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Degenerative joint disease on MRI and physical activity: a clinical study of the knee joint in 320 patients

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Abstract. We examined 320 patients with MRI and arthroscopy after an acute trauma to evaluate MRI in diagnosis of degenerative joint disease of the knee in relation to sports activity and clinical data. Lesions of cartilage and menisci on MRI were registered by two radiologists in consensus without knowledge of arthroscopy. Arthroscopy demonstrated grade-1 to grade-4 lesions of cartilage on 729 of 1920 joint surfaces of 320 knees, and MRI diagnosed 14 % of grade-1, 32 % of grade-2, 94 % of grade-3, and 100 % of grade-4 lesions. Arthroscopy explored 1280 meniscal areas and showed degenerations in 10 %, tears in 11.4 %, and complex lesions in 9.2 %. Magnetic resonance imaging was in agreement with arthroscopy in 81 % showing more degenerations but less tears of menisci than arthroscopy. Using a global system for grading the total damage of the knee joint into none, mild, moderate, or severe changes, agreement between arthroscopy and MRI was found in 82 %. Magnetic resonance imaging and arthroscopy showed coherently that degree of degenerative joint changes was significantly correlated to patient age or previous knee trauma. Patients over 40 years had moderate to severe changes on MRI in 45 % and patients under 30 years in only 22 %. Knee joints with a history of trauma without complete structural or functional reconstitution showed marked changes on MRI in 57 %, whereas stable joints without such alterations had degenerative changes in only 26 %. There was no correlation of degenerative disease to gender, weight, type, frequency, and intensity of sports activity. Therefore, MRI is an effective non-invasive imaging method for exact localization and quantification of chronic joint changes of cartilage and menisci that recommends MRI for monitoring in sports medicine.

Key words: MRI – Knee joint – Degenerative disease – Sports medicine – Arthroscopy

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Introduction

Magnetic resonance imaging is well established in examination of joint disorders, because lesions of ligaments, menisci, cartilage, and bone can be visualized and graded according to severity [1]. The mechanisms of trauma and overuse in physical activity have been examined intensively in the past two decades, and typical morphological changes of joint tissues have been described [2–4]. The jumper's knee, for instance, is characterized by degenerative changes of the knee extensors, and basketball and football players may suffer from osteochondral lesions [5–8]. Non-invasiveness, lack of biological side effects, improving availability, and demonstration of early articular alterations suggest MRI for preventive studies in sports medicine.

In this clinical study 320 middle aged patients were examined by MRI following acute distortion trauma of the knee joint. Apart from the standard spin-echo (SE) and 3D FISP sequence, newer techniques, such as fat suppression and magnetization transfer contrast (MTC), were additionally tested on a subgroup of 100 patients since these techniques were available. In addition to acute changes, degenerative disease of cartilage and menisci was evaluated and set in the context of their physical activities and clinical history. The following questions are answered:

1. Can degenerative changes be detected non-invasively using MRI as efficiently as in arthroscopy?
2. Can MRI be used to quantify the severity of degenerative changes of the knee joint?
3. Can sensitivity of MRI be improved by newer techniques such as fat suppression or magnetization transfer?
4. What type and intensity of physical activity was observed in the patient collective?
5. Are the degenerative changes shown on MRI and arthroscopy related to clinical and sports history data (age, weight, type, intensity and duration of physical activity, Tegner score, etc.)? Can risk groups be defined?

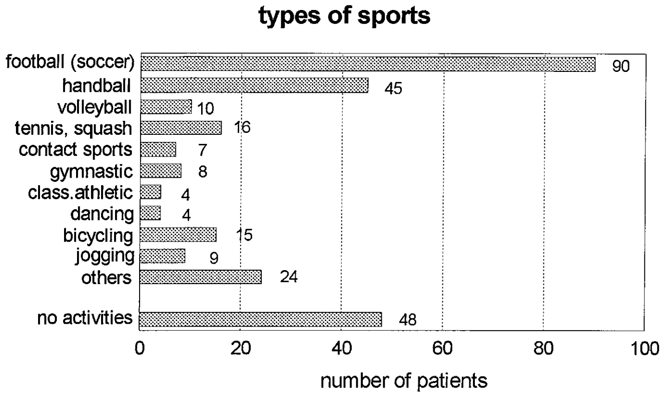

Fig. 1. Types of sports practiced by 286 interviewed patients

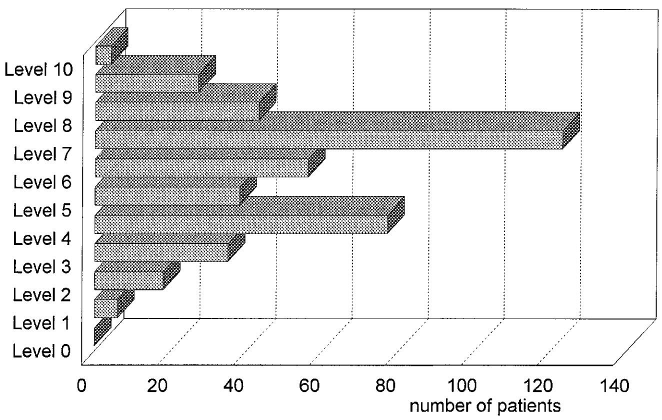

Fig. 2. Tegner scores of 286 patients. The system classifies the increase in risk of knee-joint damage according to physical activity from low risk (level 0) to high risk (level 10)

Patients and methods

The patient sample in this retrospective clinical study of chronic degenerative changes of the knee joint was composed of 320 patients (122 women and 198 men) aged 13–56 years (mean age 29.3 years, standard deviation 8.7 years). The patients were seen in the orthopedic university hospital between June 1991 through December 1996 subsequent to acute symptoms after an accident or strain. Seventy-nine percent had sports trauma (football 29 %, handball 11 %, skiing 20 %, other team sports 5 %, other sports 22 %) and 13 % household or traffic accidents. Arthroscopy showed complete rupture of anterior cruciate ligaments in 79 %, rupture of the collateral ligaments in 39 %, and tears in the lateral and medial menisci in 48 and 62 %, respectively.

