

Voxel-based Relaxometry of Knee Articular Cartilage $T_{1\rho}$ and T_2 Relaxation in Collegiate Basketball Players: A Multicenter Study

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HIGHLIGHT: The purpose of this study was to use voxel-based relaxometry (VBR), a fully automatic registration technique that aligns images to a single reference template, to compare the local distribution of knee articular cartilage $T_{1\rho}$ and T_2 relaxation times between impact athletes (basketball players) and non-impact athletes (swimmers).

INTRODUCTION: High prevalence of morphological changes has been observed in knee cartilage of jumping and impact athletes using magnetic resonance imaging (MRI). More recently, advanced MRI techniques, such as simultaneous $T_{1\rho}$ - and T_2 -weighted acquisition, have shown to be effective in quantifying biochemical changes of macromolecules that initiate cartilage degeneration prior to the manifestation of visible morphological changes. Quantitatively determining early changes in matrix biochemistry would provide insight to understanding how impact sports affect cartilage health and overall risk of degenerative disease.

METHODS: In this multicenter cross-sectional study, two cohorts of NCAA collegiate-level athletes were imaged by 3.0T MRI prior to the beginning of their competitive seasons: 42 basketball players (23 female); and 25 swimmers (11 female). The MRI protocol included 3D sagittal combined $T_{1\rho}/T_2$ magnetization-prepared angle-modulated portioned k -space spoiled gradient echo snapshots (MAPSS) sequence. For each case, sagittal MAPSS images in all echoes were rigidly registered to the first time of spin-lock/echo time (0 msec). Next, nonrigid registration to an atlas was then applied on all cases to morph the images to a common reference space, and $T_{1\rho}$ and T_2 maps were created using Levenberg-Marquardt mono-exponential fitting to the morphed images. VBR-based analysis consisted of generating statistical parametric maps (SPMs) voxel-by-voxel to assess local group differences. A classical ROI-based technique, consisting of automatic compartmental segmentation of the cartilage was performed for comparison.

RESULTS: In both impact and non-impact groups, the average $T_{1\rho}$ and T_2 SPMs from VBR-based analysis, displayed prolonged values near the trochlear groove and areas of tibio-femoral articulation, and shorter values anteriorly and posteriorly. Comparison of the two groups demonstrated significant differences by sport, with basketball players generally having higher values, particularly in femoral condyle cartilage with 28.9% and 23.9% of significant voxels in the lateral and medial compartments, respectively, showing prolonged $T_{1\rho}$ in the impact group. Group analysis also revealed differences through the depth of the articular cartilage: basketball players had higher $T_{1\rho}$ and T_2 values in the deep layer of cartilage while swimmers had higher values in the superficial layer. This is most notable in the patellofemoral joint. Amongst the ROI-based results, basketball players had significantly elevated $T_{1\rho}$ values in the medial femoral condyle and medial tibial compartments. No significant differences were detected in the patellofemoral compartment using the ROI-based approach.

DISCUSSION: Our results demonstrate the ability of a fully automatic, voxel-by-voxel quantification of MR $T_{1\rho}/T_2$ relaxation times to provide information about the local biochemical composition of the cartilage matrix. Disparity between the deep and superficial articular layers could be attributed to differences in the frequency and magnitude of loading forces in jumping and running exercises practiced in basketball. The differences detected in the patella relate well to previous research that identified this region to most likely have articular cartilage lesions in basketball players. This contrast also illustrates the disadvantages of commonly used ROI-based results, where laminar differences may be averaged out within the traditional divisions of cartilage compartments.

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