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Quantitative Evaluation of Knee Cartilage in Professional Martial Arts Athletes Using T2 Mapping: A Comparative Study

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Context: Although the relationship between high-impact sports like football and basketball and the development of knee osteoarthritis is well established, the effect of martial arts on the knee joint remains unclear.

Objective: To compare the imaging abnormalities of knee joints and T2 relaxation times of cartilage in professional martial arts athletes and healthy controls.

Design: Cross-sectional study.

Setting: Hospital imaging center.

Patients or Other Participants: Nine asymptomatic professional martial arts athletes and 18 healthy volunteers.

Main Outcome Measure(s): We performed 3T magnetic resonance imaging of the knee on both legs of athletes and the dominant leg of controls. The magnetic resonance imaging protocol included conventional sequences used for morphological assessment (cartilage, meniscus, ligaments, joint effusion, and bone marrow edema) and T2 mapping used for quantitatively evaluating the cartilage. Knee cartilage was manually divided into 8 regions, and T2 relaxation times of the corresponding subregions were measured. Fisher exact test and *t* test were used to compare the frequency of lesions and cartilage T2 values both between groups and between the athletes' limbs. $P < .05$ was considered significant.

Results: Professional martial arts athletes exhibited significantly higher frequencies of cartilage (55.6% vs 11.1%, $P = .023$) and ligament lesions (66.7% vs 16.7%, $P = .026$) compared with the control group. Athletes showed higher T2 values in 3 distinct cartilage segments: the central weight-bearing segment of the medial femoral condyle ($P = .006$), the medial tibial plateau ($P = .012$), and the trochlea ($P = .032$), when compared with the controls. Additionally, the dominant leg of athletes showed significantly higher T2 values compared with the nondominant leg.

Conclusions: The findings demonstrated the impact of martial arts on the knee joint, characterized by higher prevalence of lesions and elevated cartilage T2 values, particularly in the medial compartment. The dominant legs of martial arts athletes seem to have higher risk of cartilage degeneration due to the observed interlimb differences in T2 values.

Key Words: T2 relaxation times, sports injury, interlimb asymmetry, quantitative magnetic resonance imaging

Key Points

- Professional martial arts athletes exhibit a greater incidence of imaging abnormalities in knee joints, particularly with regard to femur, patellar cartilage, and anterior cruciate ligament lesions.
- T2 relaxation times of cartilage in athletes were higher than those of healthy controls, particularly in the medial compartment, potentially serving as an early marker of cartilage degeneration.
- In professional martial arts athletes, the dominant leg showed significantly higher T2 relaxation times compared with the nondominant leg.

Martial arts have been widely practiced as a form of physical activity in various Eastern Asian countries.[1] Since the 1950s, they have gained immense popularity in the Western world as well. For example, in the United States, the number of martial arts participants has increased by 60% during the past decade, from 3.6 million people in 1993 to 6 million people in 2001.[1] The continuous development and popularization of martial arts have also brought some negative effects while improving people's physical fitness. During martial arts training, professional athletes often perform rapid knee bending, knee extension, half knee bending, and other similar movements that can impose significant local load on the knee joint, resulting in an increased risk of knee injuries. A recent study reported that the prevalence of knee osteoarthritis (OA) in Chinese martial arts athletes is as high as 15.6%.[2,3] The degeneration of articular cartilage is a primary feature of OA pathogenesis. Therefore, it is crucial to develop a noninvasive and effective method for detecting early cartilage lesions, which may be reversible and difficult to perceive using conventional magnetic resonance imaging

(MRI) sequences, in asymptomatic martial arts athletes. Such an advancement would allow for timely implementation of preventive measures against OA and avoid long-lasting injuries.