Whereas acute trauma was directly related to accidents in sports, household, and traffic, chronic changes were related to regular physical activity in sports and profession, reflected in data of professional and sports history. This concept, which needs definite separation and localization of acute and chronic changes, was chosen in order to verify MRI findings by arthroscopy. Chronic degenerative damage (degeneration of cartilage grades 1–4, meniscal degeneration grades 1–3) was differentiated from acute lesions and regarded as the results of repetitive joint stress by chronic physical activity.

Clinical data and sports history

In addition to clinical data (gender, age, size, weight, severe previous knee trauma) patients were interviewed on physical activity. An important question was related to a former knee trauma with extensive alteration of menisci and cruciate ligaments, which did not permit full structural recovery or regaining of stability. Fifty-six of 320 patients (17 %) had experienced such a trauma. In 286 of 320 patients (90 %), data on duration of physical activity, major sports (team games, running sports, etc.), intensity (days training per week, occasional amateur or professional sports), and the degree of professional physical activity (light or heavy physical work, e.g., carrying weights, kneeling work) were obtained. Two percent of patients were professional athletes, 53 % were members of sports clubs, 28 % practiced occasional recreational sports, and 17 % were not active. Football (referred to as soccer in the U.S.) was the most commonly practiced sport (38 %), followed by handball (19 %) or other team sports (6 %; Fig. 1). Three percent practiced contact sports (judo, karate, boxing), and 8 % jogging or bicycling. Fifty-four percent practiced their sport for 5–10 years, 40 % for 11–20 years, and 6 % over 20 years. Sixty-eight percent of physically active patients trained two to three times per week, 50 % once a week, and 17 % more than three times per week. The Tegner score enables an evaluation of the total risk of knee-joint damage by evaluating different stress factors according to severity and frequency of physical activity on ten levels [9]. According to this, 51 % of patients had high levels [8–10] due to regular activity in handball or soccer, 37 % had moderate levels of 4–7 due to regular recreational sports, and 12 % had low levels of 0–3 with negligible activity (Fig. 2).

Arthroscopy

Arthroscopy was the obligatory reference method to MRI, performed within 4 weeks after the MRI study. Arthroscopy was performed by two operators with at least 6 years experience and included inspection of internal structures and study of tissue using accepted techniques. Acute and chronic joint changes (chondral and meniscal lesions) ware detected and documented in the standard fashion [10]. All lesions were documented, quantifying severity and extent, with precise localization within individual compartments of the joint.

MRI

The MR imaging examinations were done on a 1.5-T unit (Magnetom, Siemens, Erlangen, Germany) using a knee coil. The protocol included two SE sequences and a 3D FISP. The T1-weighted SE (TR/TE = 600/15 ms, 256 × 512 pixel, 3 mm slice thickness, 3 acquisitions, coronal orientation) demonstrated the cartilage layers in the medial and lateral compartments, the collateral ligaments, and the intermediate parts of the menisci. Subsequent proton-density and T2-weighted SE sequence (TR/TE = 2000/20/80 ms, 256 × 256 pixel, 3 mm slice thickness, 1 acquisition) was in sagittal orientation with 15° medial angulation for exact demonstration of the cruciate ligaments, the anterior and posterior horns of menisci, and the cartilage of the condyles. The third sequence was a 3D FISP in moderate T2-weighting (TR/TE/flip angle = 42/12 ms/40°, 64 partitions, 1.5 mm slice thickness), which was primarily sagittal to permit reevaluation of all findings.

To demonstrate the influence of new MR techniques in detection of degenerative joint disease, three other techniques could be tested on a subgroup of 100 of the 320 patients in addition to the SE and 3D FISP sequence since installed in 1993 and 1994: T1-weighted SE (TR/TE = 600/15 ms, 256 × 512 pixel, 3 mm slice thickness, 3 acquisitions, coronal) with chemical-shift fat suppression, T2-weighted gradient-echo (GE; FLASH, TR/TE/flip angle = 400/12 ms, 20°) with magnetization transfer contrast (MTC; 1400 ms offset, 240 Hz bandwidth, 8.13 ms), and T1-weighted 3D GE (FLASH, TR/TE/flip angle = 42/10 ms/60°, 1.5 mm slice thickness, sagittal orientation) with fat suppression. Sensitivity was assessed separately for the SE technique (T1-weighted, proton-density, and T2-weighted sequence), the 3D FISP, SE with fat suppression, GE with MTC and 3D FLASH with fat suppression for chondral lesions according to degree of damage and to meniscal lesions according to type.

Data analysis

In analysis of MRI all acute and chronic findings were registered on a second standard form for arthroscopy. A uniform grading of degenerative chondral and meniscal lesions was used for MRI and arthroscopy to permit comparison of both methods with regard to reproducibility of the staging of joint pathology.

