PAAVO-ILARI KUIKKA

Epidemiology and Magnetic Resonance Imaging-Based Diagnostics of Knee Injuries and Anterior Knee Pain in Young Adults

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UNIVERSITY OF TAMPERE

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1   List of Original Publications

This thesis is based on the following original publications, which are referred to in the text by the Roman numerals I–IV:

I   Kuikka, P. I., Kiuru, M. J., Niva, M. H., Kröger, H., Pihlajamäki, H. K. (2006). Sensitivity of routine 1.0-Tesla magnetic resonance imaging versus arthroscopy as gold standard in fresh traumatic chondral lesions of the knee in young adults. Arthroscopy, 22(10), 1033–1039.

II   Kuikka, P. I., Sillanpää, P., Mattila, V. M., Niva, M. H., Pihlajamäki, H. K. (2009). Magnetic resonance imaging in acute traumatic and chronic meniscal tears of the knee: A diagnostic accuracy study in young adults. Am J Sports Med, 37(5), 1003–1008.

III   Pihlajamäki, H. K., Kuikka, P. I., Leppänen, V. V., Kiuru, M. J., Mattila, V. M. (2010). Reliability of clinical findings and magnetic resonance imaging for the diagnosis of chondromalacia patellae. J Bone Joint Surg Am, 92(4), 927–934.

IV   Kuikka, P. I., Pihlajamäki, H. K., Mattila, V.M. (2011). Knee injuries related to sports in young adult males during military service – Incidence and risk factors. Scand J Med Sci Sports. Epub 2011 Oct 19.

Articles I–IV have been reprinted in this thesis with the permission from Elsevier (I), SAGE Publications (II), J Bone Joint Surg Am. (III) and Blackwell Munksgaard (IV).

2 Abbreviations

ACL = Anterior cruciate ligament

AKP= Anterior knee pain

BMI = Body mass index

CI= Confidence Interval

CMP = Chondromalacia patellae

CT = Computed tomography

ICRS = International Cartilage Repair Society

LCL = Lateral collateral ligament

MCL = Medial collateral ligament

MRI = Magnetic Resonance Imaging

NHDR = National hospital discharge register

OR = Odds Ratio

PCL = Posterior cruciate ligament

PFM = Patellofemoral malalignment

PFPS = Patellofemoral pain syndrome

SPGR = Spoiled gradient echo

T = Tesla

US = United States of America

3   Tiivistelmä

Tämän väitöskirjan tarkoituksena on selvittää nuorten aikuisten miesten polvivammojen ilmaantuvuutta ja riskitekijöitä sekä magneettikuvauspainotteista diagnostiikkaa tuoreissa polven rustovaurioissa, nivelkierukan repeämissä ja polven etuosan kivussa.

Epidemiologisena aineistona tutkimuksessa olivat kaikki tutkimusajanjakson aikana varusmiespalveluksensa suorittaneet 18–30-vuotiaat miespuoliset varusmiehet (n=128 584). Altistumisaika oli 97 503 henkilövuotta. Pakollisen asevelvollisuuden vuoksi varusmiehet edustavat erittäin hyvin perustervettä nuorta aikuista miesväestöä Suomessa. Kaikki sairaalahoitoon johtaneet polvivammat tässä aineistossa selvitettiin kansallisen hoitoilmoitusrekisterin avulla. Polvivammoja käsiteltiin kokonaisuutena ja lisäksi jaoteltuina erillisiin diagnooseihin, joita olivat ristiside- ja sivusidevammat, nivelkierukkarepeämät, traumaattiset rustovauriot ja polvilumpion sijoiltaanmenot. Tiedot palveluskelpoisuusluokan muutoksista ja mahdollisesti polvivammoihin yhteydessä olevista riskitekijöistä saatiin puolustusvoimien sisäisistä rekistereistä.

Magneettikuvauksen diagnostista validiteettia tuoreissa rustovaurioissa sekä tuoreissa ja vanhoissa nivelkierukkarepeämissä tutkittiin retrospektiivisesti. Aineistojen kaikille potilaille oli tehty magneettikuvaus ja artroskopia keskussotilassairaalassa normaalin kliinisen käytännön mukaisesti. Tuoreiden rustovaurioiden magneettikuvausta käsittelevään aineistoon otettiin mukaan 32 potilasta, joilla oli todettu artroskopiassa tuore traumaattinen rustovaurio. Potilaiden mediaani-ikä oli 19 vuotta (vaihteluväli 19–21).

Tuoreiden ja vanhojen nivelkierukkarepeämien magneettikuvausdiagnostiikkaa vertailevien aineistojen mukaanottokriteerit täytti 82 potilaista, joilla oli tuore polvivamma, ja 40 potilasta, joilla oli pidempikestoinen polviongelma. Potilaiden mediaani-ikä oli 20 vuotta (vaihteluväli 18–25).

Polven etuosan kipuun liittyvien oireiden ja statuslöydösten yhteyttä artroskooppisiin löydöksiin tutkittiin prospektiivisesti 56 varusmiehen aineistossa. Kaikilla oli pidempiaikainen, vammaan liittymätön polven etuosan kiputila. Potilaiden mediaani-ikä oli 19.5 vuotta (vaihteluväli 18–25). Kaikille tutkimukseen valituille tehtiin magneettikuvaus ja artroskopia keskussotilassairaalassa.

Sairaalahoitoon johtaneiden polvivammojen ilmaantuvuus kokonaisuutena oli 11 potilasta 1000 henkilövuotta kohden [95 % luottamusväli (CI): 10.4–11.7]. Polvivammojen riskitekijöitä analysoitiin logistisella regressiolla. Merkittävimmät riskitekijät polvi-

vammoille olivat korkeampi ikä (OR 1.7; 95 % CI: 1.3–2.2) ja ylipaino (OR 1.6; 95 % CI: 1.03–2.5). Kirurginen toimenpide tehtiin kahdelle kolmasosalle kaikista sairaalassa hoidetuista potilaista ja pidempiaikainen haitta (palveluskelpoisuusluokan muutos) jäi yhdelle kolmasosalle potilaista.

Tuoreiden traumaattisten rustovaurioiden todentamisessa 1.0 Teslan magneetti-kuvauksen sensitiivisyys oli alhainen. Sensitiivisyys oli riippuvainen rustovaurion syvyydestä, ollen pinnallisissa vaurioissa vain 17 %. Koko ruston syvyyden kattaville vaurioille sensitiivisyys oli hieman parempi, 57 %. Tulos tarkoittaa, että lähes puolet syvistä rustovaurioista jäi diagnosoimatta magneettikuvauksessa. Huolimatta normaalista magneettikuvauslöydöksestä saattaa artroskopia paljastaa korjaustoimenpiteisiin soveltuvia syviä rustovaurioita.

Tuoreiden ja vanhojen nivelkierukkarepeämien magneettikuvauksen diagnostisessa validiteetissa ei todettu merkittävää eroa. Tutkimustulokset antoivat myös viitteitä siitä, että polvinivelen turvotus tai veripolvi ei heikennä diagnostista validiteettia.

Polven etuosan kipua käsittelevässä 56 potilaan aineistossa todettiin polvilumpion rustovaurio 25 tapauksessa (45 %). Nivelkalvon poimu todettiin myös 25 polvessa, nivelkierukan repeämä 4 polvessa, femorotibiaalinen rustovaurio neljässä polvessa ja normaali anatomia kuudessa polvessa. Polvilumpion takainen krepitaatio tai polvilumpion painamisesta provosoituva kipu ei lisännyt rustovaurioiden todennäköisyyttä potilailla, joilla oli tyypilliset polven etuosan kiputilaan liittyvät oireet. Oireiden, löydösten ja polvilumpion rustovaurion asteen välillä ei todettu selkeää yhteyttä (p = 0.83). Tulokset tukevat aiempia havaintoja siitä, että polvilumpion rustovaurioita ei voida luotettavasti diagnosoida oireiden ja statuslöydösten perusteella. 1.0 Teslan magneettikuvauksen sensitiivisyys oli alhainen luokan I rustovaurioille (13 %), mutta selkeästi parempi syvemmille rustovaurioille (83 %). Magneettikuvausta voidaankin käyttää diagnostisena apuvälineenä polvilumpion syvempien, mahdollisesti operatiivista hoitoa tarvitsevien rustovaurioiden diagnostiikassa.

4   Abstract

Knee injuries and anterior knee pain are frequently encountered and treated by orthopaedic surgeons and general practitioners in daily clinical practice. Knee injuries are most common in those under 30 years of age and especially in males. Accurate incidence rates of knee injuries requiring hospitalisation (i.e. inpatient care admission) in this high-risk subgroup, however, are not known. Also unclear are the roles of intrinsic modifiable factors, such as body mass index (BMI), weight, aerobic fitness, and muscular strength, as risk factors for knee injuries.

The epidemiologic section of this dissertation is based on population-based data among Finnish young adult male conscripts. Our aim was to determine the incidence and possible risk factors for knee injuries requiring inpatient care. Moreover, knee injuries were analysed by specified diagnosis (cruciate and collateral ligament tears, meniscal tears, traumatic chondral lesions, and patellar dislocations). The total number of Finnish male conscripts performing their compulsory military service during the study period was 128,584 and total exposure time was 97,503 person-years. Risk factor analyses were performed by logistic regression. The person-based incidence of inpatient care admissions for knee injury in general was 11 cases per 1000 person-years (95% confidence interval [CI]: 10.4–11.7). The most important risk factors were higher age (odds ratio [OR] 1.7; 95% CI: 1.3–2.2) and obesity (OR 1.6; 95% CI: 1.03–2.5). Two-thirds of all subjects admitted to inpatient care for knee injuries had surgery, and one-third had long-term notable disability.

The diagnostic section of this dissertation addresses three diagnostic challenges: fresh traumatic chondral lesions, fresh meniscal tears, and anterior knee pain (AKP). Study populations were based on conscripts treated at the Central Military Hospital in Helsinki, Finland. Arthroscopic results served as the gold standard for calculating the sensitivity, specificity, and accuracy of magnetic resonance imaging (MRI) findings.