T2 mapping has been widely used to characterize and quantify the biochemical composition of cartilage before morphological damage is visible.[4] Quantitative measures of T2 relaxation times are particularly responsive to changes in cartilage water content, collagen composition, and tissue anisotropy.[5] Previous authors have investigated the alterations in the biochemical composition of knee cartilage among professional athletes from various sports disciplines (football, marathon, volleyball, etc).[6–8] However, to the best of our knowledge, no published research has yet investigated the effects of martial arts on knee cartilage. The purpose of this study was to evaluate knee-cartilage T2 relaxation times in professional elite martial arts athletes and healthy volunteers using T2 mapping. We hypothesized that the knee cartilage of professional athletes adapts to local mechanical loading, leading to elevated T2 relaxation times in the regions at risk for degeneration.

METHODS

Participants

Approval was obtained from the ethics committee of Tongji Hospital of Huazhong University of Science and Technology (TJ-IRB20220162). The procedures used in this study adhere to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants. We recruited 9 professional athletes (4 men and 5 women) aged 18 to 25 years from a local martial arts team. They were national first-class athletes, with a training history of 10 to 14 years. Eighteen gender- and age-matched volunteers (8 men and 10 women) who performed less than 2 hours of moderate-to-vigorous physical activity per week (≥4 metabolic equivalent tasks [METs]) were recruited from the local medical school as a control group. The short version of the International Physical Activity Questionnaire was used to assess the physical activity of all participants.[9] Each participant self-reported free from knee-related symptoms. Exclusion criteria included tumor, major trauma (eg, fracture, prior surgery), inflammatory disease (eg, rheumatoid arthritis), or contraindications for MRI (eg, claustrophobia, metal implants).

All participants were required to rest in a sitting position for 30 minutes before MRI scanning to minimize the impact of prior physical activity on cartilage relaxation times. Their *dominant leg* was defined as the preferred leg to kick a ball, and all participants self-reported right-side dominance. Professional elite martial arts athletes underwent bilateral knee MRI, whereas volunteers received right-knee (dominant-leg) examinations.

MRI

All MRI examinations were performed using a 3T scanner (Magnetom Skyra, Siemens Healthcare, Erlangen, Germany) with a dedicated 15-channel knee array coil. The participants lay in a supine position with their knee fully extended, and the lower edge of the patella was the scanning center. Soft pads were placed around the knee joint to minimize motion during data acquisition. The imaging protocol included 2 proton-density (PD)/T2-weighted fat-suppressed turbo spin-echo (TSE) sequences in the sagittal (repetition time [TR] 3200 milliseconds; echo time [TE] 9.9/99 milliseconds; field of view [FOV] 180 × 180 mm; slice thickness 4 mm; matrix 384 × 384) and coronal planes (TR 3000 milliseconds; TE 9.9/99 milliseconds; FOV 180 × 180 mm; slice thickness 4 mm; matrix 384 × 384), a sagittal T1-weighted TSE sequence (TR 650 milliseconds; TE 12 milliseconds; FOV 160 × 160 mm; slice thickness 4 mm; matrix 384 × 384), an axial PD TSE sequence (TR 3550 milliseconds; TE 33 milliseconds; FOV 140 × 140 mm; slice thickness 4 mm; matrix 384 × 384) and a sagittal 2D multiecho spin-echo sequence for T2 mapping (TR 1300 milliseconds; TEs 13.8, 27.6, 41.4, 55.2, 69.0, and 82.8; FOV 250 × 250 mm; slice thickness 3 mm; matrix 384 × 384).

Image Analysis

Before image analysis, MRI datasets were anonymized and distributed in a random order. Two musculoskeletal radiologists with 6 and 10 years of experience independently read all images. For morphological analysis, the modified Whole-Organ Magnetic Resonance Imaging Score (WORMS) was used to assess cartilage, meniscus, and ligament lesions as well as joint effusion and bone marrow edema.[10–12] Disagreement between the 2 radiologists occurred occasionally (approximately 1%), and in such cases, a consensus was reached through discussion. The detailed grading criteria were as follows:

