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## LONGITUDINAL, LAYER-SPECIFIC CARTILAGE COMPOSITION CHANGE (T2) DURING MATURATION AND DEGENERATION

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### Abstract:

#### Purpose:

Cartilage transverse MRI relaxation time (T2) is known to be associated with cartilage composition, particularly with hydration and collagen content, and collagen orientation. T2 represents a promising imaging biomarker of “early” OA. The objective of this study was to explore longitudinal change of T2 in medial femorotibial cartilage during maturation in a sample of top volleyball athletes at the end of adolescence. Further, we explored longitudinal T2 change associated with potential cartilage degeneration in another sample of patients with posterior cruciate ligament (PCL) rupture, who are known to loose cartilage rapidly. Analyses were conducted for both deep and superficial cartilage layers, as both differ in hydration status and collagen architecture.

#### Methods:

The dominant knees of 18 young volleyball athletes (8 men, 10 women, age 15.9±0.6y, BMI 21.5±1.8), who trained twice per day for approx. 2 hours, were followed over 2 years. Twelve patients (10 male, 2 female, age 39.6±9.9y, BMI 28.3±4.5) who had isolated and combined PCL injuries and reconstructive PCL surgery 4 to 14 years earlier were studied over 1 year. A sagittal 2D multi-echo spin echo (MESE) sequence with 6 echoes (TEs 9.7, 19.4, 29.1, 38.8, 48.5, and 58.2 ms; TR 1500ms, in-plane resolution 0.31mm, slice thickness 3 mm) was acquired at 1.5T (Siemens Avanto). T2 was calculated using non-linear curve fitting with exclusion of the first echo (9.7ms). Segmentation of the medial tibia (MT) and central, weight-bearing medial femur (cMF) was performed using images with the shortest and longest echo, with an optional overlay of the T2 values. The mean cartilage T2 was extracted for the superficial (top 50%) and deep layer (bottom 50%). Paired t-tests were used to explore the T2 differences between baseline and follow-up and unpaired t-tests to compare men and women. The association between T2 and cartilage volume change (from T2 map segmentations) was analyzed using Pearson correlation coefficients.

#### Results:

In the young volleyball athletes, a significant decrease in cartilage T2 was observed in the deep layer of MT and cMF (p<0.01; Table 1); the decrease observed in the superficial layers was not significant (p=0.07 and 0.74). A significant increase in cartilage volume was seen in cMF (+0.5%; p<0.001). Young men had greater baseline T2 values than women in the superficial layer of cMF (p<0.01), but this sex difference did not reach statistical significance in MT (p=0.07) or in the deep layers of MT or cMF (p=0.08 and 0.66). Superficial or deep baseline T2 were not significantly associated with subsequent cartilage volume change (r≤0.35), nor was the concurrent T2 and cartilage volume change in the same cartilage plate (-0.11≤r≤0.42). In PCL patients, no systematic change in T2 was observed in MT or cMF (p≥0.55, Table 1). Volume changes amounted to -1.4% in both MT and cMF, but were not significant (p≥0.34). Baseline T2 in the deep and superficial layers of MT predicted subsequent change in cartilage volume in MT (r=-0.59/-0.56; p=0.04/0.06), but no significant association was observed in cMF (r≤0.34).

There was a significant relationship of concurrent change of superficial T2 and cartilage volume in MT ( $r=0.72$ ;  $p<0.05$ ), but no significant associations for T2 of the deep layer T2, or concurrent volume and T2 change in either layer in cMF ( $-0.43 \leq r \leq 0.41$ ).

**Conclusions:** The results demonstrate that cartilage maturation at the end of adolescence is associated with a systematic decrease in deep layer T2, potentially reflecting changes in hydration and macromolecular reorganization. In PCL patients, baseline T2 predicted subsequent tibial cartilage volume change, and there was concurrent change in superficial T2 and tibial (but not femoral) cartilage volume. Future studies need to explore to what extent the maturation and degenerative processes in cartilage composition are associated with wet (synovial fluid, serum and urine) markers of collagen formation and degradation, and whether these predict the onset of radiographic changes after PCL injury.

Baseline (BL) values and mean change (MC) in cartilage T2 (ms) in the superficial and deep layer.

			Baseline				Change			
			Mean	Standard deviation	95% confidence intervals		Mean	95% confidence intervals	P-value	
Young athletes	Medial tibia	Superficial layer	50.7	2.4	49.5	52.0	-1.1	-2.0	-0.2	0.07
	(MT)	Deep layer	50.1	3.2	48.5	51.8	-2.4	-3.9	-0.9	0.002
	Central medial femur	Superficial layer	53.8	2.5	52.5	55.1	-0.8	-1.8	0.2	0.74
	(cMF)	Deep layer	47.4	2.0	46.4	48.4	-2.0	-3.0	-0.9	0.004
PCL patients	Medial tibia	Superficial layer	50.8	2.1	49.5	52.1	-0.3	-1.4	0.8	0.55
	(MT)	Deep layer	47.8	2.1	46.5	49.2	0.3	-1.5	2.2	0.70
	Central medial femur	Superficial layer	52.9	4.5	50.0	55.7	-0.5	-2.8	1.9	0.66
	(cMF)	Deep layer	47.7	6.1	43.8	51.6	-0.1	-2.1	1.9	0.91

**Category (Complete):** Imaging

**Keyword (Complete):** Knee ; Magnetic Resonance Imaging ; Quantitative MRI

**Presentation Preference (Complete):** Podium Preference

**Additional (Complete):**

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