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MR imaging of the knee in marathon runners before and after competition

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Abstract *Objective.* To evaluate the findings in MRI-studies of the knee in recreational long-distance runners after competition and to assess the reversibility of the findings.

Design and patients. Eight recreational long-distance runners underwent MRI studies of the knee before, immediately after and 6–8 weeks after taking part in the Vienna City Marathon. The studies were evaluated regarding alterations of pre-existing lesions and new pathological findings.

Results. In six runners without major pre-existing alterations no negative effects were experienced. In one runner with pre-existing grade III altera-

tions of the menisci, signs of progressive osteoarthritis were experienced 2 months after the competition. In all other cases increased meniscal signal alterations and minor signal changes in the bone marrow after the race were transitory.

Conclusion. In healthy individuals no negative long-term-effects were experienced. Pre-existing high-grade lesions of the menisci might be a predisposing risk for osteoarthritis, triggered by the stress of long-distance running.

Keywords Long-distance running · MRI · Knee

Introduction

Previous studies concerning signal alterations on MRI of structures of the knee joints in long-distance runners produced highly controversial results. There have been reports of joint effusions and increased meniscal signal in a study by Kursunoglu-Brahme et al. [1], whereas no significant changes were observed in a clinical trial by Shellock and Mink [2]. In a study of the ankle in marathon runners significant bone marrow oedema was observed by Lazzarini et al. [3].

We therefore prospectively studied the knee joints of eight marathon runners on MRI before competition, within 24 h after competition and 6 weeks later.

Material and methods

The knee joints of eight non-professional marathon runners were examined three times: 10–14 days before the competition, within

1 day after running (3–21 h after finishing the competition) and a third time 6–8 weeks later. The only criteria to be fulfilled by the participants were their own subjective feeling of being fit enough to complete the Vienna City Marathon. The first eight volunteers were accepted regardless of pre-existing clinical symptoms or previous operations on the knee. All participants were male, aged between 27 and 46 years (mean 37 years). Six were asymptomatic; two mentioned minor knee pain which they localised laterally. Two of the runners had undergone arthroscopic meniscal resection 4 and 15 years previously. They were all trained recreational runners with a history of long-distance running for between 5 and 20 years.

MRI was carried out on a 1.0 T Siemens Impact Expert imager using a flex-surface coil. The following sequences were obtained: sagittal T1-weighted fast spin-echo dataset (TR 1200 ms, TE 12 ms; slice thickness 3.0 mm; matrix 378×256), sagittal T2-weighted gradient-echo dataset: DESS 3D (TR 26.8 ms, TE 9 ms; flip angle 40°; slice thickness 2.8 mm; matrix 197×256) coronal fat-suppressed inversion recovery sequence (TR 5100 ms, TE 30 ms; TI 150 ms, slice thickness 4.0 mm, matrix 210×256).

The structures to be evaluated in all three examinations were:

- 1 *Menisci.* Grading of lesions: grade I, diffusely increased signal on T1-weighted images; grade II, linear signal on T1-weighted

- images within the meniscus but not reaching the surface; grade III, linear signal alterations reaching the meniscal surface; grade IIIA reaching one surface and IIIB reaching the upper and lower surface of one meniscus (representing a meniscal tear reaching one or two surfaces).
- 2 *Cartilages.* Grading of lesions: grade I, increased signal, smooth surface; grade II, irregular surface but lesion not reaching the bone; grade III, ulceration reaching the bone; grade IV, wide denudation of the bone.
 - 3 *Bone marrow.* The presence of bone marrow oedema was defined as an area of high signal on T2-weighted images, especially the TIRM sequence and low signal on T1-weighted images. Where present, it was classified as diffuse or localised signal changes. Localised bone marrow oedema were correlated with meniscal and cartilaginous signal alterations.
 - 4 *Joint fluid.* Normal appearance or increased (consensus of the interpreting radiologists).
 - 5 *Patellar tendon.* Signal alterations and thickening.
 - 6 *Cruciate ligaments.* Signal alterations, integrity and thickening.
 - 7 *Medial and lateral collateral complexes.* Thickening, signal alterations and continuity.

Initially, each of the three examination series was evaluated separately with the readers being masked to the participant's identity and the results of the previous examinations. In a second session

the follow-up studies were re-evaluated in direct comparison with the initial examination. Three skeletal and orthopaedic radiologists did all the film reading and the diagnoses were made by means of a consensus decision. The reporting was done on a Magicview workstation (Siemens). The observers were allowed to make use of all diagnostic features provided by the workstation (including windowing and levelling, measurements of distances and grey-value evaluations).

Results

Before the competition signal alterations of the menisci were found in all runners (Table 1). Three runners presented with normal, i.e. signal-free, lateral menisci. There were eight grade I lesions; four grade II and three grade III lesions. There were five cases of a chondropathy grade \leq II and one grade III lesion.