1. Meniscus lesions were graded separately in 6 regions (medial/lateral and anterior/body/posterior) as follows: 0 = *intact*, 1 = *intrasubstance abnormal signal*, 2 = *nondisplaced tear*, 3 = *displaced tear*, 4 = *complete maceration/destruction*.
2. Ligaments including anterior cruciate ligament (ACL), posterior cruciate ligament, medial collateral ligament, and lateral collateral ligament lesions were graded from 0 to 3: 0 = *no lesion*, 1 = *signal changes around the ligament*, 2 = *partial tear*, and 3 = *complete tear*.
3. Cartilage signal and morphology were scored in 6 articular surfaces (patella [PAT], trochlea [TRO], medial and lateral femur, and medial and lateral tibia): 0 = *normal thickness and signal*, 1 = *normal thickness but increased signal on T2-weighted images*, 2 = *partial-thickness focal defect <1 cm in greatest width*, 2.5 = *full-thickness focal defect <1 cm in greatest width*, 3 = *multiple areas of partial-thickness (grade 2) defects intermixed with areas of normal thickness, or a grade 2.0 defect wider than 1 cm but <75% of the region*, 4 = *diffuse (≥75% of the region) partial-thickness loss*, 5 = *multiple areas of full-thickness loss (grade 2.5) or a grade 2.5 lesion wider than 1 cm but <75% of the region*, 6 = *diffuse (≥75% of the region) full-thickness loss*.
4. Joint effusion was graded from 0 to 3 in terms of the estimated maximal distention of the synovial cavity: 0 = *normal*, 1 ≤ *33% of maximum potential distention*, 2 = *33% to 66% of maximum potential distention*, 3 ≥ *66% of maximum potential distention*.
5. Bone marrow edema was scored as 0 (*not present*) or 1 (*present*).

The WORMS score was obtained by adding up the scores of all regions within each structure. Any joint structure with

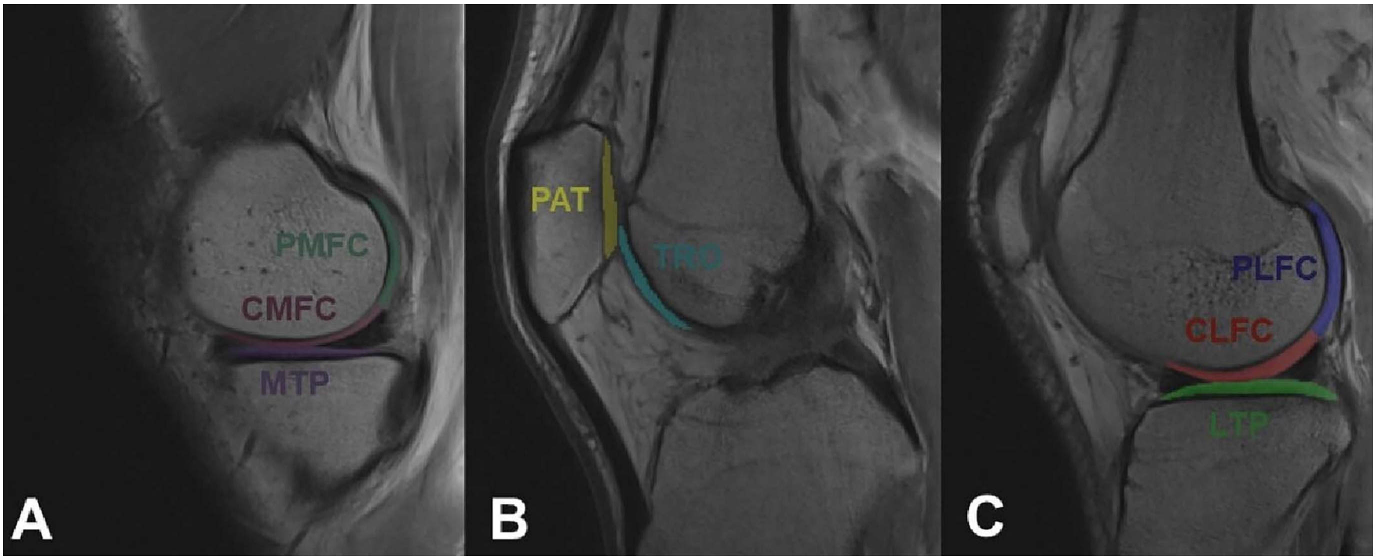

Figure. Cartilage regions of interest. A, Central medial femoral condyle (CMFC), posterior medial femoral condyle (PMFC), and medial tibial plateau (MTP). B, Patella (PAT) and trochlea (TRO). C, Central lateral femoral condyle (CLFC), posterior lateral femoral condyle (PLFC), and lateral tibial plateau (LTP).