The validity of MRI for fresh traumatic chondral lesions and for fresh vs. old meniscal tears was studied retrospectively. Study populations comprised young adult conscripts in whom both knee MRI and arthroscopy were performed at the Central Military Hospital. In the first sample, 32 patients, ranging in age from 19 to 21 years (median, 19 years), with arthroscopically proven fresh traumatic chondral lesions of the knee met the inclusion criteria.

In the samples used for comparing MRI validity in fresh traumatic and old meniscal tears, 82 patients, ranging in age from 18 to 25 (median, 20 years) met the inclusion criteria with acute knee trauma (MRI within 30 days from trauma) and 40 patients with chronic knee symptoms (symptoms lasting over 6 months before MRI).

Diagnostic studies revealed that routine clinical use of 1.0 Tesla (T) MRI has poor sensitivity (36%) for detecting fresh traumatic articular cartilage lesions. Sensitivity was associated with the lesion grade and was only 17% for superficial lesions and moderately better, 57%, for full-thickness lesions. Thus, almost half of the full-thickness cartilage lesions remained undiagnosed following preoperative MRI. Despite negative MRI findings, arthroscopy may reveal lesions amenable to cartilage repair procedures.

The diagnostic validity of MRI for meniscal tears in acute knee trauma and in knee symptoms lasting over 6 months in young adults was similar. This study also suggests that effusion and haemarthrosis are not associated with the diagnostic validity of MRI for meniscal tears.

The association between the clinical symptoms and arthroscopic findings, and the role of MRI in AKP were studied prospectively. Fifty-six young adult conscripts (median age, 19.5 years) with AKP were prospectively selected for the study and MRI of the knee followed by arthroscopy was performed at the Central Military Hospital in Finland.

Arthroscopy confirmed the presence of patellar chondral lesions in 25 (45%) of 56 knees of patients with AKP. Synovial plicae were as common a finding as patellar chondral lesions and was present in 25 knees. Normal anatomy was observed in only six knees. The presence of retropatellar crepitus or pain on manipulation of the patella was not associated with a higher proportion of patellar chondral lesions in patients with typical clinical AKP symptoms. The severity of patellar chondral lesions observed at arthroscopy was not associated with clinical symptoms of AKP syndrome (p = 0.83). This data supports earlier reports that patellar chondral lesions cannot be distinguished from other causes of AKP based on clinical symptoms and physical examination signs. The routine MRI protocol used for patients with AKP showed a sensitivity of only 13% for superficial patellar chondral lesions. For more severe lesions, the sensitivity was substantially higher, 83%, and 1.0T MRI may be considered a sensitive diagnostic tool in these cases.

5   Introduction

Injuries are the major cause of morbidity in young adults in Finland (Koskinen, 2005; Haikonen & Lounamaa, 2010). Sports injuries are the most common type of injury and young men in particular are a clear high-risk subgroup (Heiskanen, Sirén, et al., 2004; Parkkari, Kannus, et al., 2004; Haikonen & Lounamaa, 2010). Knee injuries comprise a significant portion of all sport and leisure time injuries (Haikonen & Lounamaa, 2010; Majewski, et al., 2006; Parkkari, et al., 2004). Knee injuries are a major cause of pain and disability in individuals and they are also a public health concern due to the costs associated with health care, work disability, and incapacitation. Population-based studies of the incidence and risk factors of knee injuries in young adult populations, however, are sparse. This information is essential because health differences during young adulthood may predict greater differences in health at an older age. Young adulthood is a critical age to target intervention programs because health habits are usually stabilising during that age period (Koskinen, 2005). Preventive strategies for knee injuries can only be utilised if their risk factors are known.

Valid diagnostics of knee injuries are critical for choosing the appropriate treatment methods and avoiding unnecessary treatments. Knee injury diagnostics are based on obtaining an accurate history and physical examination. Imaging modalities such as MRI can be performed when the diagnosis remains unclear after examination by a physician and analysis of plain radiographs. MRI became clinically available in the 1980s (Rappeport, et al., 1996), and is frequently used for diagnosing knee pathologies. Today, MRI of the knee joint is routine practice for the detection of trauma-related lesions, and is considered a sensitive and specific diagnostic method for evaluating meniscus and ligament injuries (Crawford, et al., 2007; Fischer, et al., 1991; Mackenzie, et al., 1996; Oei, et al., 2003; Rappeport, et al., 1996). Lower diagnostic validity is reported, however, when only acute knee injuries are included in the study (Lundberg, et al., 1996). Whether this is due to properties associated with acutely injured knees, such as haemarthrosis or catabolic processes of the meniscal tissue, or to varying methodologies and populations between studies, however, is unclear. There are no studies comparing the diagnostic validity of MRI for fresh and old meniscal lesions in an equivalent population with similar imaging methods.

Most previous studies of the diagnostic value of MRI for chondral lesions have focused on older populations in which the prevalence of osteoarthritis is high (Bredella,

et al., 1999; Disler, et al., 1996; Felson, 1988; Handelberg, et al., 1990; Hodler, et al., 1992; Potter, et al., 1998; Recht, et al., 1993; Riel, et al., 1999). MRI sensitivity varies widely between these studies (0%–100%) (Handelberg, et al., 1990; Munk, et al., 1998; Spiers, et al., 1993) and continues to be challenging (Figueroa, et al., 2007; von Engelhardt, et al., 2007). It remains unclear whether fresh traumatic chondral lesions of the knee in young adults can be diagnosed preoperatively by the routine MRI protocols used for overall knee examination.

AKP is one of the most common knee complaints in young adults. The pathophysiology behind AKP is poorly known and controversial. Patellar chondral lesions (chondromalacia patellae, CMP) was previously thought to be the reason for AKP, but this has been called into question because not all patients with AKP have patellar chondral lesions (Leslie & Bentley, 1978). According to the recently proposed tissue homeostasis theory, increased loading of the patellofemoral joint leads to a loss of tissue homeostasis in the surrounding innervated tissues, which causes the pain. Only in the most severe cases is loss of tissue homeostasis characterized by macrostructural damage such as chondral lesions (Dye, 2005). The widely accepted patellofemoral malalignment (PFM) theory is complementary to the tissue homeostasis theory. Patellofemoral malalignment may cause increased loading to the patellofemoral joint, which leads to a loss of tissue homeostasis (Sanchis-Alfonso, Vicente, 2011).

Further, the association between clinical symptoms and arthroscopic findings in AKP is not clear. Whether MRI can confirm possible patellar chondral lesions as an underlying cause of AKP is also uncertain, even if cartilage-specific sequences such as axial T1-weighted three-dimensional (3D) spoiled gradient echo (SPGR) is included in the routine knee evaluation protocol (Disler, et al., 1996; Gagliardi, et al., 1994; von Engelhardt, et al., 2007).

A reliable diagnosis of possible articular cartilage lesions as well as many other knee pathologies can be reached by arthroscopy, which allows for a direct view of the patellofemoral joint (Casscells, 1971; Figueroa, et al., 2007). Arthroscopic examination and treatment of the knee, however, also has some potential disadvantages. Because the arthroscopy procedure is invasive, it may lead to work disability, pain, and stress for the patient, and it is also associated with risks related to anaesthesia and surgery. Furthermore, unnecessary arthroscopies consume already-limited health care resources. In cases in which no surgically treatable lesion is found, arthroscopy can be considered an unnecessary diagnostic method and should be avoided. Valid preoperative diagnostics of chondral lesions are especially important in the young adult population. Within the last two decades, new treatment methods for chondral lesions, such as autologous chondrocyte implantation, have evolved and their results are generally moderate to good with a follow-up of a few years (Brittberg, et al., 1994; Gomoll, et al., 2010; Peterson, et al., 2002). These methods are especially useful for young adults with traumatic chondral lesions (Gomoll, et al., 2010; Kiviranta & Vasara, 2004; Peterson, et al., 2002; Vasara, et al., 2006). These

advanced surgical procedures are available at only a few hospitals in Finland (Vasara, et al., 2006). Valid, noninvasive diagnostic methods for deep symptomatic chondral lesions could help to choose the appropriate cartilage repair procedure.

6   Review of the Literature

6.1   Health Problems in Young Adults in Finland

The results of the Health 2000 Survey (Koskinen, 2005) conducted to evaluate the health of 18 to 29-year-old Finnish young adults indicated that young adults in Finland are generally rather healthy. For example cardiovascular diseases, diabetes, permanent injuries and severe disabilities are relatively rare in this age group.

Injuries are the major cause of morbidity in young adults in Finland as well as internationally (Haikonen & Lounamaa, 2010; Heiskanen, et al., 2004; Jones & Knapik, 1999; Parkkari, et al., 2004). In military populations, injuries can cause 10 times more limited duty days than illnesses (Jones & Knapik, 1999). In the Health 2000 Survey, 9% of the 18 to 29 year-old males and 4% of the females reported some permanent injury (Koskinen, 2005). Several studies demonstrated that sports injuries are the most common injury type in Finland, especially in younger people (Haikonen & Lounamaa, 2010; Heiskanen, et al., 2004; Parkkari, et al., 2004; Peltonen, et al., 2008) In a national victimisation survey, the incidence of sports injuries in the 15 to 24-year age group was 178 cases/1000 persons per year in 2009 (Haikonen & Lounamaa, 2010). Sports injuries were followed by injuries at home (90/1000 persons per year), at work (70/1000 persons per year), traffic-related (50/1000 persons per year), and during other leisure-time activities (30/1000 persons per year). Sports and traffic-related injuries were most common in the younger age groups, and clearly decreased with increasing age. Young men are especially a clear high-risk subgroup. Men aged 15 to 25 had 204 sports-related injuries per 1000 persons in 2009 and women in this age group reported 155 sports-related injuries per 1000 persons. The higher incidence rates in young persons may be due to more intensive sports participation (Parkkari, et al., 2004). In the Health 2000 study, approximately two-thirds of the 18 to 29 year-old responders reported taking part in leisure time sports activities two or more times a week (Koskinen, 2005). In Finnish conscripts, the person-based incidence of hospitalised injuries is close to 100 per 1000 conscripts annually, whereas the event-based incidence of musculoskeletal injuries leading to a military primary care visit is reported to be approximately 10 to 40 times higher (Heir, T. & Glomsaker, 1996; Mattila, et al., 2006; Taanila, et al., 2010). Lower limb injuries comprise a significant

portion of all musculoskeletal injuries (Almeida, et al., 1999; Heir, T. & Glomsaker, 1996; Mattila, et al., 2007; Mattila, et al., 2006; Smith & Cashman, 2002).