Four conditions of chondral lesions were separated using a modified system of Shariaree [11]:

1. Stage 1 was defined as structural changes without substance defects, seen in arthroscopy as focal softening and on MRI as focal signal changes.
2. Stage 2 was defined as superficial defects in cartilage, either shown in arthroscopy as cracks and defibrillation, or on MRI as rough contour without thinning.
3. Stage 3 was restricted to deep defects of cartilage seen as erosions in arthroscopy and as large defects of contour with focal thinning on MRI.
4. Stage 4 signified focal total loss of cartilage.

Three pathological conditions (degeneration, tear, complex lesion) of the menisci were defined for MRI and arthroscopy. Degenerative changes were seen in arthroscopy as focal softening and roughening. In MRI degeneration is defined as focal or globular intrasubstance increase [grade 1 of the modified classification of Stoller et al. [12] or horizontal linear signal increase not involving the articular surface (grade 2)]. Tears were seen as sharply delineated signal increase on MRI reaching the surface (grade 3A). Complex meniscal lesions have irregular signal increase on MRI which may encompass the entire meniscus (grade 3B). In corresponding arthroscopy various combinations of defects, tears, and degeneration were found.

Accuracy of MRI for cartilage lesions was analyzed separately for all six areas of the cartilage and for the anterior and posterior horn of the lateral and medial meniscus. Thus, 1920 cartilage surfaces and 1280 meniscal parts of the 320 knee joints were analyzed for the comparison of MRI and arthroscopy. Sensitivity, specificity, predictive values, and accuracy depending on the type, localization, and severity of chondral and meniscal lesions were defined as well as the tendency to over- or underestimate findings on MRI (Bowker's symmetry test).

In addition, the authors defined a classification in which a limited number of score values enables a grading system to quantify the total damage to the joint due to a large number of chronic lesions:

1. Score 0 applies to joints without or with only minimal changes, i. e., no damage to cartilage or slight degeneration of meniscus.
2. Score 1 denotes joints with mild changes such as degeneration of menisci and cartilage changes grades 1–2 on up to three areas of joint surface.
3. Score 2 applies to moderate joint changes with cartilage degeneration grades 1–2 on more than three areas, grade-3 cartilage degeneration on one area, or complex meniscal lesions.
4. Score 3 is restricted to severe joint lesions, grade-3 cartilage degeneration on more than one surface, or grade-4 defects.

This classification enabled the comparison of MRI and arthroscopy scores and the analysis of score values with regard to clinical data and physical activity. Correlations were proven by chi-square test, Bowker's test, or Spearman's rank correlation test.

Results

Visualisation of degenerative joint changes

In arthroscopy degenerative changes of cartilage were found in 75 % of the 320 patients (Fig. 3). The evaluation of 1920 cartilage areas in 320 knee joints showed that mild changes of grades 1 and 2 were evenly distributed on all joint surfaces, but grade-3 and grade-4 degeneration showed a predilection for the patellofemoral joint and condyle. Cartilage lesions were more common on the strongly curved surfaces of the patella and condyle than on the more plane surfaces of the trochlea and tibial plateau. Grade-1 lesions were seen on 226 ar-

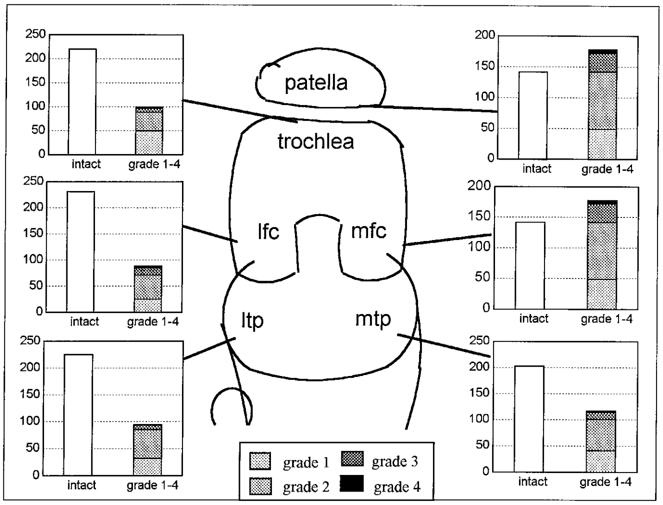

Fig. 3. Frequency and distribution of chondromatous joint changes grades 1–4 in arthroscopy of the knee joint ($n = 320$ patients). *mfc* medial femoral condyle; *lfc* lateral femoral condyle; *mtp* medial tibial plateau; *ltp* lateral tibial plateau

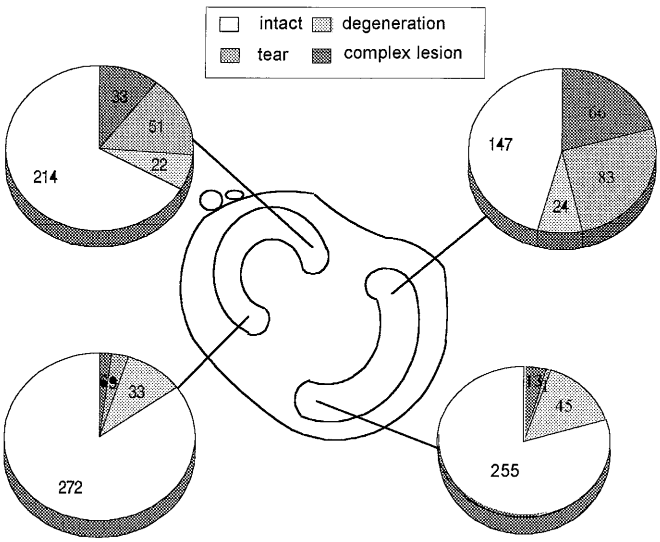

Fig. 4. Distribution of meniscal lesions (degeneration, tear, complex lesion) in the anterior and posterior horn of the medial and lateral meniscus ($n = 1274$ areas of 320 patients)

