Original Article

Effects of long-term running on the structure and biochemical composition of knee cartilage in males: a cross-sectional study

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Background: Running has been widely recognized as a beneficial activity for improving physical fitness, but it can also increase the risk of running-related injuries (RRIs). This study aims to assess the impact of long-term running on the structural and biochemical composition of the knee.

Methods: This study recruited a total of 32 participants, including 16 male recreational runners, aged 28–49 years, with a running experience of 2–7 years, and 16 matched sedentary controls. Magnetic resonance (MR) scans of T2* mapping and three-dimensional double-echo steady-state (3D-DESS) were performed on all participants. The volumes, thickness, and T2* values of joint articular cartilage were obtained via automatic segmentation software.

Results: Compared with the sedentary controls, runners exhibited significant increases in the volumes of both the femoral medial articular cartilage and the tibial medial articular cartilage. Additionally, there were significant increases in the thickness of several cartilage regions, including femoral medial cartilage, femoral medial articular cartilage, femoral medial thickness, femoral lateral cartilage, and tibial medial articular cartilage. Notably, the T2* values in the femoral lateral and tibial lateral cartilage of runners decreased significantly, while those in the patellar cartilage and medial tibial cartilage increased significantly. Runner pace was negatively correlated with the overall knee cartilage thickness (r=−0.556; P=0.02), femoral cartilage thickness (r=−0.533; P=0.03), and volume (r=−0.532; P=0.03) but positively correlated with the T2* value of the patellar cartilage (r=0.577; P=0.01).

Conclusions: Our study suggests that long-term mechanical stress from running may lead to increased thickness and volume in certain knee joint cartilage regions, possibly enhancing the functional adaptability of knee cartilage. The varying changes in T2* value in the tibial and fibular cartilage areas may indicate differing adaptability to pressure.

Keywords: Running; magnetic resonance imaging (MRI); cartilage; knee

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Introduction

Running is currently one of the most popular sports and offers a wide range of health benefits. It has been shown to reduce the risk of various chronic diseases, including obesity, metabolic syndrome, diabetes, and cancer (1). Furthermore, running contributes to increased and sustained bone mineral content and bone density (2). Although running can be a cost-effective "good medicine" as it relates to improving health and extending life, running can also increase the risk of running-related injuries (RRIs).

Osteoarthritis (OA) is a disabling, chronic musculoskeletal disease with high prevalence in adults (3). Research suggests that early-stage OA may be a reversible process, with one of its defining features being cartilage degeneration (4). Quantitative magnetic resonance (MR) technology T2* mapping is one of the methods for the early identification of cartilage lesions (5). The T2* value can reflect and detect changes in water content and collagen fiber anisotropy in cartilage. The use of the three-dimensional double-echo steady-state (3D-DESS) sequence enhances the resolution for visualizing articular cartilage and offers a superior contrast between cartilage and joint synovial fluid, facilitating a more detailed morphological analysis of articular cartilage (6). MR Chondral Health application (Siemens Healthineers, Erlangen, Germany) is believed to provide accurate and reproducible automatic segmentation of knee joint cartilage and has been used in multiple studies (7-9).

Running is one of the most popular sports in the world. Nearly 50 million people in the United States participated in running and jogging in 2021 (https://www.statista.com/topics/1743/running-and-jogging/#topicOverview). In addition, China's "2022 National Running Sports Health Report" shows that the number of active runners in China every month also exceeds 50,000 (https://health.gmw.cn/2022-12/15/content_36237123.htm). However, there is currently a lack of comprehensive comparative analyses of articular cartilage among this population of recreational runners. A recent meta-analysis (10) showed that the incidence of OA is 3.5% among recreational runners, 10.2% among sedentary individuals, and 13.3% among competitive runners. These findings suggest that recreational runners are at a lower risk of developing knee OA when compared to both sedentary individuals and competitive runners. Therefore, it is necessary to assess the state of knee joint cartilage among current recreational runners. This study used MR technology and automatic cartilage segmentation software to analyze the differences in cartilage morphology and biochemical composition between recreational runners and sedentary individuals. We considered two different results based on the joint load effect: (I) long-term regular running may reduce the T2* value of articular cartilage and increase the surface thickness and volume of cartilage; (II) conversely, long-term regular running may increase the T2* value of cartilage, and reduce the surface thickness and volume of cartilage. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-1563/rc).