6.2   Epidemiology of Knee Injuries in Young Adults

6.2.1   Overall Incidence of Knee Injuries

Of the all physical activity-related injuries, knee injuries comprise approximately 15% in Finland (Haapasalo, et al., 2007). A study of sports injuries in the general population in Finland revealed that the knee was the most commonly injured body part, accounting for approximately 12.5% of all sports-related injuries in men and 17% in women (Parkkari, et al., 2004). In the national victimisation survey of 2009 (Haikonen & Lounamaa, 2010), the most commonly injured body part during sports was the ankle (26% of the sports injuries), followed by the knee (17%) and back (9%). In other leisure time activities, the knee was injured most often (25%), followed by the ankle (13%). In the US army and in Norwegian conscripts, knee injuries comprise approximately 25% of all injuries (Almeida, et al., 1999; Heir, T. & Glomsaker, 1996) and similar results are reported in Finnish conscripts for knee and shin injuries combined (Mattila, et al., 2007). At sports injury clinics, knee injuries may account for up to 40% of all injuries (Majewski, et al., 2006).

Knee pain is also a common complaint. In the Health 2000 Survey, 8% of males aged 18 to 29 and 6% of females reported knee pain in the preceding month (Koskinen, 2005). The difference between the sexes was not statistically significant. In a UK population, the prevalence of knee pain in males between 16 to 44 years was reported to be 15%, of which about 16% was disabling and 7% intense and disabling (Webb, et al., 2004). The prevalence of knee pain and osteoarthritis, which is a main reason for knee pain, increases with age in both sexes (Kaila-Kangas, 2007).

Accurate injury incidence rates of knee injuries in young adults are still unknown, especially in Finland. Knee injuries are most common in those under 30 years of age and especially in males (Gianotti, et al., 2009; Kannus & Järvinen, 1989; Majewski, et al., 2006). Kannus and coworkers studied the incidence of knee injuries in Finnish community health centre patients in the 1980s (Kannus & Järvinen, 1989). In their prospective study of 148 patients, the cumulative incidence of knee injuries was 11 cases per 1000 persons during a 1-year study period. Most of the injuries occurred between the ages 10 to 39, but the incidence rates for different age groups were not reported. Ten percent of the visits led to surgical consultation. The study population was older than the mean age of the general population in Finland. In Denmark, the cumulative incidence of acute knee injuries treated in emergency departments at the primary health care institutions is 13.3 per 1000 inhabitants annually in males and 9.7 in females (Nielsen & Yde, 1991). Not

all knee injuries in the area were treated at the same institution and only injuries less than 24 hours old were included, which lowered the reported incidence rate. Also, two-thirds of the patients were classified as having a contusion or distortion, which may have caused only minor morbidity. In the US in 2000, a markedly lower cumulative annual incidence rate of less than 3 acute knee injuries requiring a physician's attention per 1000 persons annually was reported (Yawn, et al., 2000). Men aged 25 to 29 had a peak incidence of approximately 6 injuries per 1000 persons per year. The lower cumulative incidence rate may be due to differences in inclusion criteria, a smaller number of sports-related injuries in the US population, or even differences in insurance policies that may decrease the capture of mild injuries in the US study (Yawn, et al., 2000). In Finnish conscripts, the event-based incidence of knee disorders leading to a visit to the garrison clinic is reported to be approximately 730 cases per 1000 person years with a mean of two health care visits per knee disorder (Taanila, et al., 2010). Another report of the same study group showed that 35% of the knee disorders at the garrison clinics are acute injuries (Taanila, et al., 2009). Based on these data, the patient-based incidence of acute knee injuries treated as outpatients in garrison clinics are estimated to be as high as 130 cases per 1000 person-years. Most of the above-mentioned studies reported injuries only according to anatomical location (knee); did not describe specified injury diagnoses, or included nonspecific diagnoses such as knee sprains, strains, or contusions (Kannus & Järvinen, 1989; Taanila, et al., 2010; Yawn, et al., 2000); or the study methodology led to a clear underestimation of the injury incidence rate (Nielsen & Yde, 1991). Also, rather than reporting exact person-time (i.e., first admission due to knee injury, death, or moving out of the area as a censoring event), investigators usually reported the cumulative annual incidence, which assumes that the person is at risk for the whole study period (Kannus & Järvinen, 1989; Nielsen & Yde, 1991; Yawn, et al., 2000) and leads to a minor overestimation of time at risk and thus lowers the incidence rate.

To our knowledge, there are no comprehensive studies in the literature reporting the accurate incidence rates of knee injuries needing inpatient care in general and according to specified diagnoses in the young adult population.

6.2.2   Incidence and Relative Frequency of Common Specified Knee Injuries and Anterior Knee Pain

The National Institute for Health and Welfare collects statistics from all outpatient visits to the special health care clinics in Finland and the most common main diagnoses are reported on a yearly basis. In the latest report from the year 2009, 28,035 patients were included in the diagnosis group S80–89 (injury of knee or shin). Of these, diagnosis code S83 (dislocation or distortion of the knee joint or ligaments) was applied to 8127 patients. A main diagnosis of M23, internal derangement of the knee, including old meniscal tears, was applied to 10,964 patients. A main diagnosis of M22, patellar diseases, was applied

to 2579 patients (Forsström & Pelanteri, 2011). Majewski and coworkers (Majewski, et al., 2006) studied the epidemiology and relative frequency of knee injuries in sports. Knee sprain without clearly identifiable internal derangement was the most common injury reported. The most commonly identified internal knee derangement was an ACL tear (20.3%), followed by a medial meniscal tear (10.8%), chondral lesion (10.6%), MCL tear (7.9%), contusion injury due to direct trauma (5.5%), lateral meniscal tear (3.7%), and patellar dislocation (3.3%). Also, a few lateral collateral ligament injuries (1.1%) and PCL injuries (0.65%) were reported. In acute knee haemarthrosis patients, the most common arthroscopic finding was ACL injury (45% of patients), followed by patellar dislocation (23%), MCL or meniscal rupture (23% each), chondral lesions (18%), and PCL rupture (3%) (Sarimo, et al., 2002). The most common nontraumatic knee disorder in young adults is AKP (Devereaux & Lachmann, 1984; Sanchis-Alfonso, Vicente, 2011).

Most ACL injuries occur during sports (Gianotti, et al., 2009). In the Finnish adolescent and young adult population, the injury incidence rate for hospitalisations due to cruciate ligament injuries is reported to be 1 per 1000 person-years for males and 0.3 per 1000 person years for females (Parkkari, et al., 2008). A slightly higher incidence rate in this age group is reported for surgically-treated ACL injuries in the general population of New Zealand (Gianotti, et al., 2009). For all age groups, the cumulative incidence rate for ACL surgeries was only 0.4 per 1000 persons annually. The injury incidence rate was highest among young adult males in their early thirties, reaching 1.6 cases per 1000 persons annually. In females, the peak incidence occurred in the late thirties: 0.8 cases per 1000 persons annually. The study is limited, however, in that the number of nonsurgically treated ACL injuries was not reported. In a US population of all ages, the incidence rate for ACL injuries treated at the orthopaedic knee injury clinic was 0.4 per 1000 persons annually (Miyasaka, et al., 1991). The incidence rate included only those injuries with pathological anteroposterior motion in physical examination. In a general population-based UK study, the cumulative person-based incidence of ACL ruptures treated at the orthopaedic trauma unit was markedly lower, 0.08 per 1000 persons annually (Clayton & Court-Brown, 2008). Both inpatient and outpatient care were taken into account and the age of the patient ranged from 12 to 89 years. The cumulative incidence was highest in males aged 20 to 29 years, nearly 0.4/1000 persons per year, and declining rapidly after that. In females, the age-related incidence curve was similar, but peak cumulative incidence was clearly lower, less than 0.1/1000 persons per year. The overall male to female ratio was 76/24. It must be noted that many of the patients were referred to a knee surgeon instead of the clinic involved, leading to an underestimation of the incidence rates.

The reported cumulative incidence rates in primary health care emergency department patients in Denmark are only 0.4 for isolated or combined acute cruciate ligament injuries per 1000 inhabitants per year for males and 0.2 for females (Nielsen &

Yde, 1991). Only injuries less than 24 hours old were included, which lowers the incidence reported.

Posterior cruciate ligament injury typically occurs in car collisions when the shin forcefully strikes the dashboard or during sports when a player falls forcefully on the flexed knee (Moore & Dalley, 2006). Patients are usually young adult males (Schulz, et al., 2003). Posterior cruciate ligament and posterolateral corner injuries are frequently combined with other ligamentous injuries (LaPrade, et al., 2007). Isolated PCL injuries are present in 5% of the knee injuries with acute knee haemarthrosis (LaPrade, et al., 2007). The accurate population-based incidence of PCL injuries is not known. In a study by Mattila and co-workers (Mattila, et al., 2008), PCL injuries constituted less than 10% of all cruciate ligament injuries in Finnish conscripts. Similar results were reported in Denmark (Nielsen & Yde, 1991), suggesting that the cumulative incidence of acute PCL injuries leading to a primary health care visit within 24 hours of injury might be as low as 0.02 cases per 1000 inhabitants per year. The cumulative person-based incidence of PCL injuries with associated pathologic anteroposterior motion was approximately 0.04 per 1000 persons annually in the US (Miyasaka, et al., 1991). Only those PCL injuries that were repaired were reported in the UK study mentioned above (Clayton & Court-Brown, 2008). The clearly underestimated incidence was only 0.005/1000 persons annually. The male to female ratio was 83/17 and the incidence was highest in males in the second or third decade, and declined thereafter (Clayton & Court-Brown, 2008).