There were seven cases of localised areas of high signal intensity on T2-weighted images within the bone marrow: in one subject there were subtle signs of circumscribed signal increase in the distal metaphysis of

Table 1 Summary of findings

Runner no.	Examination no.	Age (years)	Medial meniscus	Lateral meniscus	Bone marrow oedema	Other changes
1, right knee	1	45	IIIA	II	Patella apex	Signal alteration. patellar tendon 5 mm No change No change
	2		No change	Increased signal	No change	
	3		No change	As for exam. 1	Increased	
2, right knee	1	43	IIIA	Normal	Nil	
	2		Increased signal	No change	No change	
	3		Decreased signal	No change	No change	
3, right knee	1	41	I	I		Increased signal patellar tendon 3 mm No change Normal signal
	2		Increased signal	Increased signal		
	3		As for exam. 1	As for exam. 1		
4, left knee	1	27	I	0	Lateral femoral condyle	
	2		Increased signal	No change	No change	
	3		As for exam. 1	No change	No change	
5, left knee	1	46	II	II	Nil	
	2		Increased signal	Increased signal	No change	
	3		As for exam. 1	As for exam 1	No change	
6, right knee	1	31	I	II	Femoral metaphysis	
	2		Increased signal	No change	Slightly increased	
	3		As for exam. 1	No change	As for exam. 1	
7, right knee	1	31	I	0	Lateral femoral condyle	Increased signal patellar tendon 3 mm No change No change
	2		Increased signal	No change	No change	
	3		Normal signal	No change	No change	
8, left knee	1	45	IIIB	I	Medial condyle	Increased signal 1 cm in the patellar tendon No change Subcortical cyst; tendon almost normal
	2		Increased signal	I increased signal	Increased	
	3		As for exam. 1	As for exam. 1	Medial condyle no change; new area in the medial condyle	



Fig. 1 A T1-weighted spin echo image before competition, showing a subtle grade II lesion of the posterior horn of the lateral meniscus. B Lesion shows a slight increase in signal after running

Fig. 2 A T1-weighted spin echo image showing a grade I signal alteration of a medial meniscus before running. B A hardly visible increase in signal of the posterior horn after running

Fig. 3 A Fat-suppressed TIRM before running showing very mild localised oedema in the bone marrow. B Slight signal increase after competition

the femur; in two cases the changes were localised in the lateral and in two cases in the medial femoral condyle. In two runners small areas of high signal intensity were also found in the bone marrow of the patella, near the apex. In two cases the amount of joint fluid was considered slightly increased.

There were four cases of signal alterations of the patellar tendon showing increased signal on T1-weighted images. Only small parts of the tendon were affected in all cases and there were no signal changes in the surrounding soft tissue. These athletes were asymptomatic in this respect before and after running.

In one case a grade I lesion of the posterior cruciate ligament was found. The anterior cruciate ligament was

normal in all participants. The medial and lateral collateral ligaments were normal in all subjects.

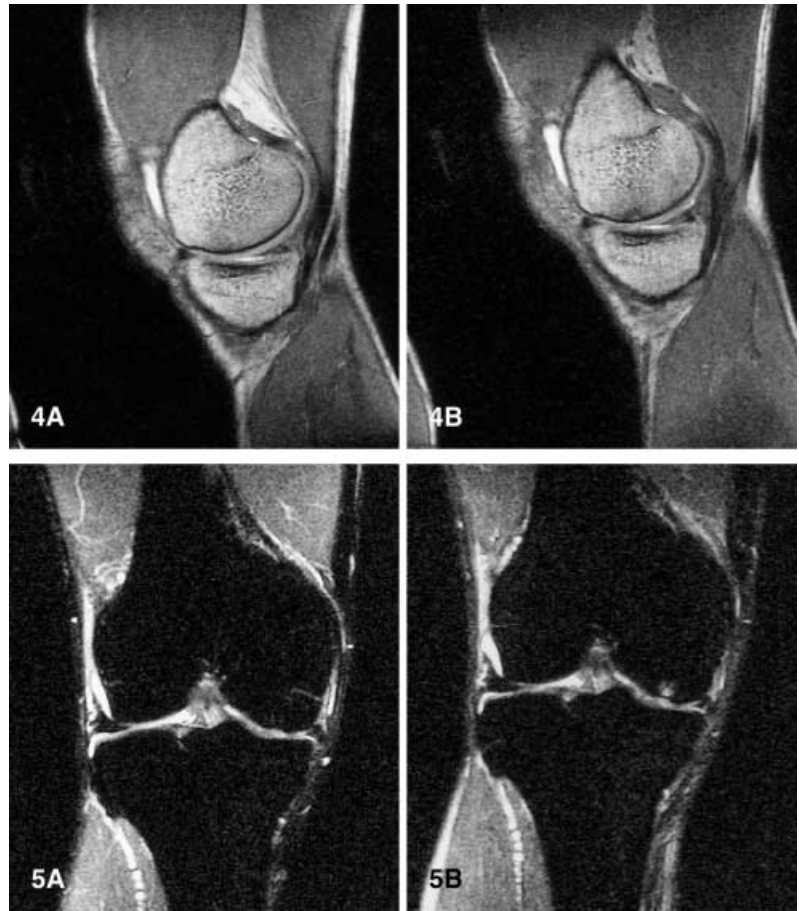
One participant who underwent resection of the posterior horn of the lateral meniscus 15 years previously and presented with a grade IIIB lesion of the posterior horn of the lateral meniscus in the other knee, also presented with a 4 mm subchondral cystic lesion of the lateral condyle which was surrounded by a 1 cm large area of localised oedema. In this subject there were signs of subchondral sclerosis in the lateral compartment.