Methods

Study participants

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of The Affiliated Hospital of Hangzhou Normal University (No. 2020[E2]-HS-011). Informed consent was obtained from all individual participants. A total of 16 recreational runners were recruited from the Zhejiang University Entrepreneurs Outdoor Association, and 16 matched sedentary individuals were recruited from the community. Demographic and running related information were obtained from a questionnaire filled by the participants, including name, age, sex, height, weight, running experience, running days per week, daily running distance, monthly running distance, and running pace. Running pace is considered to be the amount of time it takes to cover a certain distance and is typically measured in minutes per mile or minutes per kilometer. Therefore, a smaller running pace value indicates a faster running speed, as it means the runner covers the distance in less time. To eliminate potential variations in cartilage data due to gender differences, all participants were male (11,12).

The inclusion criteria of the recreational runners were as follows: (I) no history of knee trauma or surgery, (II) consistent running experience spanning over 2 years, (III) a running distance of more than 80 km per month, and (IV)

Table 1 Twenty-one subregions of the automatic segmentation of cartilage

Variables	Subregion
Femur	Femoral medial posterior
	Femoral trochlear medial
	Femoral lateral posterior
	Femoral medial central
	Femoral trochlear central
	Femoral lateral central
	Femoral medial anterior
	Femoral trochlear lateral
	Femoral lateral anterior
Patella	Patellar lateral inferior
	Patellar medial inferior
	Patellar lateral central
	Patellar medial central
	Patellar lateral superior
	Patellar medial superior
Tibia	Tibial lateral posterior
	Tibial medial posterior
	Tibial lateral central
	Tibial medial central
	Tibial lateral anterior
	Tibial medial anterior

two or more regular weekly running sessions.

The inclusion criteria of sedentary controls were as follows: (I) no history of knee trauma or surgery, (II) no strong interest in sports, (III) daily work requiring long periods of sitting, and (IV) performing less than 150 minutes of moderate-intensity physical activity per week.

The exclusion criteria were as follows: (I) individuals with existing injuries or experiencing pain (greater than 3 on the visual analogue scale), (II) individuals with a history of knee trauma or surgery, and (III) individuals with contraindications to undergoing magnetic resonance imaging (MRI) scans.

MRI procedures

All participants were scanned in the supine position. The knee joint was bent naturally within a coil fixed with sandbags to reduce motion artifacts. The maximum flexion angle for the knee joint was limited to 15°. Additionally, all scans were conducted in the evening (7:00 PM to 10:00 PM) to eliminate potential influences from diurnal variations and daily physical activities on the assessment of knee cartilage. All participants were instructed not to perform any form of exercise for at least 3 days before the MRI scan. Furthermore, to minimize the potential impact of recent physical activities on knee cartilage, they were asked to lie down and rest for an additional 30 minutes prior to the scan. All participants worked during the day and rested at night.

MRI was performed using a 1.5 T MR scanner (MAGNETOM Aera, Siemens Healthineers, Erlangen, Germany) equipped with a 15-channel knee coil. The automated day optimizing throughput (DOT) engine was used to customize the MRI examination for each participants, ensuring as consistent positioning as feasible for each scan. The scanning sequence include (I) a sagittal T1-weighted sequence (T1W) [repetition time (TR) =700.00 ms, time to echo (TE) =12.00 ms, flip angle =150°, field of view (FOV) =160.00 mm × 160.00 mm, slice thickness =3.00 mm, gap =0.60 mm, bandwidth =150 Hz/Px, scan time =1 min 27 s], (II) a sagittal proton density-weighted fat-saturated turbo spin echo sequence (PDw FS TSE) (TR =3,300.00 ms, TE =38.00 ms, FOV =160.00 mm × 160.00 mm, slice thickness =3.00 mm, gap =0.60 mm, bandwidth =193 Hz/Px, scan time =1 min 23 s), (III) a 3D-DESS sequence (TR =19.88 ms, TE =7.34 ms, FOV =160.00 mm × 160.00 mm, slice thickness =0.64 mm, gap =0.12 mm, bandwidth =199 Hz/Px, scan time =6 min), and (IV) sagittal T2* mapping (TR =905.00 ms, TE =4.35/11.57/18.89/26.21/33.53 ms, FOV =160.00 mm × 160.00 mm, slice thickness =3.00 mm, gap =0.60 mm, bandwidth =260 Hz/Px, and scan time =2 min 18 s). The total scan time was 11 min and 8 s.