Meniscal tears may represent as many as 15% of all sports-related knee injuries and 25% of all knee injuries requiring surgery (Majewski, et al., 2006). Slightly more than one-third of meniscal tears include associated ACL injury. This occurs most commonly in males aged 21 to 30, whereas solitary meniscal tears are most common in those 31 to 40 years of age (Poehling, et al., 1990).

A cumulative incidence of 0.24 to 0.27 meniscal tears per 1000 persons annually was reported at orthopaedic clinics in the UK and US (Clayton & Court-Brown, 2008; Miyasaka, et al., 1991). The overall male to female ratio in a UK study was 75/25 and the incidence was highest in young adult males, declining after the third decade. The prevalence of asymptomatic degenerative meniscal tears was high, as much as 6%, in older populations, which may, among other factors, lower the reported incidence rate (LaPrade, et al., 1994; Negendank, et al., 1990). Higher incidence rates are reported in primary health care emergency department patients in Denmark where the corresponding incidence for males is 1/1000 persons per year and for females 0.6/1000. This is also considered a possible underestimate. In Finnish primary health care, meniscal tears are reported to account for 20% of all knee injury visits, which can be recalculated to correspond to a cumulative annual person-based incidence of 2 cases per 1000 persons (Kannus & Järvinen, 1989). The highest person-based incidence rates reported are from the garrison clinics of Norwegian military conscripts, approximately 15.6 cases per 1000 person-years (Heir, T. & Glomsaker, 1996).

Traumatic chondral lesions of the knee are common in physically active young adults. Detected injuries are not always reported as a separate diagnosis, and the incidence rates and localisations are not well known (Kiviranta & Vasara, 2004). Curl and coworkers examined 31,516 knee arthroscopies, and chondral lesions were found in 63% of the patients with the mean age of 43 years (Curl, et al., 1997). The male to female ratio was 62/38. The prevalence of osteochondritis dissecans in performed arthroscopies was 0.7%, articular fractures 1.3%, grade I chondral lesions 28%, grade II 28%, grade III 41%, and grade IV 19%. Sarimo and coworkers arthroscopically examined 320 consecutive knee haemarthrosis patients in Turku University Hospital and found that 18% of the patients had chondral lesions. The precise incidence rate was not reported, but the mean annual incidence of acute traumatic haemarthrosis was 0.5 per 1000 inhabitants. Based on these statistics, the cumulative annual incidence of chondral lesions in traumatic knee haemarthrosis patients is approximately 0.1 per 1000 inhabitants. This assumption, however, has two severe limitations. First, only acute knee haemarthroses were included in the study and thus only a minor part of the all knee injuries requiring treatment were captured in the study. Second, these knee injuries were treated at the university hospital and not all haemarthrosis patients of the area were treated there.

Acute dislocations of the patella typically occur in young adults (Atkin, et al., 2000). Redislocations are common (Mäenpää, et al., 1997). The incidence of primary traumatic patellar dislocations in Finnish young adult male conscripts is 0.77 per 1000 person-years (Sillanpää, et al., 2008). In the US, the cumulative incidence rates of acute first time patellar dislocations (also nontraumatic) for Kaiser Foundation health plan members in the second decade of life are 0.3 cases per 1000 persons annually for females and 0.3 for males. In the third decade of life, the annual incidence rates are reported to be 0.09/1000 for females and 0.14/1000 for males (Atkin, et al., 2000). In the general population of Denmark, the annual incidence of patellar dislocations is 0.2/1000 inhabitants for males and 0.5/1000 for females. It must be taken into account that the US numbers are based on patients visiting a knee injury clinic and the Denmark study did not include all injuries in the study area. Of these, the study of Sillanpää and coworkers is the most generalisable to the general population of Finnish young adult males without known underestimations of incidence rates.

The annual cumulative incidence of acute collateral ligament injuries leading to an immediate visit to emergency department is 1 case per 1000 Danish men and 0.5 per 1000 women (Nielsen & Yde, 1991). Of the collateral ligament injuries, MCL injuries are the most common by far. In the US, cumulative person-based incidence of collateral ligament injuries treated at orthopaedic knee injury clinics was reported to be 0.68/1000 persons annually for MCL and 0.04/1000 for LCL injuries (Miyasaka, et al., 1991). The corresponding UK incidence rates reported in 2008 were 0.05 per 1000 persons annually for MCL injuries compared with 0.002/1000 for LCL injuries (Clayton & Court-Brown, 2008). The male to female ratio was 75/25 for MCL injuries. For LCL injuries, the male to

female ratio was 100/0, but there were only 5 cases included in the study. The incidence curve for both MCL and LCL injuries was similar to PCL injuries, highest in males in the second or third decade of life, and subsequently declining.

Anterior knee pain is suggested to be the most common knee complaint in adolescents and young adults (Sanchis-Alfonso, Vicente, 2011). The multifactorial uncertain aetiology, and confusing and changing terminology makes comprehensive analysis of the condition challenging. The earliest theory was that pain was caused by CMP (i.e., patellar chondral lesions) alone. This theory was brought into question by the finding that only half of the patients with clinical symptoms show patellar chondral lesions in arthroscopy (Leslie & Bentley, 1978). Later, the term CMP was applied only when chondral lesions and degeneration of the articular cartilage of the patella were present. Since the 1970s, PFM has been the most important and widely used theory to explain the genesis of AKP and the term patellofemoral pain syndrome (PFPS) has replaced the term CMP. The PFM theory, however, represents similar problems as CMP. While some people with remarkable PFM are asymptomatic, others have AKP and normal patellofemoral alignment (Sanchis-Alfonso, Vicente, 2011). Various other knee pathologies can also cause pain to the anterior aspect of the knee and new theories have challenged the traditional views of the origin of the pain. Some of the pathological conditions most commonly linked to AKP other than PFM and patellar chondral lesions are patellar instability and synovial impingement syndrome, including pathological plicae and fat pad impingement, patellar tendinopathy, osteochondroses, iliotibial band syndrome (runner's knee), and bursitis (Houghton, 2007; Kodali, et al., 2011; Llopis & Padron, 2007). New theories of the origins of the pain includes pathophysiological processes such as neural proliferation in the lateral retinaculum due to periodic short-term ischaemia (Sanchis-Alfonso, V. & Rosello-Sastre, 2003) or a tissue homeostasis imbalance (Dye, 2005). The tissue homeostasis theory has received widespread attention over the last few years. The basic idea behind the theory is that the knee joint is a living, metabolically active unit and normal tissue homeostasis is required for proper maintenance and healing of the tissues. Increased loading of the patellofemoral joint leads to a loss of tissue homeostasis in the surrounding innervated tissues, which causes pain. The normal knee joint can withstand a wide range of loading and maintains its tissue homeostasis. This is called the zone of homeostatic loading. Increased repetitive loading or a single loading event sufficient to cause loss of tissue homeostasis but not macrostructural damage is considered supraphysiological. When loading is increased further, it may cause macrostructural damage such as a chondral lesion or ligament rupture. This is termed the zone of macrostructural failure. According to Dye, the various pathological conditions described above can be considered together as a loss of tissue homeostasis (Dye, 2005). One of the key points of the tissue homeostasis theory is that it can explain pain in knees with normal anatomy. The tissue homeostasis theory can be considered complementary to the PFM theory. PFM may cause increased

loading to the patellofemoral joint, thus making it more susceptible to a loss of tissue homeostasis (Sanchis-Alfonso, Vicente, 2011).

PFPS can be considered only as a nonsensical replacement of the term CMP (Sanchis-Alfonso, Vicente, 2011). Abandonment of both terms, CMP and PFPS, has been proposed (Grelsamer, 2005; Sanchis-Alfonso, Vicente, 2011). Instead of CMP, the term chondral or cartilage lesion should be used with a clear description of the detected injury. AKP appears to be the most appropriate term to be used as a main heading to describe pain in the anterior aspect of the knee that may be caused by various pathological knee conditions.

The reported incidence rates of AKP are highly varied and there are no accurate statistics taking actual exposure time into account. In sports medicine clinics, AKP may comprise up to 25% of all knee problems (Devereaux & Lachmann, 1984). In athletic young adult students, AKP was reported to occur in 24 of 282 persons during a 2-year study period, but the total exposure time and incidence rates were not reported (Witvrouw, et al., 2000). Calculations based on these numbers indicate a cumulative incidence rate of up to 43 persons per 1000 persons annually. In Norwegian conscripts, the person-based incidence of overuse knee injury, such as PFPS, iliotibial band friction syndrome, and patellar tendinitis, during basic military training is reported to be more than 200 per 1000 persons annually (Heir, T. & Glomsaker, 1996). In Israeli male infantry recruits, AKP occurred in 60 (15%) of a total of 390 study subjects during 14 weeks of basic training (Milgrom, et al., 1991). Again, total exposure time and incidence rate were not reported, but the statistics presented indicate that annual cumulative person-based incidence could be as high as 573 per 1000 persons.

These statistics provide general information concerning the importance and relative frequency of knee injuries in Finland, as well as internationally. The main results are represented in Table 1. Accurate injury incidence rates of even the most common specified knee injuries in young adults remain unclear. In Finland, the incidence rates for this high-risk subgroup are available only for cruciate ligaments and primary traumatic patellar dislocations (Parkkari, et al., 2008; Sillanpää, et al., 2008). Also, many other available studies reporting the incidence of knee injuries or disorders are based on patient populations of specialized clinics and do not include all injuries from the study area (Atkin, et al., 2000; Clayton & Court-Brown, 2008), specific patient groups like athletes or military cadets (Uhorchak, et al., 2003; Witvrouw, et al., 2000), or only very specific subgroups of injuries like surgically-treated ACL tears, knee haemarthrosis, or only injuries less than 24 hours old (Gianotti, et al., 2009; Nielsen & Yde, 1991; Sarimo, et al., 2002). This makes generalisation of these results challenging and their application for clinical practice difficult.