eas (11.8 %), grade-2 lesions on 372 areas (19.4 %), and grade-3 and grade-4 lesions on 131 areas (6.8 %). Degenerative meniscal changes had the same localizations as tears (Fig. 4). The posterior horns were much more affected than the anterior horns, and the medial meniscus more often then the lateral meniscus. Evaluation of four areas of meniscus per joint showed that 888 of 1280 meniscal areas (69.4 %) were intact, 10 % ($n = 128$) had degenerations, 11.4 % ($n = 146$) had tears, and 9.2 % ($n = 118$) had complex lesions.

Comparison of MRI and arthroscopy for each individual cartilage surface and meniscal area of the 320 joints showed sensitivity and specificity as well as predictive values (Table 1). Magnetic resonance imaging diagnosed grade-1 and grade-2 lesions in 14 and 32 % of cases, respectively (Fig. 5 a, b). The more serious stages of defects (grades 3 and 4) were sensitively detected in 94 and 100 %, respectively (Fig. 5 c, d). Using fat suppression or MTC a remarkable improvement in sensitivity was found especially for interstitial or superficial lesions (grades 1 or 2; Fig. 6). Advanced stages with focal thinning or denudation of cartilage (grades 3 or 4) were demonstrated with sensitivities of over 90 % in all sequences (Fig. 6). Five percent of cartilage surfaces showed focal changes on MRI which were not observed in arthroscopy. The diagnosis of cartilage changes depended on localization. Lesions on the posterior surface of the patella were best visualized (80 %), followed by lesions of the condyles (63 vs 65 %), trochlea (55 %), and, least sensitively, changes on both tibial plateaus (33 and 27 %). The arthroscopic stages of cartilage degeneration could be correlated with the respective stages of MRI, showing agreement in 75 %; 1435 of 1920 cartilage surfaces were staged identically. However, MRI showed a tendency to underestimate the severity of damage (Bowker's test of symmetry; $p < 0.001$, significant).

Table 1. Accuracy (%) of MRI in diagnosis of lesions of the cartilage and meniscus. Altogether, 1920 cartilage surfaces and 1280 meniscal areas of 320 patients were examined. *PPV* positive predictive value; *NPV* negative predictive value

Parameter	Cartilage (grade 1–4 lesions)	Meniscus (tears and complex lesions)
Sensitivity	26–96	72
Specificity	95	99
PPV	88	96
NPV	78	93
Accuracy	81	94

The detection of meniscal tears was lower on MRI than on arthroscopy, but degeneration of the meniscus was visualized more often on MRI (Bowker's test of symmetry; $p < 0.01$, significant). Two hundred twenty-two degenerations of individual parts of the meniscus were seen on MRI, but only 85 of these were seen on arthroscopy. All together, the diagnosis on MRI and arthroscopy for degenerations, tears, and complex lesions of meniscus was in agreement in 81 %. Diagnosis of tears was difficult in extensively degenerated menisci. If MRI staged meniscal degeneration grade 1 or 2 (222 meniscal parts), 45 % were normal in arthroscopy, 38 % were degenerated, and only 17 % were torn. The MRI diagnosis of a meniscal degeneration grade 3 (196 meniscal areas) showed 3 % normal, 0.5 % degenerated, 43 % torn, and 53 % complex changed menisci in arthroscopy. Detection of meniscal lesions (tears and complex lesions) was not improved using techniques with fat suppression or MTC. Sensitivity was reduced to 38 % (FLASH with MTC), 50 % (3D FLASH with fat suppression), and 71 % (SE with fat suppression) compared with standard technique (72 %).

Score values enabling grading of the total damage to the knee joint (mild, moderate, or severe changes) were used to enable comparison of MRI and arthroscopic findings (Table 2). The overall agreement be-