a WORMS score exceeding 0 was considered indicative of a lesion. The frequency of lesions was defined as the percentage of individuals with a WORMS score greater than 0 across different structures.

T2 maps were automatically created via an online reconstruction process, which involved a pixelwise, mono-exponential, nonnegative least-squares fit analysis of the source multiecho T2 mapping images (MapIt, Siemens Medical Solutions).[13] The pixel values on the T2 maps represented the T2 relaxation times at the corresponding locations. Therefore, delineating the region of interest (ROI) directly on the T2 maps allowed for the determination of the T2 values for a specific cartilage area. During the cartilage segmentation process, the 2 radiologists separately performed segmentations for all participants using ImageJ software (version 1.52v; National Institutes of Health). After this, the T2 relaxation times for each ROI were averaged between the radiologists before being used in the subsequent statistical analysis. The knee cartilage was partitioned into 3 compartments, namely the medial tibiofemoral, lateral tibiofemoral, and patellofemoral cartilage. One midsagittal slice of the medial joint compartment, one midsagittal slice of the lateral joint compartment, and one midsagittal slice of the patella were selected for analysis. The selection was determined by counting the total number of slices through these structures, and in cases where 2 central slices were available, the one with the visually clearest bone-cartilage interface was preferred.[14,15] The medial and lateral femoral condyles (MFC and LFC) were further separated into central and posterior weight-bearing segments, which were bounded by the meniscus border. The TRO cartilage was defined as the entire cartilage visible on the midsagittal slice of the patella. Thus, each knee joint was divided into 8 subregions: central weight-bearing and posterior weight-bearing segments of the MFC and LFC, medial tibial plateau (MTP) and lateral tibial plateau, PAT, and TRO.[16,17] The ROI was manually delineated by 2 independent radiologists on the above-mentioned 3 slices of the T2 maps, with the first echo images serving as the morphological reference (Figure). Mean T2 relaxation times for each subregion were measured individually, and then an average of all ROIs was computed to obtain global knee T2 value. It is worth noting that meniscus and joint effusion were excluded to reduce the impact of partial volume effects.

Statistical Analysis

A priori power analysis was performed using G*power software (version 3.1.9.7; Heinrich-Heine-Universität Düsseldorf) to determine the sample size. The power calculation was performed using a 2-tailed t test between 2 independent groups, with an α level of .05, a power of 80%, and an effect size of 1.4. The effect sizes required for this analysis were derived from relevant previous studies and were calculated based on the mean and standard deviation of T2 relaxation times in dancers and control groups.[18] Specifically, the effect sizes for the 3 talar cartilage zones (anterior, middle, and posterior) were determined as 1.7, 1.4, and 2.1, and a conservative estimate of 1.4 was selected for sample size calculations. The analysis results indicated that a sample size of 22 individuals (7 athletes and 15 controls) would be adequate for detecting differences between the 2 groups.

Statistical analysis was performed using SPSS software (version 26.0; IBM Corp). The Shapiro-Wilk test was used to assess normal distribution of all measurement values. The Fisher exact test was used to compare the frequency of lesions, and the Mann-Whitney U test was used to compare the WORMS scores of morphological abnormalities. The interobserver agreement regarding the measurements of T2 relaxation times was evaluated using the intraclass correlation coefficient (ICC) with a 2-way random-effects model, where an ICC of 0.00 to 0.39 was considered poor, 0.40 to 0.59 was fair, 0.60 to 0.74 was good, and 0.75 to 1.00 was excellent for assessing the degree of agreement.