Image analysis

Based on 3D-DESS and T2* mapping images, we used automated segmentation software (Siemens Chondral Health 3.1.0, Siemens Healthineers, Erlangen, Germany) to segment the knee joint cartilage into 21 subregions. The software automatically computed the volume, thickness, and T2* value of each of these cartilage areas. Following the completion of the automatic cartilage segmentation process, necessary manual adjustments were made to avoid synovial fluid from affecting the accuracy of the results (see *Table 1*, *Figure 1*). The postprocessing of images was

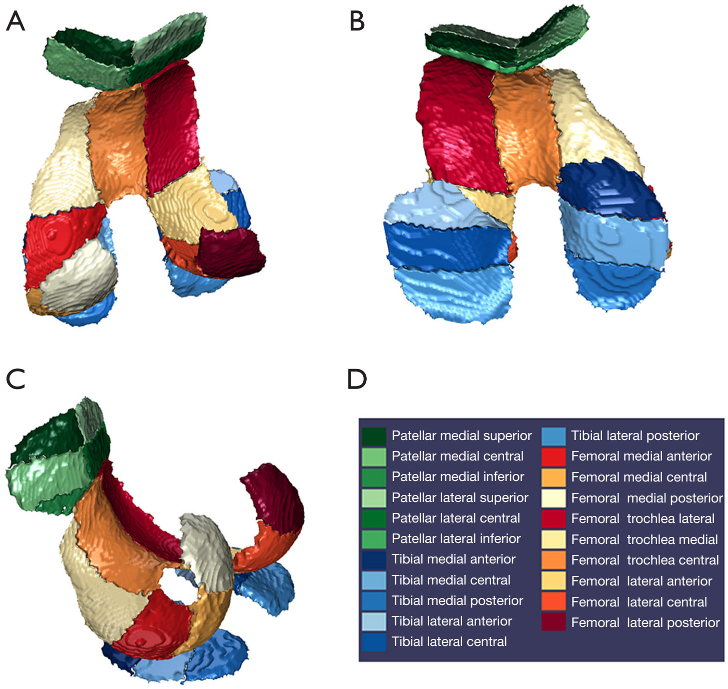

Figure 1 Cartilage automatically segmented using MR Chondral Health: (A) cranial view; (B) caudal view; (C) side view; (D) the color codes of the 21 subregions. MR, magnetic resonance.

completed by a physician with over 5 years of expertise in musculoskeletal imaging diagnosis. Notably, the doctor did not know the specific grouping of the participants during the postprocessing phase.

Statistical analysis

SPSS 23.0 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Measurement data are presented as the mean ± standard deviation (SD). The independent samples *t*-test was used to compare the knee joint cartilage thickness, volume, and T2* value between the running group and the control group. Pearson correlation coefficient was used to evaluate the correlation between daily running conditions and the average thickness, volume, and T2* value of knee cartilage. Statistical significance was set at $P<0.05$.

Results

All participants (16 recreational runners and 16 sedentary controls) completed the MRI examinations. The demographic data of all participants are detailed in *Table 2*.

Compared with the sedentary controls, the runners exhibited significant increases in the volumes of both the femoral medial anterior (FMA) (10.6%) and tibial medial anterior (TMA) (13.6%). Additionally, there were significant increases in the thickness of several cartilage regions, including the femoral medial central (FMC) (9.5%), FMA (9.6%), femoral trochlear medial (FTM) (8.9%), femoral lateral central (FLC) (10.8%), and TMA (12.0%). No significant differences were found between the two groups in the volume or thickness of the remaining areas (*Tables 3,4*; *Figures 2,3*).

However, there were two differences in the T2* values of the knee cartilage among runners compared to matched sedentary people. The T2* value of runners' knee cartilage was significantly lower than that of sedentary individuals in the femoral trochlear lateral (FTL) (−10.0%) and femoral lateral anterior (FLA) (−15.0%). Conversely, the T2* values of runners were significantly higher than those of the control group in the tibial lateral posterior (TLP) (13.0%) and tibial medial posterior (TMP) (11.2%). No significant differences were found between the two groups for the T2* values in the other areas (*Table 5*, *Figure 4*).

In addition, the running pace was negatively correlated with overall knee cartilage thickness ($r=-0.556$; $P=0.02$), femoral cartilage thickness ($r=-0.533$; $P=0.03$), and volume ($r=-0.532$; $P=0.03$) but positively correlated with the T2*

Table 2 The characteristics of the participants [mean ± SD (range)]

Variables	Recreational runners (N=16)	Sedentary controls (N=16)	F	P value
Age (years)	37.19±6.89 (28–49)	35.94±6.01 (28–49)	0.254	0.61
Height (cm)	170.25±4.55 (160–179)	169.44±6.54 (156–182)	0.92	0.34
Weight (kg)	65.13±5.85 (56–75)	67.31±7.37 (55–83)	0.648	0.42
BMI (kg/m^2)	22.49±2.02 (18.73–25.35)	23.44±2.11 (20.06–28.72)	0.218	0.64
Running experience (years)	3.50±1.28 (2–7)	–	–	–
Running days per week (days)	4.16±1.23 (2–6)	–	–	–
Daily running distance (km)	8.94±2.43 (4–14)	–	–	–
Monthly running distance (km)	165.00±65.80 (80–315)	–	–	–
Pace (min/km)	5.25±0.54 (4.15–6.00)	–	–	–

SD, standard deviation; BMI, body mass index.