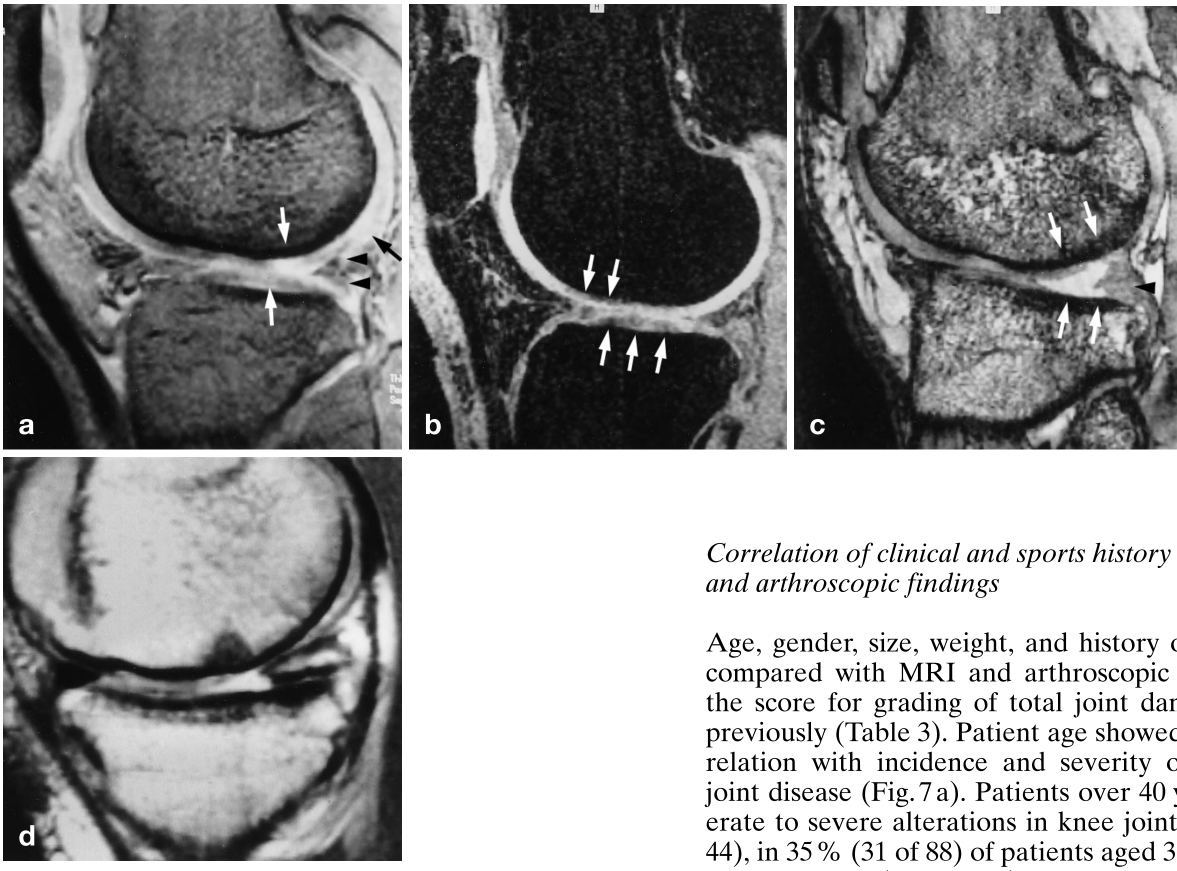

Fig. 5a–d. Demonstration of degenerative changes in cartilage and meniscus on MRI. **a** Signal increase in cartilage of lateral condyle and tibial plateau without thinning *(arrows)*. A 24-year-old soccer player after subtotal resection of the lateral meniscus (*arrowheads*; 3D FISP) with grade-1 and grade-2 lesions at arthroscopy. **b** Superficial and signal changes in cartilage are at the limit of resolution with 3D FLASH sequence with fat suppression *(arrows)*. Arthroscopy of this 27-year-old jogger showed grade-2 lesions on condyle and tibial plateau. **c** Advanced degeneration of cartilage (28-year-old soccer player). MRI with 3D FISP shows chondromatous defects on condyle and tibial plateau *(arrows)* adjacent to subtotal resected meniscus *(arrowhead)*. Grade-3 and grade-4 lesions at arthroscopy. **d** Patient (34-year-old soccer player) with severe alterations in the knee joint. Nearly complete loss of cartilage and advanced degeneration of the posterior horn of the medial mensiscus (SE sequence; TR/TE = 2000/20 ms)

Table 2. Correlation of scores for total knee damage between MRI and arthroscopy (n = 320 patients)

Arthroscopy	MRI			
	Score 0	Score 1	Score 2	Score 3
Score 0	74	7	0	0
Score 1	12	103	7	0
Score 2	4	26	65	1
Score 3	0	0	5	16

tween the individual score values of both methods was 81 % (285 of 320 joints), proving that MRI permits global grading of joint damage. Magnetic resonance imaging showed an overall tendency to underestimate severity of joint damage (Bowker's test; $p < 0.001$, significant).

Correlation of clinical and sports history with MRI and arthroscopic findings

Age, gender, size, weight, and history of trauma were compared with MRI and arthroscopic findings, using the score for grading of total joint damage described previously (Table 3). Patient age showed a positive correlation with incidence and severity of degenerative joint disease (Fig. 7 a). Patients over 40 years had moderate to severe alterations in knee joint in 45 % (20 of 44), in 35 % (31 of 88) of patients aged 30–40 years, and in only 22 % (42 of 188) of patients under 30 years ($\chi^2 = 22$, $p < 0.001$; Spearman's rank correlation, $p < 0.001$). Patients with severe trauma in their previous history without complete structural or functional reconstitution of the knee showed severe changes in menisci or cartilage on MRI in 57 % (24 of 42 patients; Fig. 7 b). However, only 26 % of patients with a stable knee joint without defects subsequent to trauma had severe joint changes (52 of 198 patients). The relationship between posttraumatic defects and joint degeneration was significant ($\chi^2 = 45$, $p < 0.001$). The other three factors (size, gender, and weight) had no statistically significant influence on the frequency of joint damage.