An independent-samples t test was used to determine the differences in T2 values between the dominant legs of professional martial arts athletes and healthy controls. Additionally, a paired-samples t test was used to compare the T2 values between the dominant and nondominant legs in athletes. Because a substantial number of comparisons (a total

Table 1. Frequency and WORMS Score of Knee Lesions in Professional Martial Arts Athletes and Healthy Controls[a]

	Professional Athletes				
	Right Knee	Left Knee	*P* Value[b]	Healthy Controls	*P* Value[c]
Cartilage lesions					
Frequency, No. %	5 (55.6)	1 (11.1)	.131	2 (11.1)	**.023**
WORMS, mean ± SD	3.8 ± 4.1	0.3 ± 1.0	**.031**	0.2 ± 0.5	**.006**
Meniscal lesions					
Frequency, No. %	3 (33.3)	2 (22.2)	1.000	2 (11.1)	.295
WORMS, mean ± SD	0.4 ± 0.7	0.3 ± 0.7	.654	0.1 ± 0.3	.148
Ligament lesions					
Frequency, No. %	6 (66.7)	2 (22.2)	.153	3 (16.7)	**.026**
WORMS, mean ± SD	0.9 ± 0.8	0.3 ± 0.7	.094	0.2 ± 0.4	**.007**
Joint effusion					
Frequency, No. %	6 (66.7)	3 (33.3)	.347	6 (33.3)	.127
WORMS, mean ± SD	0.8 ± 0.7	0.3 ± 0.5	.136	0.3 ± 0.5	.077
Bone marrow edema	0 (0.0)	0 (0.0)	1.000	0 (0.0)	1.000
Total WORMS	5.9 ± 4.5	1.3 ± 1.4	**.014**	0.8 ± 1.2	**.001**

Abbreviation: WORMS, Whole-Organ Magnetic Resonance Imaging Score.
[a] *P* values < .05 indicate statistically significant results and are marked in bold.
[b] *P* values represent the difference between right (dominant leg) and left (nondominant leg) knee cartilage in professional martial arts athletes.
[c] *P* values represent the difference between professional martial arts athletes and healthy controls.

of 18 individual tests) were conducted, the Benjamini-Hochberg method was used for the correction of multiple comparisons, with a false discovery rate threshold set at 0.05.[19] The associated *P* values presented in the paper underwent adjustment using the Benjamini-Hochberg method. $P < .05$ was considered statistically significant.

RESULTS

No significant differences were observed between professional martial arts athletes and volunteers in relation to various demographic and physical characteristics. In this study, characteristics included sex, age (20.1 ± 1.1 vs 20.9 ± 1.3; $P = .101$), height (167.3 ± 8.2 vs 168.3 ± 8.3; $P = .844$), weight (61.1 ± 8.7 vs 60.5 ± 9.8; $P = .686$) and body mass index (21.7 ± 1.1 vs 21.3 ± 2.1; $P = .444$). Professional athletes had been practicing martial arts for 11.6 ± 1.9 years and 14.7 ± 1.0 hours per week. The activity levels were quantified using the International Physical Activity Questionnaire, and the results indicated an average of 7469.2 ± 545.0 MET-min/w for athletes and 454.0 ± 60.9 MET-min/w for healthy controls.

Morphological Assessment

Table 1 presents the results of the knee morphological assessment using PD-weighted, T1-weighted, and T2-weighted images, as measured by the WORMS score and frequency. The total score of WORMS in professional martial arts athletes was significantly higher than that in the control group (5.9 ± 4.5 vs 0.8 ± 1.2; $P = .001$), with statistically significant differences observed in the assessment of cartilage (3.8 ± 4.1 vs 0.2 ± 0.5; $P = .006$) and ligaments (0.9 ± 0.8 vs 0.2 ± 0.4; $P = .007$) between the 2 groups. According to the findings of the Fisher exact test, the incidences of cartilage and ligament lesions were higher in athletes (55.6% and 66.7%, respectively) than in controls (11.1% and 16.7%; $P = .023$ and $P = 0026$). Specifically, there were significant differences in the PAT (44.4% vs 0%, $P = .007$), MFC (44.4% vs 0%, $P = .007$), and LFC (33.3% vs 0%, $P = .029$), whereas no significant differences were observed in the TRO (11.1% vs 0%, $P = .333$), MTP (22.2% vs 5.6%, $P = .250$), or lateral tibial plateau (0% vs 5.6%, $P = 1.000$). There was a significant difference in the frequency of ACL lesions (55.6% vs 11.1%; $P = .023$), whereas no significant differences were observed for posterior cruciate ligament, medial collateral ligament, or lateral collateral ligament.