Table 3 Comparison of knee cartilage subregion volume between recreational runners and sedentary controls (mean ± SD)

Group	Recreational runners (mL)	Sedentary controls (mL)	*t* value	P value
Femoral medial posterior	1.22±0.20	1.10±0.23	0.211	0.83
Femoral medial central	1.05±0.12	0.98±0.16	1.726	0.09
Femoral medial anterior	0.34±0.06	0.38±0.07	2.579	0.01
Femoral trochlear medial	1.08±0.14	1.07±0.13	1.725	0.09
Femoral trochlear central	0.52±0.12	0.44±0.12	1.754	0.09
Femoral trochlear lateral	0.23±0.05	0.25±0.06	1.416	0.16
Femoral lateral posterior	0.78±0.09	0.74±0.12	–0.073	0.94
Femoral lateral central	0.27±0.06	0.22±0.07	1.581	0.12
Femoral lateral anterior	0.81±0.15	0.77±0.15	1.446	0.15
Patellar lateral inferior	1.09±0.13	1.08±0.12	–1.769	0.08
Patellar lateral central	0.61±0.08	0.63±0.12	0.304	0.76
Patellar lateral superior	0.51±0.09	0.50±0.12	1.851	0.07
Patellar medial inferior	0.90±0.11	0.85±0.13	–0.913	0.36
Patellar medial central	0.64±0.08	0.56±0.08	1.149	0.26
Patellar medial superior	1.22±0.20	1.10±0.23	1.88	0.07
Tibial lateral posterior	1.05±0.12	0.98±0.16	0.704	0.48
Tibial lateral central	0.34±0.06	0.38±0.07	0.14	0.89
Tibial lateral anterior	1.08±0.14	1.07±0.13	–0.453	0.65
Tibial medial posterior	0.52±0.12	0.44±0.12	0.442	0.66
Tibial medial central	0.23±0.05	0.25±0.06	1.24	0.22
Tibial medial anterior	0.78±0.09	0.74±0.12	2.787	0.009

SD, standard deviation.

Table 4 Comparison of knee cartilage subregion thickness between recreational runners and sedentary controls (mean ± SD)

Group	Recreational runners (mm)	Sedentary controls (mm)	*t* value	P value
Femoral medial posterior	1.47±0.18	1.41±0.18	1.076	0.29
Femoral medial central	1.61±0.17	1.47±0.16	2.362	0.02
Femoral medial anterior	1.83±0.18	1.67±0.17	2.593	0.01
Femoral trochlear medial	1.73±0.18	1.59±0.18	2.219	0.03
Femoral trochlear central	2.34±0.30	2.16±0.33	1.561	0.12
Femoral trochlear lateral	1.98±0.22	1.89±0.26	1.052	0.30
Femoral lateral posterior	1.62±0.14	1.57±0.17	0.937	0.35
Femoral lateral central	1.91±0.17	1.72±0.26	2.397	0.02
Femoral lateral anterior	1.60±0.15	1.50±0.20	1.562	0.12
Patellar lateral inferior	1.66±0.20	1.77±0.22	−1.531	0.13
Patellar lateral central	3.04±0.33	3.13±0.43	−0.678	0.50
Patellar lateral superior	2.11±0.27	2.06±0.23	0.639	0.52
Patellar medial inferior	1.75±0.19	1.82±0.30	−0.713	0.48
Patellar medial central	2.69±0.31	2.72±0.47	−0.205	0.83
Patellar medial superior	1.76±0.19	1.74±0.26	0.271	0.78
Tibial lateral posterior	1.85±0.21	1.76±0.24	1.175	0.24
Tibial lateral central	2.63±0.26	2.62±0.18	0.12	0.90
Tibial lateral anterior	1.81±0.15	1.83±0.19	−0.311	0.75
Tibial medial posterior	1.43±0.20	1.32±0.15	1.763	0.08
Tibial medial central	1.91±0.19	1.79±0.16	1.833	0.07
Tibial medial anterior	1.56±0.12	1.39±0.14	3.564	0.001

SD, standard deviation.

value of the patellar cartilage (r=0.577; P=0.01) The smaller the pace number is, the faster the pace. Running experience, running days per week, daily running distance, and monthly running distance had no significant correlation with knee joint cartilage thickness, volume, or T2* value (*Figure 5*).