The type and intensity of physical activity was not directly related to the frequency of severe joint degeneration (Table 3). Active athletes in top leagues (national, regional, or state leagues) even had less moderate to severe joint changes on MRI than less competitive active athletes (17 vs 37 %; Fisher's exact test, $p < 0.0001$), although top league athletes trained more than the others. In the group of athletes with four to seven training sessions per week, severe joint damage was found less frequently than in the group of less active athletes with two to three training sessions (16 vs 36 %; Fisher's exact test, $p = 0.018$). There was no correlation between the Tegner score and the frequency of joint damage. Athletes with high scores of 8–10 did not have a higher frequency of joint damage (37 %) than those with moderate scores of 4–7 (38 %) or lower scores of 1–3 (35 %) (Spearman's rank correlation, $p = 0.572$). The individual types of sports were unimportant for the risk of irreparable joint damage. Soccer and handball players had

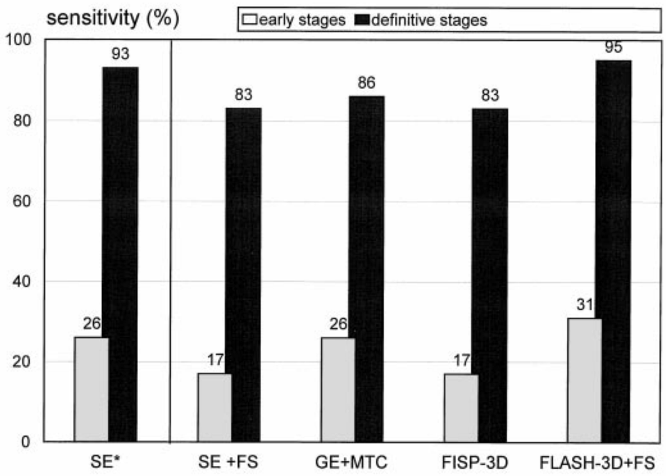

Fig. 6. Sensitivity of different MR techniques in diagnosis of early stages (grade-1 and grade-2 lesions with interstitial and superficial degeneration) and definitive stages (grade-3 and grade-4 lesions with thinning and denudation) of cartilage damage. *SE** total sensitivity of two sequences (SE with 512 × 512 matrix, coronal slices, plus proton-density and T2-weighted SE sagittal slices). The other techniques are single sequences in sagittal orientation

the same frequency of joint damage (34 vs 27 %) as bicyclists, gymnasts, or runners (29 % each), and those without any type of physical activity (31 %). There was no indication of joint damage being more frequent or severe depending on the total duration of physical activity. Athletes with 5–10 years activity had the same frequency of moderate to severe joint changes (33 %) as those with 15–20 years of practice (31 %) or longer (38 %).

Finally, the relationship between severity of joint damage and influencing factors was examined using arthroscopy instead of MRI. The comparison was made possible since the same classification for joint change was used and an acceptable correlation between staging on MRI and arthroscopy had been found. The same relationships between historical and clinical data were found for arthroscopy and MRI (Table 3). The MRI technique therefore shows the overall condition of the knee joint non-invasively precisely enough for use in sports medicine.

Discussion

Although MRI has been used in some epidemiological studies of joint changes in athletes, the method is gaining more importance in this field. Mainly, particular groups of athletes, such as professional football and basketball players, [5], joggers [13], long-distance runners [7], and junior soccer players [6, 14] were examined. The studies showed signal changes in menisci and reconstructive processes in cartilage more frequently in highly active persons than in less active individuals. Brunner et al. [15] observed signal changes in the menisci in 55 % of professional basketball players, and Kornick et al. [16] in only 25 % of non-athletes. The relationship between meniscal changes and physical activity was further suggested by increased signal intensity in only 10 % of active individuals after physical exertion, but in 50 % of physically untrained individuals after exertion [13]. In addition, Reinig et al. [6] showed an increased signal intensity of the menisci in longitudinal controls during 1 year of continued physical activity. The absence of arthroscopic verification is an important objection to the results of these studies, which made an estimation of the clinical and pathophysiological significance of MRI findings difficult. Signal changes in bradytrophic tissue could even be a sign of physiological adaptive processes. Recognition of early degenerative stages on MRI requires a reference method of proven reliability.

Physiological stress and joint movement are essential for nutrition and function of bradytrophic joint tissues. However, extreme exertion can cause ongoing damage to cartilage and menisci. Physical exertion can support or damage bradytrophic tissues, without the limits being

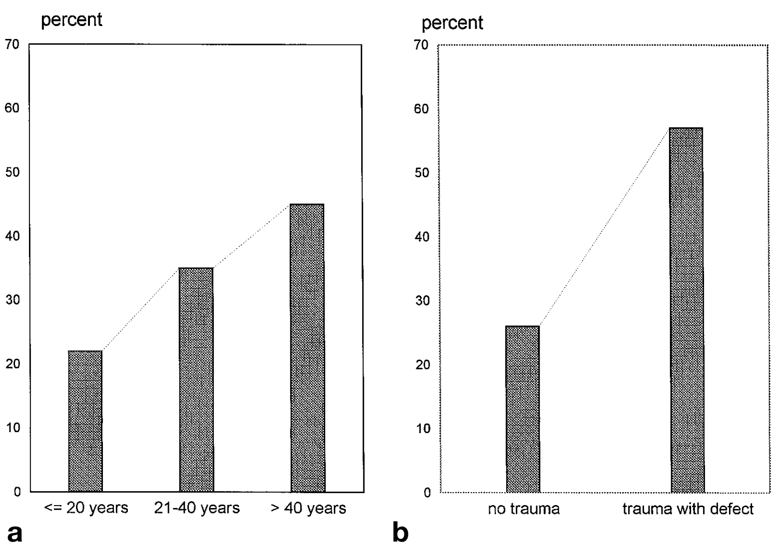

Fig. 7. Frequency of moderate to severe joint changes on MRI depending on **a** patient age and **b** history of severe knee trauma

Table 3. Correlation of the total lesion score of the knee joint on MRI and arthroscopy with clinical and physical activity history using multiple χ^2 test. Body mass index (BMI) was used instead of weight and size. MRI and arthroscopy showed in coherence that severity of joint damage was significantly correlated to age and history of massive knee trauma, but not to gender, BMI, or type and intensity of physical activity