When comparing the dominant and nondominant legs of professional martial arts athletes, a greater prevalence of cartilage lesions and higher WORMS score were observed in the dominant leg (Table 1). However, no significant difference was detected in other structural abnormalities between the 2 legs.

Comparisons of T2 Relaxation Time

The interobserver agreement was excellent for all segmental cartilage measurements (ICC ranged from 0.819 to 0.918). Regional analysis showed that the professional athletes had significantly higher cartilage T2 times than healthy controls in the following regions: central weight-bearing MFC (43.8 ± 2.9 vs 38.8 ± 3.0 milliseconds; $P = .006$), MTP (41.8 ± 2.9 vs 38.4 ± 2.1 milliseconds; $P = .012$), and TRO (42.9 ± 2.6 vs 40.2 ± 2.2 milliseconds; $P = .032$). The central weight-bearing MFC demonstrated the largest difference between the 2 groups, followed by the MTP.

In addition, when comparing the bilateral knee joints of martial arts athletes, significantly higher T2 values in the dominant leg were found in the central weight-bearing MFC (43.8 ± 2.9 vs 40.6 ± 2.5 milliseconds; $P = .014$) and MTP (41.8 ± 2.9 vs 36.6 ± 2.2 milliseconds; $P = .009$). These results are summarized in Table 2.

DISCUSSION

In this study, we performed a conventional MRI-based morphological assessment of the knee joints of asymptomatic professional elite martial arts athletes and quantified their

Table 2. T2 Relaxation Time for Different Regions of Interest (ROIs) of Knee Cartilage[a]

Location	Elite Martial Arts Athletes T2 (Right)	T2 (Left)	*P* Value[b]	Healthy Controls	*P* Value[c]
Global	40.4 ± 1.9	39.3 ± 1.8	0.122	38.8 ± 1.0	0.100
ROI 1 (CMFC)	43.8 ± 2.9	40.6 ± 2.5	**0.014**	38.8 ± 3.0	**0.006**
ROI 2 (PMFC)	38.4 ± 3.0	38.1 ± 1.7	0.971	38.6 ± 3.9	0.971
ROI 3 (MTP)	41.8 ± 2.9	36.6 ± 2.2	**0.009**	38.4 ± 2.1	**0.012**
ROI 4 (PAT)	38.1 ± 2.7	37.6 ± 2.7	0.751	37.5 ± 3.0	0.894
ROI 5 (TRO)	42.9 ± 2.6	40.9 ± 2.2	0.100	40.2 ± 2.2	**0.032**
ROI 6 (CLFC)	41.7 ± 3.9	40.6 ± 3.5	0.761	39.8 ± 2.0	0.369
ROI 7 (PLFC)	37.6 ± 3.3	40.0 ± 2.3	0.122	37.8 ± 2.3	0.971
ROI 8 (LTP)	39.3 ± 3.8	39.7 ± 2.8	0.971	39.5 ± 2.4	0.971

Abbreviations: CLFC, central weight-bearing of lateral femoral condyle; CMFC, central weight-bearing of medial femoral condyle; LTP, lateral tibial plateau; MTP, medial tibial plateau; PAT, patella; PLFC, posterior weight-bearing of lateral femoral condyle; PMFC, posterior weight-bearing of medial femoral condyle; TRO, trochlea.

[a] T2 relaxation times are presented in milliseconds. *P* values $< .05$ indicate statistically significant results and are marked in bold.