Table 1. Overview of the Knee Injury Incidence Research

Authors	Country	Sample	Age	Injury outcome	Incidence of injuries/ 1000/ year	Incidence of knee injuries/ 1000/ year	Incidence of cruciate ligament injuries/ 1000/ year	Incidence of meniscal tears/ 1000/ year	Incidence of collateral ligament injuries/ 1000/ year	Incidence of chondral lesions/ 1000/ year	Incidence of patellar dislocation/ 1000/ year	Incidence of anterior knee pain/ 1000/ year
Taanila, et al., 2010	Finland	Male Conscripts	18–28	Musculoskeletal disorders treated as outpatients at the garrison clinic	3833[3,4]	730[3,4]	NA	NA	NA	NA	NA	NA
Mattila, et al., 2006	Finland	Male conscripts	18–29	Hospitalised injuries	93.7[2]	NA	NA	NA	NA	NA	NA	NA
Heir, T. & Glomsaker, 1996	Norway	Conscripts (99% male)	18–30	Musculoskeletal injuries treated at the garrison clinic	1116 to 1836[3,4]	NA (approximately 25% of the injuries)	NA	15.6[3,4]	NA	NA	NA	209[3,4,7]
Clayton & Court-Brown, 2008	UK	General population	12–90	Visits to orthopaedic trauma unit Due to musculoskeletal injuries	1.06[1,2] (Males 1.67, females 0.52)	0.38[1,2]	ACL 0.08[1,2] PCL requiring repair 0.005[1,2]	0.24[1,2]	MCL 0.05[1,2] LCL 0.002[1,2]	NA	NA	NA
Yawn, et al., 2000	US	General population	17–	Initial visits to physician due to acute isolated knee injury	NA	2.8[1,3] (Males 3.1 (peak 6.0[4]), Females 2.4, (peak 4.2[4])	NA	NA	NA	NA	NA	NA
Kannus & Järvinen, 1989	Finland	General population	NA (Patients <90)	Visits to physician due to knee injuries	NA	11[1,2]	NA	2[1,2,4]	NA	NA	0.3[1,2,4]	NA
Sarimo, et al., 2002	Finland	General population	NA Patients (16 to 68)	Knee hemarthrosis patients treated in Turku University Hospital	NA	0.5[1,2,6]	ACL 0.2[1,2,4] PCL 0.02[1,2,4]	0.1[1,2,4]	MCL 0.1[1,2,4]	0.08[1,2,4]	0.11[1,2,4]	NA
Nielsen & Yde, 1991	Denmark	General population	NA	Less than 24 hour old knee injuries treated at the emergency department (primary health care)	NA	11.6[1,3] (Males 13.3, Females 9.7)	0.3[1,3] (Males 0.4, Females 0.2)	0.7[1,3] (Males 1.0, Females 0.6)	0.7[1,3] (Males 1.0, Females 0.5)	NA	0.3[1,3] (Males 0.2, Females 0.5)	0.4[1,3,5] (Males 0.3, Females 0.5)
Parkkari, et al., 2008	Finland	General Population based cohort	Baseline 14–18, follow-up in 2001 19–33.	Surgically repaired ACL injuries	NA	NA	0.61[2] (Males 0.97, females 0.30)	NA	NA	NA	NA	NA
Gianotti, et al., 2009	New Zealand	General population	NA	Number of ACL surgeries	NA	NA	0.37[1,3] Peak Incidence in males 1.6, in females 0.8)	NA	NA	NA	NA	NA

Study	Country	Population	Age	Description								
Sillanpää, et al., 2008	Finland	Male conscripts	17–30	Hospitalised primary traumatic patellar dislocation	NA	NA	NA	NA	NA	NA	0.77[3]	NA
Atkin, et al., 2000	US	Kaiser health plan population	NA (Patients 10–59)	Primary patellar dislocations treated at the knee injury clinic	NA	NA	NA	NA	NA	NA	0.07[1,3] (Peak incidence in males 0.30 and in females 033)	NA
Witvrouw, et al., 2000	Belgium	Students taking physical education classes	17–21	Development of anterior knee pain during two year study period	NA	NA	NA	NA	NA	NA	NA	42.6[1,2,4] (Males 36.4, females 49.6)
Milgrom, et al., 1991	Israel	Male infantry recruits	NA	Development of patellofemoral pain during 14-weeks basic training	NA	NA	NA	NA	NA	NA	NA	573.0[1,2,4]
Miyasaka, et al., 1991	US	Kaiser health plan population	NA	Knee ligament injuries treated at the knee injury clinic	NA	1.24[1,2,4,8]	ACL 0.38[1,2,4,9] PCL 0.04[1,2,4,9]	0.27[1,2,4]	MCL 0.63[1,2,4] LCL 0.04[1,2,4]	NA	NA	NA

[1]Cumulative annual incidence
[2]Person-based incidence
[3]Event-based incidence
[4]Approximation/conversion/calculation from the data presented
[5]Patellofemoral overuse
[6]Acute knee haemarthrosis
[7]Overuse knee injuries including patellofemoral pain syndrome, iliotibial band friction syndrome and patellar tendinitis
[8]Including only ligament and meniscal tears
[9]Including only ligament injuries with pathologic anteroposterior motion
NA= Not Available

6.2.3   Risk Factors for Musculoskeletal Injuries in General

Risk factor research has focused mainly on injuries as a whole rather than knee injuries or their underlying diagnoses. Low aerobic fitness as measured by running capability is considered a risk factor for injuries in studies conducted in conscripts as well as in recruit armies (Jones, et al., 1993; Jones & Knapik, 1999; Taanila, et al., 2010). Low aerobic fitness also increases the risk for medical discharge from military service in Finnish conscripts (Taanila, et al., 2011). It must be taken into account that opposite results have also been reported. In a study considering Finnish conscripts, those with excellent aerobic fitness had an OR of 1.3 for inpatient care due to lower limb injury compared with those with poor results in running tests (Mattila, et al., 2007). In Norwegian conscripts, poor running fitness seemed to be a risk factor for musculoskeletal injuries in univariate analysis, but adjusted multivariate analysis showed it to be statistically nonsignificant (Heir, T. & Eide, 1996, 1997). In addition, in the study of Jones and coworkers (Jones, et al., 1993) dealing with male US army infantry trainees, statistical significance was obtained only in univariate analysis and running test results were not included in the multivariate analysis.

Co-impairments in muscular strength tests and Cooper's 12-minute running tests are a risk factor for musculoskeletal disorders leading to a visit at the garrison clinic as well as for medical discharge from the military service in Finland (Taanila, et al., 2011; Taanila, et al., 2010). The overall results in muscular fitness index used by the Finnish defence forces were not associated with injuries in either of these studies, and another study concerning Finnish conscripts showed that good muscular fitness increases the injury hospitalisation risk (Mattila, et al., 2007).

The association of BMI with injuries as a whole remains controversial. In Norwegian conscripts, higher BMI increased the risk for musculoskeletal injuries treated at the military primary care in one study, but not in another (Heir, T. & Eide, 1996, 1997). Two studies reported that BMI is not associated with the injuries in US army (Jones, et al., 1993; Reynolds, et al., 2000). In Finnish conscripts, a higher BMI increases risk for musculoskeletal disorders leading to a visit at the garrison clinic and for injuries requiring inpatient care (Mattila, et al., 2007; Taanila, et al., 2010), but is not a risk factor for medical discharge from the military service (Taanila, et al., 2011). Height and weight independently are not associated with the injury risk (Heir, T. & Eide, 1996, 1997; Taanila, et al., 2011; Taanila, et al., 2010). Older age seems to increase the risk for musculoskeletal injuries in young adult Norwegian conscripts in univariate analysis, but multivariate analysis showed conflicting results (Heir, T. & Eide, 1996, 1997). Other multivariate analyses reported that older age was a significant risk factor in US army trainees, but a nonsignificant risk factor in Finnish conscripts (Jones, et al., 1993; Taanila, et al., 2010). Older age is also not a risk factor for medical discharge from the military service in Finland (Taanila, et al., 2011).

6.2.4   Risk Factors for Knee Injuries and Anterior Knee Pain

The role of demographic and anthropometric characteristics as well as physical fitness as a possible risk factor for knee injuries is not well established. An overview of the available risk factor data is presented in Table 2. There are currently no data for whether factors like height, weight, BMI, or physical fitness predisposes to knee injuries in general. The overall risk of physical activity-related knee injuries is highest in the 15 to 25 year-old age group (Haapasalo, et al., 2007). The risk of disabling knee injuries among young men in the US army increases until the age of 26 years (Sulsky, et al., 2000). In general practice populations in UK, obese subjects were nearly four times more likely to report knee pain with disability than those with a normal BMI (Webb, et al., 2004). Whether knee pain was caused by injury or osteoarthritis was not reported. Other known risk factors include sports participation, and as many as half of all knee injuries may occur during sports activities (Haapasalo, et al., 2007; Kannus & Järvinen, 1989). In Finland, females have a higher risk for knee injuries in commuting activities, whereas hazard ratios are not significantly different for lifestyle activities or recreational and competitive sports. In some specific activities, such as endurance, power, and contact sports, females have a higher injury risk than men (Haapasalo, et al., 2007).

Few investigators have examined the risk factors for specific knee diagnoses. The amount of data on intrinsic, modifiable risk factors such as BMI, weight, aerobic fitness, and muscular strength in general populations is very limited. For example, there is no single study of collateral ligament tears or chondral lesions.

Data is not available regarding whether poor aerobic fitness or older age predisposes to cruciate ligament injuries in Finland or internationally. The strength of the knee flexors and extensors is not associated with noncontact arthroscopically-confirmed ACL injuries in US Military Academy cadets (Uhorchak, et al., 2003). The authors also reported that height is a nonsignificant factor in both sexes. Higher weight and BMI increases ACL injury risk in females, but are nonsignificant in males (Uhorchak, et al., 2003). In Finnish adolescents and the young adult population, BMI is not associated with cruciate ligament injuries. The data for weight, height, and muscle strength, however, were not reported (Parkkari, et al., 2008). Participation in sports is a well-known risk factor for cruciate ligament injuries in young adults (Parkkari, et al., 2008). Even if the injury incidence rate for ACL injuries is higher for men than for women in the general population (Gianotti, et al., 2009; Parkkari, et al., 2008), the injury incidence rate and risk for cruciate ligament injuries is higher for female athletes (Mountcastle, et al., 2007; Parkkari, et al., 2008; Prodromos, et al., 2007). There are also other, nonmodifiable risk factors for ACL injuries, such as a small femoral notch width and generalised joint laxity (Uhorchak, et al., 2003). Another study, however, reported that femoral notch width did not predict ACL injuries (Lombardo, et al., 2005).