Parameter	MRI			Arthroscopy		
	χ^2	*p*-value	Significance	χ^2	*p*-value	Significance
Gender	5.4	0.144	–	4.2	0.23	–
Age (years)	22	< 0.001	+ + +	32	< 0.001	+ + +
BMI	54	0.131	–	45	< 0.001	+ + +
Tegner score	8.1	0.24	–	5.6	0.56	–
Type of sport	31	0.168	–	27	0.073	–
League	21	0.05	–	26	0.37	–
Per week	9.8	0.36	–	20	0.32	–
Years of activity	62	0.71	–	59	0.78	–
Knee-trauma history	45	< 0.001	+ + +	41	< 0.001	+ + +

The possible relationship between arthroscopy score and BMI was not confirmed by Spearman's rank correlation

known. Wacker et al. [14] observed an increase in thickness of cartilage on the femoral condyles on MRI to be a sign of physiological adaptation to activity in young soccer players after extensive training for several years. The cartilage was on average 25 % thicker than in controls. On the other hand, in older football players marked degenerative joint changes have been observed [2].

In this study MRI was used in addition to arthroscopy for comparison with historical data. Soccer players with a known high risk for joint damage were examined as well as other patients with less physical activity. Reliable visualization of lesions in many joints, ability to grade total damage, and the diagnosis of early degeneration are the prerequisites for MRI in sports medicine. Arthroscopy was chosen as the reference technique due to its proven high efficiency in demonstrating extent and severity of joint damage. The notable limitations of arthroscopy are central degenerations of the menisci and intrameniscal tears, especially near the posterior horns which are not always visualized by arthroscopy [17]. Subchondral lesions are further indications for MRI, because they cannot be detected by arthroscopy [18].

We did not examine asymptomatic volunteers but instead examined patients after an acute trauma to be able to use invasive arthroscopy as a reference. This strategy necessitates differentiation of acute traumatic from chronic degenerative changes in arthroscopy or MRI. Degenerative and traumatic changes to ligaments, menisci, and cartilage share etiologies (stress, repetitive trauma), predilections, and histological characteristics. This is especially true for fibrocartilaginous tissue of the meniscus, where degenerative zones and tears show the same signal intensities [19]. Chronic changes in the hyaline cartilage are shown on MRI as focal changes with reduced or increased signal intensity or as defects [20]. Concomitant subchondral bone bruise adjacent to pathological cartilage indicate acute damage as it disappears within 2 months [18]. In arthroscopy acute lesions are characterized by hemorrhage and edema of ligaments, tears of menisci, and localized softening with impression of cartilage. Thus, in the majority of lesions acute and chronic changes could be differentiated, even without examination before trauma.

The comparison of MRI and arthroscopy shows that a standard protocol of SE sequences and 3D FISP enables diagnosis of chronic joint changes and graduation of total joint damage by MRI. Sensitivity depends on the severity of the lesion, less from the localization in the joint, and not from the size of the lesion. The low sensitivity for interstitial or superficial lesions reduces the value of MRI for diagnosis of early stages of cartilage damage. Some new techniques, including volume acquisition, use of 512 × 512 matrices, selective cartilage imaging with fat suppression and MTC, and MR arthrography after intra-articular or transvenous application of Gd-DTPA, were tested in experimental and clinical studies and improved detectability as compared with SE and FISP sequences [21–26]. Nevertheless, chondral lesions with interstitial or superficial degradation, which are regarded as precursors of definitive damage, still constitute a major problem. Our own experimental studies showed that MTC, fat suppression, and the invasive MR arthrography improved diagnosis of early stages to a sensitivity of up to 45 %, which is still very low for routine diagnosis [26]. Other experimental techniques include diffusion-weighted imaging, proton-densitiy mapping, sodium imaging, or intra-articular application of proteoglycan-affine Mangan [27]. Magnetic resonance imaging has no diagnostic advantages compared with arthroscopy, because pathological cartilage was found in only 5 % of cases with normal arthroscopy. However, MRI was advantageous in degeneration of the meniscus. The examination of 640 menisci showed that in 34 % of cases signal changes were seen in the meniscus but not detected on arthroscopy. It is generally accepted that MRI detects tears and degenerative changes in the meniscus accurately [24]. But depiction of a tear within highly degenerated meniscal tissue is a problem because both lesions produce an increased signal on all sequences [19]. Many structures at different sites with various extent and severity can be involved in degenerative joint disease. In evaluation of the whole joint instead of single lesions, the total score including all joint lesions showed good correlation between MRI and arthroscopy for grading purposes.

The correlation of lesion score with a large number of clinical and historical data showed that even extensive physical activity cannot be regarded as the major single cause of chronic joint damage. Patients with a high risk (Tegner scores of 8–10 with active football or handball players) and activity for over 10 years showed severe joint changes in up to 35 %. However, even patients with low scores (Tegner scores of 1–5, 45 % of patients with irregular recreation activities) showed joint changes in 25 %. Neither the sport practice nor the frequency of training, nor the number of years of activity, had an influence on the incidence of chronic joint damage. Two factors were found that correlated with the frequency of joint changes: patient age and previous trauma without full remission. Patients aged over 40 years had more frequent and more severe joint damage than those under 40 years. An explanation is probably the extremely protracted course of chronic joint disease, causing detectable changes only in higher age. The more common incidence of joint changes in patients with subtotal meniscal resection or cruciate ligament rupture in their history underlines the importance of internal joint structures for joint function. Our observations support the tendency in therapy of knee lesions to resort to reconstructive surgery instead of simple resection of damaged structures.