[b] *P* values represent the difference between right (dominant leg) and left (nondominant leg) knee cartilage in elite martial arts athletes.

[c] *P* values represent the difference between elite martial arts athletes and healthy controls.

cartilage T2 relaxation times using T2 mapping in comparison with healthy controls. As hypothesized, professional martial arts athletes showed significantly more imaging abnormalities and higher cartilage T2 relaxation times, particularly in the medial compartment. Furthermore, we observed elevated T2 relaxation times in the dominant legs of martial arts athletes compared with their nondominant legs. To the best of our knowledge, this is the first cross-sectional study to assess potential cartilage differences in young professional martial arts athletes using T2 mapping.

The presence of abnormal MRI findings in the knee joint of asymptomatic individuals has been reported in both athletic and general populations. Our study revealed a high incidence of MRI abnormalities in asymptomatic professional martial arts athletes, which is consistent with previous studies in asymptomatic professional basketball players, asymptomatic adolescent soccer players, and asymptomatic adolescent swimmers.[20–22] The important finding of this study was a significantly greater frequency and WORMS score of cartilage and ligament lesions in the knees of professional martial arts athletes compared with the control group. Specifically, cartilage and ligament lesions were observed in 55.6% and 66.7% of athletes, respectively, whereas only 11.1% and 16.7% of controls exhibited such lesions. Notably, prospective studies have correlated imaging findings in asymptomatic athletes with subsequent development of symptoms.[23] Magnetic resonance imaging examinations can enable the identification of at-risk asymptomatic athletes, which is critical for early detection and proactive intervention to prevent subsequent symptomatic injury among this population.

Articular cartilage is composed of chondrocytes surrounded by the extracellular matrix, composed mainly of proteoglycans, water, and type II collagen. Early degenerative cartilage changes include decreases in proteoglycan content due to limited synthesis and excessive loss, as well as destruction of collagen fiber structure and changes in arrangement. Such alterations increase the permeability of the cartilage surface to water molecules and the fluidity of free water within the cartilage, ultimately resulting in an elevation in T2 value.[5] Numerous studies conducted to date have shown that T2 mapping holds significant promise as a biomarker for cartilage degeneration.[24] This noninvasive imaging technique has been extensively used to investigate cartilage changes in the setting of OA risk factors, such as physical activity. Previous studies have demonstrated that physically active individuals have higher cartilage T2 relaxation times compared with healthy participants, which is consistent with the findings of our study.[25,26] In a recent study focusing on adolescent volleyball players, Roth et al found that the maximum T2 relaxation times of competitive athletes exceeded those of the controls.[27] The authors concluded that volleyball as a competitive sport in adolescence leads to preclinical knee-cartilage changes, potentially representing the initial signs of cartilage degeneration. Similarly, a cross-sectional study by Cha et al revealed a trend toward increasing cartilage T2 values in professional female ballet dancers when compared with control participants, suggesting that the dancers may be at higher risk of development of early OA manifestations.[18] Notably, several subsequent longitudinal studies have provided further support to these hypotheses by confirming an increased likelihood of incident knee OA associated with higher T2 values.[28–30] Therefore, T2 values assessed before the onset of clinical subjective or objective symptoms may be useful in identifying individuals at risk of OA, particularly among professional athletes.

Our quantitative analysis demonstrated statistically significant differences in T2 relaxation times of knee cartilage between professional martial arts athletes and healthy controls, suggesting that chronic high-intensity loading in martial arts practice may have an effect on the composition and structure of cartilage in young adults. Regional analysis further revealed significant differences in T2 values in the central weight-bearing MFC, MTP, and TRO regions, indicating a higher risk for early degenerative changes in these areas. Notably, the greatest increase in T2 values was observed in the medial compartment, particularly in the central weight-bearing MFC and MTP. The vulnerability of the medial compartment can be explained by the passage of the main load axis of the body through this structure. Previous authors have consistently confirmed that the MFC supports higher biomechanical load in normal knees when compared with the LFC, with approximately 60% to 80% of the knee-joint loading transmitted through the medial cartilage.[31–34] Several studies involving athletes have reported comparable findings, including the work of Schenk et al, who identified the medial cartilage as an anatomically vulnerable region susceptible to early degeneration in young professional soccer players.[6] With the assistance of T2 mapping, risk-prone regions can be pinpointed, enabling targeted monitoring and management of these areas. By implementing appropriate preventive measures, it is possible to reduce further cartilage damage and prevent the progression of OA.