To our knowledge, there are no studies describing whether the risk of meniscal tears is associated with physical fitness. In the study of Baker and coworkers, higher weight

was shown to increase the risk when acute and degenerative meniscal tears were analysed together. Height was not associated with meniscal tears. A higher BMI increased the risk for degenerative tears, but not acute tears (Baker, et al., 2002). Degeneration occurs with aging and weakens the meniscal structures, making them susceptible to injuries (Negendank, et al., 1990). No direct evidence supports an increase in the injury risk as aging progresses. Weak quadriceps muscles, mechanical deviations, and congenital abnormalities are also suggested to increase injury rates(Miller III, 2003). The risk for meniscal tears is increased among sports participants, especially those playing soccer or rugby (Baker, et al., 2002; Baker, et al., 2003).

Young adult male patients in their early twenties with deep chondral lesions have a significantly higher mean body mass and BMI and are a little older than patients with superficial lesions (Eskelinen, et al., 2004). Height was not associated with chondral lesions in that study and physical fitness data was not available. A limitation of the study, however, was that all of the patients included had arthroscopically diagnosed chondral lesions, and thus the risk factors that predispose to chondral lesions in general are not known.

Patellar dislocations often occur during sports (Atkin, et al., 2000). Mean standing limb alignment, quadriceps angle, and rotational measurements are not associated with acute patellar dislocations. Fithian and coworkers conducted a prospective cohort study in an orthopaedic knee injury clinic to evaluate risk factors for primary and recurrent patellar dislocations. The risk factors for recurrent dislocations were female sex and older age. Their study also showed that the odds for subsequent instability are 7 times higher in patients with a previous history of patellofemoral instability (Fithian, et al., 2004). Only one study described the association of modifiable risk factors such as physical fitness and BMI with primary traumatic patellar dislocations in young adult males (Sillanpää, et al., 2008). In that study, male patients with primary traumatic patellar dislocation were typically taller and weighed more than controls (Sillanpää, et al., 2008). Factors of poor physical performance, older age, and higher BMI do not increase the risk. Most of the cases occurred during sports activities and the injury mechanism was knee flexion with a tibial valgus position in more than 90% of the injuries. Concomitant injuries were detected in almost half of the cases and haemarthrosis was present in all of the knees. Service class had to be lowered in 1 of every 5 patients, indicating a remarkable inability to cope with physically challenging duties (Sillanpää, et al., 2008).

Witvrouw and coworkers conducted a 2-year prospective study of the intrinsic risk factors associated with the development of AKP (Witvrouw, et al., 2000). Anthropometric characteristics such as weight and height, as well as cardiovascular endurance measured by an ergometer test, were not associated with the development of AKP. Of the various physical fitness tests, only a decreased explosive strength predisposed subjects to AKP. Other statistically significant risk factors were shortened quadriceps muscle, altered vastus medialis obliquus reflex time, and a hypermobile patella. Another prospective

study by Milgrom et al. reported that physical fitness and muscle strength measured by 2 km running and number of push-ups and sit-ups were not risk factors for AKP in a logistic regression analysis (Milgrom, et al., 1991). Increased isometric strength of the quadriceps muscle, medial tibial intercondylar distance, weight, and height were also not associated with the injuries. According to pooled analyses in a recent meta-analysis, BMI and older age are also not risk factors (Lankhorst, et al., 2012). Although PFM plays a major role in the genesis of AKP, there is evidence that patellofemoral alignment characteristics such as the Q-angle and genu varum/valgum and foot pronation are not associated with the development of AKP (Hetsroni, et al., 2006; Park & Stefanyshyn, 2011; Witvrouw, et al., 2000). A recent systematic review confirmed that most of the earlier suggested risk factors for AKP rely on very limited evidence (Lankhorst, et al., 2012).

As mentioned above, there is extensive research concerning musculoskeletal injuries as a whole and a limited amount of research concerning knee injuries. Most of the study populations do not represent the general population and the patient sample is restricted to a special subpopulation such as elite athletes and patient catchment of a specialised clinic or voluntary recruit armies (Jones, et al., 1993; Jones & Knapik, 1999; Majewski, et al., 2006; Milgrom, et al., 1991; Sulsky, et al., 2000; Uhorchak, et al., 2003; Witvrouw, et al., 2000). The incidence and risk factor data available are therefore difficult to generalise to the general population in clinical practice.

Another limitation of the data available is that most of the studies published only took into account knee or other musculoskeletal injuries as a whole or alternatively only according to a solitary specific knee diagnosis, such as cruciate ligament tears or AKP (Baker, et al., 2002; Heir, T. & Eide, 1996, 1997; Milgrom, et al., 1991; Parkkari, et al., 2008). This limits the ability to evaluate whether the suggested risk factors are valid for all knee injuries or only for a certain knee diagnosis. There are no comprehensive studies taking knee injuries into account as a whole or according to specific knee diagnoses. Knowledge about the specific risk factors for different injuries will allow for better analysis of possible causal relationships and facilitate the development of possible preventive measures for the appropriate targets.

Table 2. Overview of the risk factor research

Authors	Country	Sample	Age	Injury outcome	Higher height	Higher weight	Higher BMI	Older age	Poor running fitness	Poor muscle strength
Heir, T. & Eide, 1996	Norway	Conscripts	18-29	Musculoskeletal injuries treated at the military training camps	NS[1,2]	NS[1,2]	+[1,2]	+[1] / NS[2]	+[1] / NS[2]	NA
Heir, T. & Eide, 1997	Norway	Conscripts	19-28	Musculoskeletal injuries treated at the military training camps	NS[1,2]	NS[1,2]	NS[1,2]	+[1,2]	+[1] / NS[2]	NA
Mattila, et al., 2007	Finland	Conscripts	18-30	Injury hospitalisations Multiple injury hospitalisations Lower limb injury hospitalisations	NA NA NA	NA NA NA	+[2] +[2] +[2]	NA NA NA	NA NA −[2]	−[2] NS[2] NA
Jones, et al., 1993	US	Male army infantry trainees	17-35	Injuries requiring sick call visit during 12 weeks of basic training	NA	NA	NS[1,2]	+[1,2]	+[1] / NA[2]	+[1,3] / NA[2]
Taanila, et al., 2010	Finland	Male Conscripts	18-28	Musculoskeletal disorders treated at the garrison clinic as outpatients	NS[2]	NA	+[2]	NS[2]	+[2]	NS[2] / +[2,4]
Taanila, et al., 2011	Finland	Male conscripts	18-28	Medical discharge from the military service	NS[2]	NA	NS[2]	NS[2] / +[2,5]	+[2]	NS[2] / +[2,4]
Uhorchak, et al., 2003	US	US Military Academy cadets	17-23[6]	Non-contact arthroscopically confirmed ACL injuries	NS[1,2]	NS[1,2] (Males) / +[1,2] (Females)	NS[1,2] (Males) / +[1,2] (Females)	NA	NA	NS[1,2,7]
Parkkari, et al., 2008	Finland	General Population based cohort	Baseline 14-18, follow-up in 2001 19-33.	Hospitalised cruciate ligament injuries	NA	NA	NS[2]	NA	NA	NA
Baker, et al., 2002	UK	General Population	20-59	arthroscopically proven primary acute meniscal tears Degenerative meniscal tears	NS[2,8] NS[2,8]	+[2,8] +[2,8]	NS[2] +[2]	NA	NA	NA
Eskelinen, et al., 2004	Finland	Male Conscripts with arthroscopically proven chondral lesion	NA	Arthroscopically proven chondral lesions	NS[1]	+[1,9]	+[1,9]	+[1,9]	NA	NA
Sillanpää, et al., 2008	Finland	Male conscripts	17-30	Hospitalised primary traumatic patellar dislocations	+[1]	+[1]	NS[1]	NS[1]	NS[1]	NS[1]
Milgrom, et al., 1991	Israel	Male infantry recruits	NA	Development of patellofemoral pain during 14-weeks basic training	NS[1,2]	NS[1,2]	NA	NA	NS[1,2]	−[1,2,10] / NS[1,11] / +[1,3]
Witvrouw, et al., 2000	Belgium	Students taking physical education classes	17-21	Development of anterior knee pain during two year study period	NS[1,2]	NS[1,2]	NA	NA	NA[12]	NS[1,2] / +[1,2,13]

Study	Country	Population	Age	Outcome						
Lankhorst, et al., 2011	Netherlands/ multinational	7 prospective studies chosen from the 3845 potentially relevant articles	NA	Review of prospective risk factor studies concerning patellofemoral pain syndrome	NS[14]	NS[14]	NS[14]	NS[14]	NA	+[3,10]
Sulsky, et al., 2000	US	Active-duty enlisted soldiers	17-54	Discharge from army for knee-related disability	NA	NA	NA	+[2,15]	NA	NA
Haapasalo, et al., 2006	Finland	Population cohort	15-74	Knee injuries reported by study subjects	NA	NA	NA	+[16] -[17]	NA	NA

+ = Increases the risk
- = Decreases the risk
NA = Not available
NS = Not statistically significant
[1]Univariate analysis
[2]Multivariate analysis
[3]Push-up test
[4] Co-impairments in Cooper's running test and muscular fitness tests
[5]Only for discharges due to mental health problems
[6]At the time of enrolment, follow-up time 4 years
[7]Strength of knee flexors and extensors
[8] Both acute and degenerative tears were analysed together
[9] increases risk for deep chondral lesions
[10]Knee extension strength
[11]Number of sit-ups
[12]Cardiorespiratory fitness evaluated by submaximal ergometer test was NS
[13]Explosive strength measured by vertical jump test
[14]Pooled analyses
[15]Odds ratio increased in white European men until 26 years of age and then decreased
[16]In lifestyle activities
[17]In commuting activities and in recreational and competitive sports. Overall knee injury risk was highest in the age group 15 to 25 years.