Discussion

This study discovered significant differences in knee cartilage between recreational runners and sedentary individuals. Long-term running may be associated with increased thickness and volume in certain cartilage regions as well as alterations in the biochemical composition. Furthermore, these changes seemed to be more pronounced in faster runners.

We observed a significant increase in the thickness and volume of knee joint cartilage among recreational runners compared to sedentary individuals. This finding is consistent with previous research (13-15). Babayeva *et al.* (13) found that femoral cartilage thickness was greater in elite athletes than in sedentary individuals, with physical activity level (PA) identified as an independent factor influencing cartilage thickness. Moshtagh *et al.* (16) indicated that moderate-intensity running could lead to the increase and hypertrophy of chondrocytes in rats. Petrigna *et al.* (17) reported that running can intervene in the progression of OA and consolidate articular cartilage tissue. Liu *et al.* (9) found that daily training for up to 1 year could increase the volume of knee cartilage in college students, although it did not affect cartilage thickness. In contrast, the immediate changes in cartilage thickness and volume following a single running are reduced or unchanged (12,18,19) and often

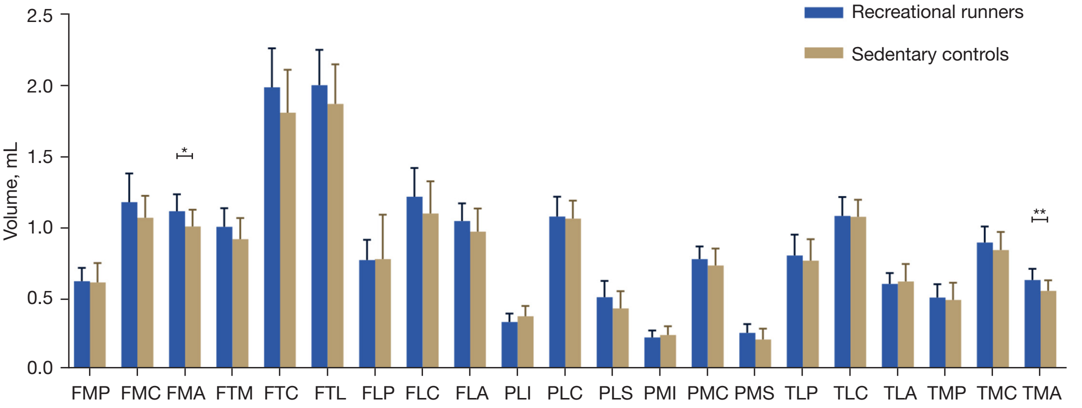

Figure 2 Comparison of knee cartilage volumes in 21 subregions between recreational runners and sedentary participants. *, P<0.05; **, P<0.01. FMP, femoral medial posterior; FMC, femoral medial central; FMA, femoral medial anterior; FTM, femoral trochlear medial; FTC, femoral trochlear central; FTL, femoral trochlear lateral; FLP, femoral lateral posterior; FLC, femoral lateral central; FLA, femoral lateral anterior; PLI, patellar lateral inferior; PLC, patellar lateral central; PLS, patellar lateral superior; PMI, patellar medial inferior; PMC, patellar medial central; PMS, patellar medial superior; TLP, tibial lateral posterior; TLC, tibial lateral central; TLA, tibial lateral anterior; TMP, tibial medial posterior; TMC, tibial medial central; TMA, tibial medial anterior.