After running there was no signal alteration that graded differently from the initial findings on the masked interpretation of the film reading. Following image comparison it was found that in all but one case of grade II lesions of the menisci, the signal alterations were slightly more visible (Fig. 1). The size of the lesion had not changed in any case. Grade I lesions did not change significantly although grey-value evaluations showed slightly higher values of the affected menisci. Unlike the changes in grade II lesions these changes were hardly noticeable to the observers (Fig. 2).

No changes in the cartilages regarding thickness, surface or signal intensity were found. Little change was observed in the signal alterations of the bone marrow. In

Fig. 4 **A** T2-weighted gradient echo image after competition, showing mild subchondral sclerosis and no obvious cartilaginous lesion. **B** Six weeks later a subchondral cyst, increased sclerosis and inhomogeneous cartilage are visible

Fig. 5 **A** Fat-suppressed TIRM image showing normal findings after running. **B** Subchondral cyst and mild perifocal oedema



the runner presenting with a signal alteration in the metaphysis of the femur, this change became brighter and slightly larger on the fat-suppressed TIRM (Fig. 3). In a participant with a grade III lesion of the medial meniscus there was an increased signal intensity in the medial condyle in the second study.

There was no joint effusion in any participant. In two of the runners the amount of joint fluid had decreased slightly but was not increased in any participant.

The signal alteration of the patellar tendons showed almost unchanged signal after running. All lesions remained unchanged in size. All cruciate ligaments and the collateral complex remained unchanged in signal.

Two competitors complained about unspecified minor knee-pain after the competition and during jogging, but without any correlation on MRI. Between the second and third examination all participants continued with their regular running but cut back regarding frequency and length of the runs.

At the final examination the one participant who had presented with grade III lesions of the menisci and signs of osteoarthritis at the initial examination, showed signs of progressive osteoarthritis manifest as a new subcortical cyst (Fig. 4), surrounded by subtle, localised bone

marrow oedema (Fig. 5) and a slightly increased amount of joint fluid. This subject did not report increased symptoms. In all other subjects the signal alterations of the marrow had decreased again. In all cases the signal alterations of the menisci returned to their initial intensity or were slightly less noticeable than at the first examination. One grade I meniscal lesion was no longer noticeable. This meniscus was finally found to be normal. There was no evidence of joint effusion. No changes in the ligaments were experienced.

Discussion

In accordance with previous studies, no negative effects were experienced in healthy runners within the control interval. Minor meniscal signal alterations were slightly more noticeable soon after running but had returned to normal 6 weeks after the competition. Without exception the increase in pre-existing low-grade signal alterations were transient. In one participant an initial grade I meniscal lesion was no longer noticeable in the final examination. Localised bone marrow signal changes were also transient in all participants, except for one who initially

presented with a grade IIIB meniscal tear. In this subject the MRI signs of osteoarthritis increased. It is not possible to judge from one case, but it raises the possibility that pre-existing high-grade meniscal lesions may be a predisposing factor for osteoarthritis, triggered by the stress of long-distance running.

Most of these areas of increased signal within the bone marrow were not localised in the subchondral areas of the joint. As such areas of high signal were frequent findings in the study there is an increased suspicion that they are related to the process of the marathon. As the localisation in most cases is atypical for stress-related oedema or a bone bruise the authors favour the hypothesis of spots of increased haematopoietic activity, as haematopoietic bone marrow hyperplasia is a known change in asymptomatic marathon runners. Shellock et al. [4] described similar findings as a response to what they called "sports anaemia". Only the cases presenting with increased signal near the apex of the patella are likely to be stress-related due to the forces during the run.

In spite of the relatively small study group it would seem legitimate to conclude that in "healthy" individuals marathon running does not cause permanent damage to the knee joint.

In accordance with the study of Kursunoglu-Brahme et al. [1], the incidence of increased meniscal signal was high, but we could not find any participants showing associated joint effusions as described by this group. As did Shellock and Mink [2], we found unchanged or even slightly decreased amounts of joint fluids. These authors did not report any changes in meniscal alterations after running in comparison with the initial status. Meniscal signal alterations were reported in 10% of cases by these authors but in 80% by Kursunoglu-Brahme et al. [1]. However, the absence of any signal changes in the collateral or cruciate ligaments is a very consistent finding in all studies.

As this study is small and there remain the different results concerning incidence and changes of the menisci, further evaluation may be appropriate.

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