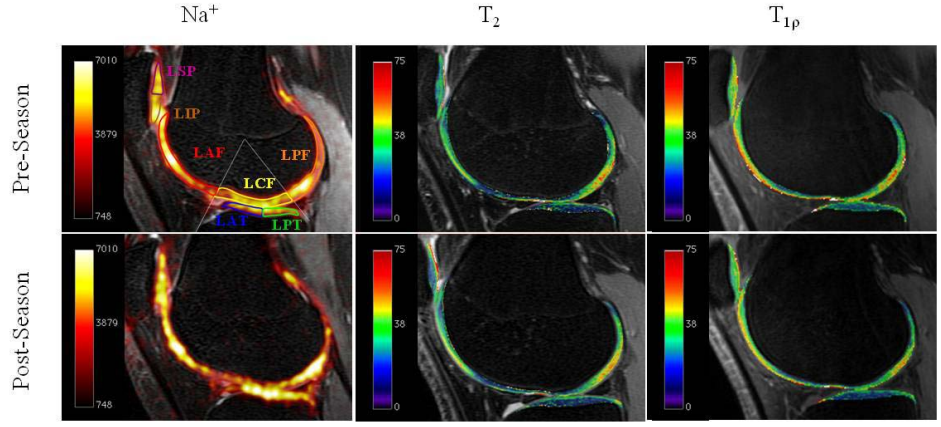

Figure 1. Examples of sodium images (overlaid on proton images) as well as T_2 and $T_{1\rho}$ fit maps before and after the season. The pre-season sodium scan shows examples of lateral ROIs. Note the general increase in T_2 and decrease in $T_{1\rho}$ relaxation times.

References

1. Roos and Dahlberg. Arth & Rheum 2005; 52(11):3507-14.
2. Tiderius et al. Magn Resn Med 2004;51:286-90.
3. Mosher et al. Radiology 2000; 21:259-66.
4. Regatte et al. Acad Radiol 2002; 9(12): 1388-94.
5. Shapiro et al. Magn Resn Med 2002; 47(2): 284-91.
6. Li et al. Magn Res Med 2009; 61: 1310-18.
7. Staroswiecki et al., J Magn Reson Imaging 2010;32(2):446-51.

Acknowledgements

NIH EB002524, EB005790, GE Healthcare, SCTB/MR