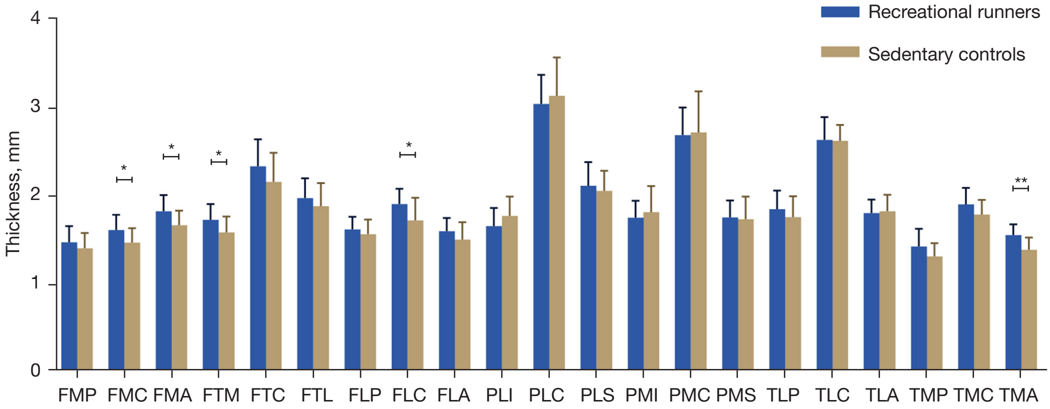

Figure 3 Comparison of knee cartilage thickness in the 21 subregions between the recreational runners and sedentary participants. *, P<0.05; **, P<0.01. FMP, femoral medial posterior; FMC, femoral medial central; FMA, femoral medial anterior; FTM, femoral trochlear medial; FTC, femoral trochlear central; FTL, femoral trochlear lateral; FLP, femoral lateral posterior; FLC, femoral lateral central; FLA, femoral lateral anterior; PLI, patellar lateral inferior; PLC, patellar lateral central; PLS, patellar lateral superior; PMI, patellar medial inferior; PMC, patellar medial central; PMS, patellar medial superior; TLP, tibial lateral posterior; TLC, tibial lateral central; TLA, tibial lateral anterior; TMP, tibial medial posterior; TMC, tibial medial central; TMA, tibial medial anterior.

return to baseline within 1–24 hours (20,21). Although changes in cartilage thickness and volume caused by a single run are reversible, long-term running may enhance knee joint functional adaptability by increasing cartilage thickness and volume.

T2* mapping is a valuable imaging technique that not only captures variations in collagen fiber anisotropy and water content within cartilage but also provides additional information into local field inhomogeneities. This additional capability makes it potentially more sensitive to detecting changes in tissue composition (22). Tsai *et al.* (22) demonstrated the feasibility of using 1.5 T MR T2* measurements to detect early changes in cartilage degeneration. As individuals age or OA progresses, there are alterations in the collagen network, an increase in water content within the joint cartilage, and an associated rise

Table 5 Comparison of knee cartilage subregion T2* value between recreational runners and sedentary controls (mean ± SD)

Group	Recreational runners (ms)	Sedentary controls (ms)	Y value	P value
Femoral medial posterior	25.00±2.02	24.95±2.34	0.07	0.94
Femoral medial central	28.67±3.25	27.71±2.34	0.966	0.34
Femoral medial anterior	25.51±4.39	24.90±2.74	0.469	0.64
Femoral trochlear medial	24.54±4.18	25.21±2.80	−0.532	0.59
Femoral trochlear central	28.06±3.20	28.36±2.82	−0.283	0.77
Femoral trochlear lateral	27.98±2.68	31.09±3.62	−2.766	0.01
Femoral lateral posterior	23.84±2.73	24.72±2.40	−0.967	0.34
Femoral lateral central	27.78±2.95	27.07±3.27	0.647	0.52
Femoral lateral anterior	23.77±3.80	27.98±5.02	−2.669	0.01
Patellar lateral inferior	27.68±5.39	27.88±4.32	−0.114	0.91
Patellar lateral central	27.29±5.53	29.20±4.91	−1.033	0.31
Patellar lateral superior	26.58±3.59	28.13±3.01	−1.325	0.19
Patellar medial inferior	25.30±3.48	26.45±5.18	−0.736	0.46
Patellar medial central	24.36±5.51	26.33±5.21	−1.04	0.30
Patellar medial superior	22.84±3.67	23.68±2.61	−0.747	0.46
Tibial lateral posterior	26.24±4.12	23.23±3.12	2.335	0.02
Tibial lateral central	19.79±2.56	18.80±2.91	1.028	0.31
Tibial lateral anterior	20.28±5.17	22.61±7.16	−1.053	0.30
Tibial medial posterior	22.41±2.94	20.15±2.60	2.301	0.02
Tibial medial central	22.04±5.60	21.41±3.60	0.375	0.71
Tibial medial anterior	24.09±4.00	22.47±2.64	1.353	0.18

SD, standard deviation.