6.3 Diagnostics of Meniscal Tears, Chondral Lesions and Anterior Knee pain

6.3.1 History and Physical Examination

Medical imaging technology is continuously advancing, but the basis of knee injury diagnostics remains history taking and physical examination by which the majority of knee injuries can be diagnosed prior to any imaging or surgical procedures (Orndorff, et al., 2005). Useful factors in the differential diagnosis of knee pain are patient's age, activity level, and whether the pain is of traumatic origin. In older patients, there is an increased prevalence of osteoarthritis (Felson, 1988) and malignancies and infections are possibilities. In younger patients, knee pain often has a traumatic origin (Gianotti, et al., 2009; Kannus & Järvinen, 1989; Majewski, et al., 2006). In cases of high energy trauma with deformity or significant pain and swelling of the knee joint, the possibility of fractures must be taken into account (Orndorff, et al., 2005). Fractures are fairly rare in young adults (Kannus & Järvinen, 1989), however, and usually their knee pain of traumatic origin is caused by ligamentous, meniscal, or chondral lesions of the knee (Majewski, et al., 2006).

A typical injury mechanism for meniscal tear is twisting or hyperflexion of the knee. Meniscal injuries usually occur between the ages of 21 to 30 years in men and are frequently associated with an ACL injury (Munjal & Krackow, 2005). The most commonly used clinical tests for evaluating meniscal injury are McMurray's, Apley's, and Thessaly's tests, and joint line tenderness (Bhandari, 2011). A high quality meta-analysis published in 2001 reported that mean sensitivity of joint line tenderness for meniscal tears is 79% and specificity 15% (Solomon, et al., 2001). For McMurray's test, mean sensitivity is 53% and specificity is 59%. The sensitivity of the composite examination of different tests is 77% and the specificity 91%. A new clinical test for diagnosing meniscal tears named after the Thessaly region in Greece was published in 2005 (Karachalios, et al., 2005). The Thessaly test at 20° knee flexion is considered the most effective first-line screening test for meniscal tears. The sensitivity for medial meniscal tears is as high as 89%, for lateral meniscal tears 92%, and for combined injuries of the ACL and meniscus 80% (Karachalios, et al., 2005). Corresponding figures for other tests in the same study were lower, 66%, 81%, and 65%, respectively, for the Thessaly test at 5° knee flexion; 71%, 78%, and 65% for joint-line tenderness; 41%, 41%, and 20% for Apley's test; and 48%, 65%, and 45% for the McMurray test. The Thessaly test at 20° knee flexion also has superior specificity: 97% for medial meniscus, 96% for lateral meniscus, and 91% for combined injuries of the ACL and meniscus.

Articular cartilage injuries are commonly diagnosed together with other knee injuries. The most commonly associated injuries in young adults are ACL injuries and

meniscal tears (Curl, et al., 1997). The mechanism of injury is not clear, but a twisting force and direct blow to the knee are suggested (Rubin, et al., 2000). According to the tissue homeostasis theory of Dye, increased loading of the knee joint can also lead to a loss of tissue homeostasis and even macrostructural failure, such as chondral lesions (Dye, 2005). Articular cartilage has a very limited ability to heal spontaneously and chondral lesions likely lead to early osteoarthritis (Bhandari, 2011; Messner & Maletius, 1996). When symptomatic, chondral lesions may cause prolonged or activity-related pain, effusion, and sometimes catching of the knee joint (Gomoll, et al., 2010; Messner & Maletius, 1996; Sellards, et al., 2002). At their worst, focal chondral lesions may impair quality of life as much as severe osteoarthritis (Heir, S., et al., 2010). Patients with more severe cartilage lesions of the patellofemoral joint are reported to have more subjective symptoms and functional limitations than those without lesions or with small cartilage lesions (Kettunen, et al., 2005). In contrast, chondral lesions are asymptomatic even on direct probing, which is logical as articular cartilage has no innervation (Dye, et al., 1998). An explanation for the contradictory results might be that more extensive pressure on the weight-bearing knee during daily activities irritates the richly innervated subchondral bone and causes pain. Patients with chondral lesions do not have any specific findings in clinical examination (Gomoll, et al., 2010). Retropatellar crepitus, effusion, and quadriceps wasting are sometimes associated with chondral lesions, but none of these signs is pathognomonic (Leslie & Bentley, 1978). Pain in the patellar compression (grind) test may be indicative of patellofemoral chondral lesions (Houghton, 2007). The diagnostic validity of this test, as well as the commonly used patellar apprehension, patellar inhibition, and sustained knee flexion tests, for the diagnosis of patellar chondral lesions is poor. Pain provoked by patellar compression against the femoral groove has the best sensitivity (56%), but the poorest specificity (55%), of these tests (Niskanen, et al., 2001). In the sustained knee flexion test, intraosseous pressure on the patella is significantly higher in painful knees, which may be the cause of the pain originating from the patella (Hejgaard & Arnoldi, 1984). For arthroscopically detected patellar chondral lesions, the sensitivity of this test is only 35%. The specificity, 85%, however, is acceptable (Niskanen, et al., 2001). Altogether, the clinical diagnosis of chondral lesions is very difficult. The diagnostic validity of the history, symptoms, and clinical findings is poor or not known, and chondral lesions are often associated and easily confused with other injuries such as meniscal tears (Rubin, et al., 2000).

The multifactorial and uncertain aetiology of AKP makes diagnostics both challenging and imperative. The bases for the diagnosis are physical examination and symptoms. Typical clinical symptoms of AKP syndrome are dull pain in the anterior aspect of the knee that worsens when climbing stairs, sitting with the knees flexed, and rising from a sitting position. Extending the knee against resistance may also cause pain, and there may also be catching or locking and giving-way sensations. Sometimes the pain can be sharp and sudden in nature. The exact pain location may vary and can

be difficult to localize (Gambardella, 1999; Houghton, 2007; Sanchis-Alfonso, Vicente, 2011). Insecurity and giving-way sensations are usually related to walking or other straight-ahead activities, rather than twisting or torquing activities as in ligamentous instability or meniscal tears (Gambardella, 1999). Locking or catching sensations are also usually milder than with meniscal tears and patients can actively unlock the knee (Sanchis-Alfonso, Vicente, 2011).

Differential diagnostics are extensive. Menisci and cruciate ligaments must be kept in mind, especially for AKP of traumatic origin and swelling of the knee joint. Almost all patients with AKP have pain on the lateral retinaculum, which may be due to repeated strain causing chronic irritation of the area (Fulkerson, 1983). Also, iliotibial band syndrome (runner's knee) causes pain to the lateral aspect of the knee. Ober's test (Sanchis-Alfonso, Vicente, 2011) can be used to evaluate the tightness of the iliotibial band. Iliotibial band syndrome may also be associated with lateral patellar displacement and tilt (Sanchis-Alfonso, Vicente, 2011). Medial collateral bursitis must be taken into account in patients who have pain on the medial joint line, especially if the pain is worse during valgus stress of the knee. Other commonly tender sites include the patella itself and the patellar tendon. Remarkable palpation tenderness in the inferior pole of the patella might indicate patellar tendinopathy, especially if exacerbated by activity or resisted leg extension (Kodali, et al., 2011; Wilson & Best, 2005). A decline squat test places increased stress on the patellar tendon and pain during this test suggests patellar tendinopathy (Wilson & Best, 2005). Behind the patellar tendon is Hoffa's fat pad(Hoffa, 1904). Pain or apprehension provoked by a Hoffa manoeuvre or knee extension reveals whether this highly innervated structure is irritated (Ellen, et al., 1999). The Hoffa manoeuvre is performed by applying compression to the fat pad on the sides of the patellar tendon while simultaneously extending the knee (Kodali, et al., 2011). In synovial impingement syndromes, pain is typically aggravated by knee flexion and relieved by extension (Kodali, et al., 2011). Positive active extension as a kick test and the flexion test may establish a painful medial plica (Irha & Vrdoljak, 2003).

Clinical evaluation of PFM and chondral lesions is considered important although their roles in the genesis of AKP is now questioned. In cases in which no possible pain source other than patellofemoral chondral lesions are found, PFM and chondral lesions must be taken into account when planning treatment (Gomoll, et al., 2010). Clinical diagnosis of patellofemoral chondral lesions is described in the above chapter on chondral lesions in all knee compartments. Patellofemoral malalignment and instability must be taken into consideration especially in nontraumatic AKP with bilateral symptoms (Houghton, 2007). Determining whether the main complaint is pain or instability possibly related to patellar subluxation is important (Sanchis-Alfonso, Vicente, 2011). Patellofemoral malalignment and patellar instability can be evaluated by observing whether genu varum/valgum, an abnormal Q-angle, external torsion of the tibia, or femoral anteversion is present. Abnormal patellar or tibial tuberosity positions can also

be observed (Kodali, et al., 2011; Llopis & Padron, 2007). A patellar tilt test is a special test used to evaluate patellar malalignment and lateral retinaculum tightness. The patient has lateral patellar tilt if the lateral border of the patella is posterior to the medial border. This indicates lateral retinaculum tightness and leads to abnormally high contact forces in the patellofemoral joint. The J-sign is used to describe patellar maltracking during knee motions. It is considered pathonomic for lateral patellar subluxation (Boden, et al., 1997). Patellar mobility and possible instability can be tested with a patellar glide test. Subjective feelings of dislocation during a patellar apprehension test indicate patellar instability (Kodali, et al., 2011). The sensitivities for these tests in detecting AKP are generally poor, whereas specificities are somewhat better (Haim, et al., 2006). Poor diagnostic validity is logical as PFM and patellofemoral instability itself are considered to be very nonspecific findings in the genesis of AKP (Sanchis-Alfonso, Vicente, 2011).

Physical examination and differential diagnosis of AKP are difficult. There are various suggested aetiologies and clinical tests. The validity of these tests is generally poor or not known. No single test exists to determine the exact diagnosis, and comprehensive evaluation of AKP requires a combination of thorough history taking, multiple tests, and radiologic imaging (Fredericson & Yoon, 2006). When no accurate diagnosis can be established, the patient is often diagnosed with idiopathic AKP (Kodali, et al., 2011).