In this study, we observed that professional elite martial arts athletes exhibited considerable differences between their dominant and nondominant legs in terms of both T2 relaxation times and pathology. Specifically, the dominant leg exhibited higher cartilage T2 relaxation times and higher WORMS scores of cartilage lesions compared with the nondominant leg. One possible explanation for the observed interlimb difference in cartilage is the asymmetric impact of martial arts movements on the knee joint. Routine martial arts training involves frequent jumping actions, predominantly characterized by single-leg takeoff and single-leg landing.[35,36] When landing, there are many movements that require one knee to touch or kneel on the ground. The technical characteristics and exercise habits of martial arts athletes may result in greater pressure being exerted on the knee joint of the dominant limb during movements, potentially making that side more susceptible to cartilage lesions. However, because mechanical loading was not directly assessed in this study, this interpretation should be interpreted cautiously. A growing body of evidence suggests a potential U-shaped dose-response relationship between mechanical loading and knee OA progression.[37–39] In addition to the negative impact of overloading discussed in our study, it is essential to note that underloading can also be detrimental to knee cartilage. This is because knee cartilage requires a minimum amount of mechanical loading to generate biochemical signals and stimulate the anabolic activity of chondrocytes, thus maintaining its health.[40] The complex relationship between various loading levels and cartilage degeneration still requires further research to better assist high-risk populations in preventing OA.

This study has several limitations that must be acknowledged. First, the cross-sectional design and the relatively small number of athletes analyzed were significant limitations. Second, it is essential to consider that athletes, particularly at elite levels, can develop a higher tolerance for pain as a result of their intense training and competition. This increased pain threshold can lead them to downplay or ignore certain discomforts or injuries that would be more easily perceived in nonathletic individuals. In our study, all participants self-reported as asymptomatic. Due to their high pain threshold, athletes may have a tendency to underreport symptoms or minor injuries, potentially indicating that their "asymptomatic" status may not be entirely accurate. This could result in an overestimation of imaging findings. Finally, it is worth noting that our study did not conduct a horizontal separation of knee cartilage into a deep and superficial layer for each cartilage segment. This choice was made based on concerns that the cartilage thickness in certain regions might be too thin, with only 2 to 3 pixels (surface to base) present. Dividing such regions in half could potentially compromising the reliability of our results, as it may not provide an adequate number of pixels within a single ROI for accurate analysis. Accordingly, we adopted a more cautious methodological approach to ensure the credibility and robustness of our findings. This study represents a preliminary investigation, and future research with a larger sample size and a longitudinal cohort would be beneficial for obtaining more comprehensive results. Despite these limitations, this study still demonstrated statistically significant results that provided insight into the impact of martial arts training on the biochemical composition of knee cartilage.

In summary, our study demonstrated a significantly higher incidence of imaging abnormalities in the knee joints of asymptomatic professional martial arts athletes compared with healthy controls, particularly with regard to cartilage and ligament lesions. Furthermore, T2 relaxation times of cartilage in professional athletes exhibited a higher trend, with the medial compartment, particularly the central weight-bearing MFC and MTP, being most affected, potentially indicating a predilection for early degenerative cartilage changes. Future prospective studies are needed to determine whether such T2 changes represent the early stages of OA. Notably, a significant interlimb asymmetry was observed in professional athletes, which may contribute to a higher risk of knee-joint injury in the dominant leg. Our study provides valuable insights for sports medicine researchers and trainers to develop targeted preventive strategies and interventions that can promote the long-term musculoskeletal health of professional martial arts athletes.

DISCLOSURE

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