in the T2* value. Recent research suggests that changes in the knee cartilage composition caused by a single run are mild and transient (23). It is safe for knee cartilage to repeatedly withstand the mechanical stimulation of running after a certain period of rest. Furthermore, after running, the acute change in T2* value of cartilage may be related to the running distance (8,24). The T2* value of cartilage tends to decrease after short-distance running, increase after long-distance running, and return to baseline levels within a few months (25). Schütz *et al.* (24) found that the T2* value of knee joint cartilage in runners of a 4,486 km transcontinental multistage ultra-marathon increased significantly within the first 1,100 km, but a decreasing trend in cartilage T2* value was observed after 3,500 km of running. In addition, they found that the change in T2* value of femoral cartilage after running was significantly higher than that of tibial cartilage, which may be related to joint load and glycosaminoglycan content of cartilage. In our study, we observed that the T2* values in the femoral and tibial cartilage areas of the running group exhibited contrasting tendencies when compared to the control group. We hypothesize that these differences may be attributed to the distinct abilities of various cartilage regions to respond to mechanical loading. However, this still needs to be substantiated by mechanical experiments. In addition, our findings indicated that areas with variations in cartilage thickness and volume did not align with areas displaying differences in T2* values. This suggests that changes in cartilage composition do not always correlate with changes in cartilage thickness (26) and vice versa.

Furthermore, our findings indicate that the smaller a runner's pace value is (the faster running speed), the greater

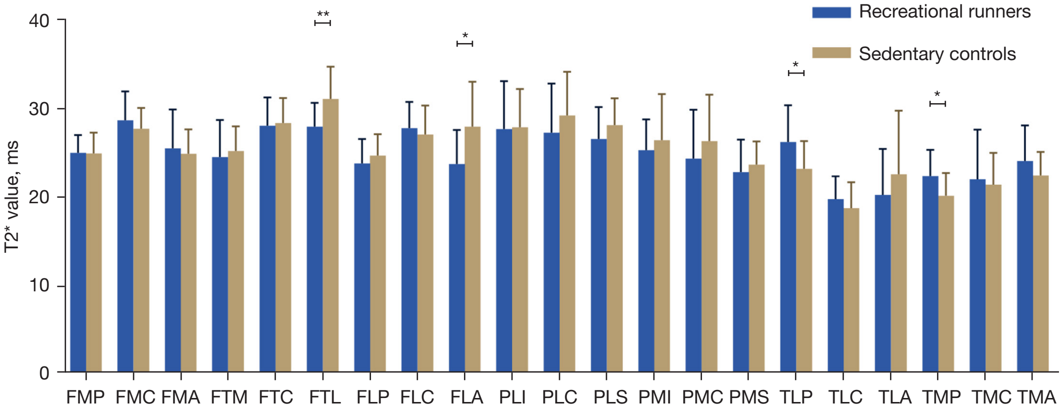

Figure 4 Comparison of knee cartilage T2* values in 21 subregions between recreational runners and sedentary participants. *, $P<0.05$; **, $P<0.01$. FMP, femoral medial posterior; FMC, femoral medial central; FMA, femoral medial anterior; FTM, femoral trochlear medial; FTC, femoral trochlear central; FTL, femoral trochlear lateral; FLP, femoral lateral posterior; FLC, femoral lateral central; FLA, femoral lateral anterior; PLI, patellar lateral inferior; PLC, patellar lateral central; PLS, patellar lateral superior; PMI, patellar medial inferior; PMC, patellar medial central; PMS, patellar medial superior; TLP, tibial lateral posterior; TLC, tibial lateral central; TLA, tibial lateral anterior; TMP, tibial medial posterior; TMC, tibial medial central; TMA, tibial medial anterior.

thickness and volume of the cartilage and the lower the local T2* values. Running experience, running days per week, daily running distance, and monthly running distance were not significantly correlated with the thickness, volume, or T2* value of knee joint cartilage. This suggests that within a certain range, running at a faster pace may be more beneficial to cartilage health. While the pace range within our runner's group was limited (4.15–6.00 min/km), we still believe that this trend may follow an inverted U-shaped curve, with health benefits suddenly decreasing when running faster than a certain value (27). McAlindon *et al.* (28) found that high-intensity physical activity is an important risk factor for knee OA in older adults. A meta-analysis by Bricca *et al.* (26) concluded that moderate exercise can facilitate the nourishment of cells within the cartilage matrix by the synovial fluid, which increases cartilage thickness. On the other hand, high-intensity exercise may overload the joint, leading to pathological changes. Further research could investigate the differences in cartilage morphology and T2* values between professional and recreational runners.

Moreover, it is critical to examine the correlation between long-term running and knee cartilage health. Both animal experiments and human experiments suggest that regular moderate exercise does not increase the risk of knee OA and can maintain the metabolic homeostasis of cartilage tissue (17,29). Our study evaluated differences in knee cartilage between recreational runners and healthy sedentary individuals. Similar to previous studies (23,30), we believe that running can be used as one of the preventive measures for cartilage lesions.