In conclusion, MRI enables reliable examination of chronic joint changes with non-invasive detection and grading. With increasing availability MRI and development of new techniques is certain to gain importance in sports medicine and epidemiological studies. The method will be widely accepted only when early stages of degeneration can be detected sensitively.

References

1. Mink JH, Reicher MA, Crues JV, Deutsch AL (1993) MRI of the knee, 2nd edn. Raven Press, New York, pp 91–188
2. Lee P, Rooney PJ, Sturrock RD (1974) The etiology and pathogenesis of osteoarthritis. Semin Arthritis Rheum 3: 189–218
3. Chapchal G (1983) Sportverletzungen und Sportschäden. Thieme, Stuttgart, pp 115–190
4. Sohn RS, Micheli LJ (1985) The effect of running on the pathogenesis of osteoarthritis of the hips and knees. Clin Orthop 198: 106–109
5. Brunner MC, Flower SP, Evancho AM, Altman FL, Apple DF, Fajman WA (1989) MRI of the athletic knee: findings in asymptomatic professional basketball and collegiate football players. Invest Radiol 24: 72–75
6. Reinig JW, McDevitt ER, Ove PN (1991) Progression of meniscal degenerative changes in college football players: evaluation with MR imaging. Radiology 181: 255–257
7. Shellock FG, Mink JH (1991) Knees of trained long-distance runners: MR imaging before and after competition. Radiology 179: 635–637
8. Wacker F, Bolze X, Mellerowicz H, Wolf KJ (1995) Diagnostik von Veränderungen des Kniegelenkes bei Leistungssportlern. Radiologe 35: 94–100
9. Tegner Y, Lysholm J (1985) Rating system in the evaluation of knee ligament injuries. Clin Orthop 198: 43–49
10. Klein W, Jensen KU (1992) Dokumentationsbögen für die arthroskopische Chirurgie: Knie-, Schulter- und Sprunggelenk. Arthroskopie 5: 185–192
11. Shariaree H (1985) Chondromalacia. Contemp Orthop 11: 27–39
12. Stoller DW, Martin C, Crues JV, Kaplan L, Mink JH (1987) Meniscal tears: pathologic correlation with MR imaging. Radiology 163: 731–735
13. Kursunoglu-Brahme S, Schwaighofer B, Gundry C, Ho C, Resnick D (1990) Jogging causes acute changes in the knee joint: an MR study in normal volunteers. Am J Roentgenol 154: 1233–1235
14. Wacker F, König H, Felsenberg D, Wolf KJ (1994) MRT der Kniegelenke jugendlicher Fussballspieler: Gibt es Frühveränderungen von Kniebinnenstrukturen durch Leistungssport? Fortschr Röntgenstr 160: 149–153
15. Brunner MC, Garret JC, Stiles RG (1990) A directed approach to MRI of the athletic knee. Am J Sports Med 30: 222–228
16. Kornick J, Trefelner E, McCarthy S, Lange R, Lynch K, Jokl P (1990) Meniscal abnormalities in the asymptomatic population at MR imaging. Radiology 177: 463–465
17. Solomon SL, Totty WG, Lee JKT (1989) MR imaging of the knee: comparison of three-dimensional FISP and two-dimensional spin-echo pulse sequences. Radiology 173: 739–742
18. Vallet AD, Marks PH, Fowler PJ, Munro TG (1991) Occult posttraumatic osteochondral lesions of the knee: prevalence, classification, and short-term sequelae evaluated with MR imaging. Radiology 178: 271–276
19. Hodler J, Haghighi P, Trudell D, Resnick D (1993) Degenerative changes of the menisci of the knee: value of different MR pulse sequences. Acta Radiol 34: 404–407
20. Lehner KB, Recht HP, Gmeinwieser JK, Heuck AF, Lukas HP, Kohl HP (1989) Structure, function, and degeneration of bovine hyaline cartilage: assessment with MR imaging in vitro. Radiology 170: 495–499
21. Recht MP, Kramer J, Marcelis S, Pathria MN et al. (1993) Abnormalities of articular cartilage in the knee: analysis of available MR techniques. Radiology 187: 473–478
22. Engel A, Kramer J, Stiglbauer R, Hajek PC, Imhof H (1993) Articular cartilage defect detectability in human knees with MR arthrography. Eur Radiol 3: 161–165
23. Chalkias SM, Pozzi-Mucelli RS, Pozzi-Mucelli M, Frezza F, Longo R (1994) Hyaline articular cartilage: relaxation times, pulse-sequence parameters and MR appearance at 1.5 T. Eur Radiol 4: 353–359
24. Sittek H, Heuck A, Eckstein F, Reiser M (1995) Magnetresonanztomographie bei Traumen des Kniegelenks. Radiologe 35: 101–108
25. Vahlensieck M, Peterfy CG, Wischer T, Sommer T, Lang P, Schlippert U, Genant HK, Schild HH (1996) Indirekt MR arthrography: optimization and clinical applications. Radiology 200: 249–254
26. Bachmann G, Heinrichs C, Jürgensen I, Rominger M, Scheiter A, Rau WS (1997) Vergleich von verschiedenen MRT-Techniken in der Diagnose von degenerativen Knorpelerkankungen: In vitro-Studie an 50 Gelenkpräparaten des Knies bei 1.5 T. Fortschr Röntgenstr 166: 429–436
27. Trattnig S (1997) Overuse of hyaline cartilage and imaging. Eur J Radiol 25: 188–198