Our study also has certain limitations that should be mentioned. First, this study employed a cross-sectional design, and thus it is difficult to determine the causal relationship between running and cartilage health. Further longitudinal research, such as that involving the long-term (10–20 years) tracking of runners' knee cartilage health, is needed. Second, our study analyzed a small sample size, and only male runners were included. Therefore, the findings of this study may not be directly applicable to female runners. To add further credibility to our findings, we plan to increase the sample size and include female runners in the future.

Conclusions

We found that in certain regions, the knee cartilage thickness and volume of mass in recreational runners are greater than those of sedentary individuals. This could be attributed to the long-term mechanical stress associated with running, which appears to stimulate cartilage metabolism and enhance the functional adaptability of knee joint cartilage. Compared with sedentary individuals, recreational runners had lower T2* values in the femoral cartilage area and higher T2* values in the tibial cartilage area. These differences might be linked to the varying

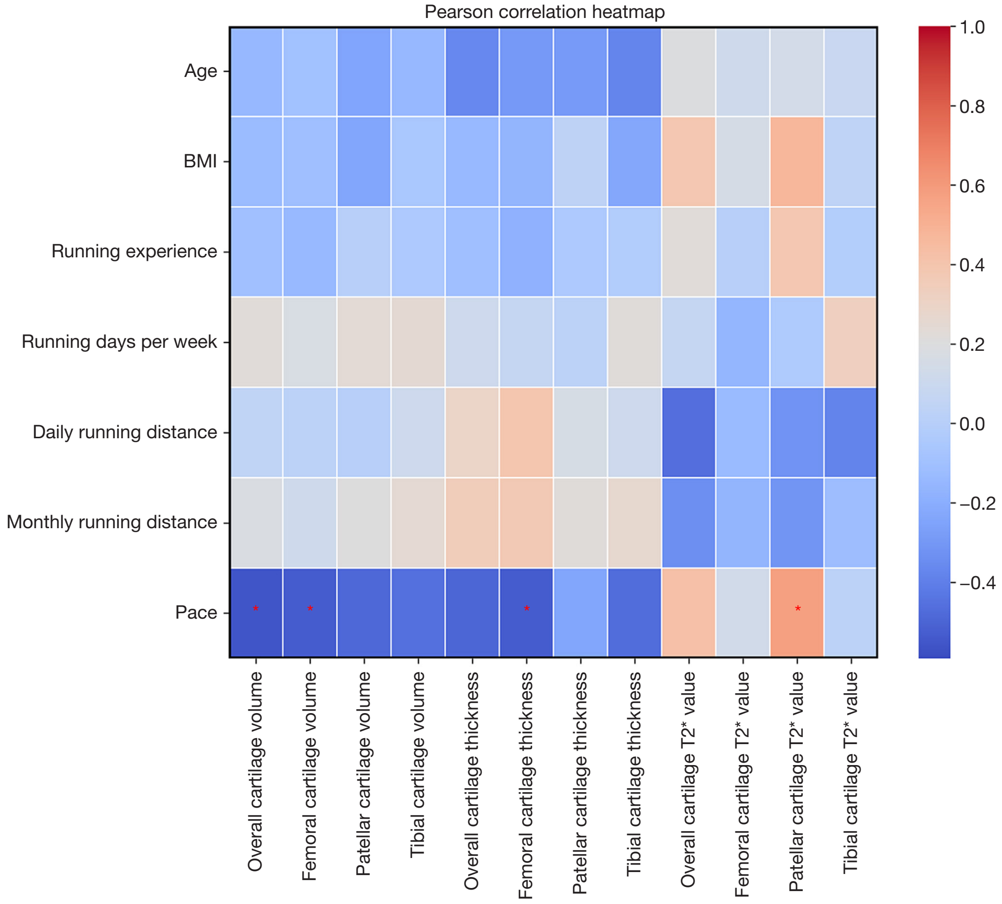

Figure 5 The heatmap of correlation matrix for running dataset. In this heatmap, warm colors represent positive correlations, while cool colors represent negative correlations. The chart has been truncated to display essential data. *, P<0.05. BMI, body mass index.

adaptability of different cartilage regions to mechanical stress. Furthermore, changes in cartilage composition do not necessarily cause changes in cartilage thickness. Within a certain range, running at a faster pace appears to be associated with better knee joint health.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-1563/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-1563/coif). T.C.C. is an employee of Siemens Healthineers and provided technical MRI guidance for this paper. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of The Affiliated Hospital of Hangzhou Normal University (No. 2020[E2]-HS-011). Informed consent was obtained from all individual participants.

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