6.3.2   Imaging of Knee Injuries and Anterior Knee Pain

6.3.2.1   *Plain Radiographs and Computed Tomography*

Diagnostic imaging of acute knee injuries and AKP is routinely performed when diagnosis remains uncertain after a clinician's physical examination and when imaging might influence the treatment decisions. Knee radiographs in young adults are used mainly to confirm or exclude fracture of the injured knee. Fractures are far less common than ligamentous, meniscal, or chondral lesions (Kannus & Järvinen, 1989; Majewski, et al., 2006). When determining whether knee radiographs should be performed to exclude fractures in acute knee injuries, the Ottawa knee rule can be used (Table 3). The Ottawa knee rule is very sensitive but not specific for predicting fractures (Jackson, et al., 2003; Stiell, et al., 1995). Radiographs can also reveal osteochondritis dissecans or joint-space narrowing related to deep large chondral lesions or severe osteoarthritis. It must be noted, however, that radiographs are useful only in the advanced stages of disease and cannot reveal superficial defects (Chan, et al., 1991; Wright, et al., 2006). Routine radiograph views used to evaluate knee injuries are standing weight-bearing anteroposterior and lateral views. The posteroanterior semiflexed view may be helpful for evaluating the posterior margin of the joint space. In addition, tunnel views of the intercondylar notch and axial (skyline/sunrise) views of the patella may be indicated (Hollingworth, et al., 2011; Potter & Foo, 2006). Skyline views at 30° knee flexion are

routine for AKP and patellar instability imaging. The main purpose of these views is to evaluate possible patellar malalignment. The main radiographic malalignment patterns evaluated are patellar subluxation with and without tilt, and tilt without subluxation. Other malalignments that are commonly evaluated radiographically include increased Q-angle and trochlear-tubercle distance (Christian, et al., 2006; Schutzer, et al., 1986). Altogether, physical examination is more useful than radiographs for evaluating AKP. Only patellar subluxation is increased in patients with AKP as compared with healthy controls (Haim, et al., 2006). Even if the role of PFM in the genesis of AKP is questioned, addressing it is important especially when planning cartilage repair techniques. In this setting, the mechanical axis of the knee and possible varus or valgus malalignment should also be evaluated from full-length anteroposterior hip-to-ankle radiographs. Undiagnosed and uncorrected malalignments may account for premature failure of cartilage repair (Gomoll, et al., 2010; Potter & Foo, 2006).

In complicated or prolonged cases of AKP, computed tomography (CT) can be used alternatively to MRI for more subtle evaluation of osseous structures and possible malalignment than routine radiographs. Kinetic CT can be used to evaluate patellar malalignment in loaded and more physiological conditions than conventional techniques. This may reveal PFM or maltracking in some cases with normal findings in conventional CT images (Christian, et al., 2006). CT can also be used to detect occult or intra-articular fractures of the injured knee (Onyema, et al., 2011).

Table 3. Ottawa knee rule criteria for radiography of acute knee injury (Stiell, et al., 1995)

Age 55 or older; or
Tenderness at head of fibula; or
Isolated tenderness of the patella; or
Inability to flex 90°; or
Inability to bear weight both immediately and in the emergency department for four steps

6.3.2.2   Magnetic Resonance Imaging

When clinical diagnosis and proper treatment are uncertain, the value of MRI is emphasized and is currently commonly used to evaluate various knee joint injuries. Magnetic resonance imaging is especially useful in multiple knee lesions for which the diagnostic accuracy of physical examination decreases significantly and may be as low as 30% (Oberlander 1993). Magnetic resonance imaging can reduce the need for arthroscopy and the number of negative arthroscopic examinations in patients for whom arthroscopy is considered after physical examination (Hollingworth, et al., 2011; Munshi, et al., 2000; Spiers, et al., 1993; Vincken, et al., 2002). In patients with non-acute (lasting over 4 weeks) knee symptoms and clinically highly suspected intra-articular knee pathology, MRI

is also a cost-effective method for obviating knee arthroscopy (Vincken, et al., 2007). For acute knee injuries, it is not clear if MRI is cost effective and this requires further research (Hollingworth, et al., 2011).

Magnetic resonance imaging examination of the knee can be performed with various methods and only general guidelines for the routine protocol selection can be given. Overall MRI examination of the knee routinely includes axial, coronal, and sagittal planes and multiple sequences that are selected according to suspected internal derangements. Coronal plane images can be used primarily to evaluate the collateral ligaments. Other structures that can be evaluated in this plane include the cruciate ligaments, the menisci, articular cartilage, osseous structures, and the iliotibial tract. Sagittal images are used to evaluate the menisci, the cruciate ligaments, and the articular cartilage surfaces of the medial and lateral compartments and trochlear groove. Sagittal plane images are also used to evaluate the articular cartilage of the patellar facets, structures of the posteromedial and lateral corner, the patellar and quadriceps tendons, subchondral bone and bone marrow, joint fluid and possible effusion, Hoffa's fat pad, plicae, tibiofibular joint, collateral ligaments, and lateral tendons. Axial plane images are used to evaluate the articular cartilage surfaces of the patellofemoral joint, especially the patellar facets. The other structures examined in this plane include the intercondylar notch, the menisci, the collateral ligaments, proximal attachment of ACL, patellar tendon, and the amount of joint fluid (Stoller, 2007).

A routine knee imaging protocol should include fat suppressed proton density fast spin echo or some other form of T2 weighting in each of the three planes. This allows for sensible evaluation of the articular cartilage, bone marrow, pathological fluid, ligament injuries, and meniscal morphology. Visualisation of meniscal degeneration or tears can be further improved by choosing fat suppressed proton density conventional spin echo or T2* gradient echo sequences in the sagittal plane. The T1-weighted images should be obtained at least in one plane as they allow for the evaluation of marrow fat signal changes in sclerosis or oedema that may be associated with trauma, infection, or neoplasias. (Stoller, 2007). Due to the short repetition times, T1 images can be obtained quickly, which allows for the production of 3D volumetric datasets. Fat-suppressed T1-weighted 3D SPGR is a valuable tool for evaluating articular cartilage surfaces (Disler, et al., 1996; Yoshioka, et al., 2004).

The diagnostic validity of MRI is good for ligament and meniscal injuries of the knee (Crawford, et al., 2007; Fischer, et al., 1991; Mackenzie, et al., 1996; Oei, et al., 2003; Rappeport, et al., 1996). The results of several meta-analysis and multicentre studies revealed that the mean sensitivity of MRI ranges from 91% to 93% for medial meniscal tears and is much lower, 69% to 79%, for lateral meniscal tears (Crawford, et al., 2007; Fischer, et al., 1991; Mackenzie, et al., 1996; Oei, et al., 2003). Mean specificity of MRI ranges from 81% to 88% for medial meniscal tears and 93% to 96% for lateral meniscal tears. For ACL tears, sensitivity ranges from 87% to 94% and specificity from 94%

to 95%. For PCL injuries, the sensitivity ranges from 91% to 94% and the specificity is approximately 99%. It must be noted, however, that the results vary widely among different studies. Published sensitivity rates are at lowest 19% for medial meniscal tears, 10% for lateral meniscal tears, 39% for ACL tears, and 33% for PCL tears (Krampla, et al., 2009; Lundberg, et al., 1996). The lowest specificities are reported in the older studies, 29%, 27% (Adalberth, et al., 1997), 82% (Glashow, et al., 1989), and 96% (Niitsu, et al., 1991).

Lower than average diagnostic validity is reported when only acute knee injuries are included (Lundberg, et al., 1996). Whether this is associated with haemarthrosis or other characteristics of acutely injured knees of the study or due to the MRI methods, sample selection, or other methodological variables as compared to other studies is not clear. Higher MRI field strength improves diagnostic performance only modestly, and significant effects can be seen only for injuries of the ACL (Oei, et al., 2003). This result is further supported by new results using 3.0T MRI. Sampson and coworkers reported that the sensitivity and specificity, respectively, of 3.0T MRI is average for medial meniscal tears (91%, 93%) and lateral meniscal tears (77%, 93%), and as high as 100% (100%) for ACL tears (Sampson, et al., 2008). Very good diagnostic validity can be also achieved with low field systems. For example, Riel et al (Riel, et al., 1999) used a 0.2T scanner and reported sensitivity, specificity, and accuracy rates of 93%, 97%, and 95% for medial meniscal tears, and 82%, 96%, and 93% for lateral meniscal tears. The diagnostic validity of the 0.2T MRI scanner was similar or even slightly better than the 3T MRI scanner used by Sampson. Grossman and coworkers compared the diagnostic validity of 1.5T MRI to 3.0T MRI in the diagnosis of meniscal tears. In a series of 100 consecutive patients who underwent 1.5T MRI, sensitivity was 93% for medial meniscal tears and 68% for lateral meniscal tears. In a comparative sample of 100 consecutive patients who underwent 3.0T MRI, the sensitivities were 93% and 69%, respectively. The specificities for medial meniscal tears were 82% for 1.5T MRI and 76% for 3.0T MRI. For the lateral meniscal tears, specificities were 95% and 92%, respectively. None of these small differences between field strengths, however, was statistically significant (Grossman, et al., 2009). Another recently published study comparing the 1.0T, 1.5T, and 3.0T field strengths reported no differences in the diagnostic validity between the field strengths for the detection of meniscal tears or ACL injuries (Krampla, et al., 2009).

Imaging cartilage with MRI is challenging. Depending on the location and depth of the lesion, MRI sequences, or other methodological variations, sensitivity has ranged from 0% to 100%, and specificity from 50% to 100% (Bredella, et al., 1999; Disler, et al., 1996; Friemert, et al., 2004; Handelberg, et al., 1990; Irie, et al., 2000; Munk, et al., 1998; Potter, et al., 1998; Recht, et al., 1993; Riel, et al., 1999; Spiers, et al., 1993; Vallotton, et al., 1995; Yoshioka, et al., 2004). Fat-suppressed T1-weighted 3D SPGR is one of the most valid and currently generally available sequences for evaluating articular cartilage lesions related to trauma and/or osteoarthritis of the knee, with a sensitivity ranging

from 75% to 97% and specificity ranging from 85% to 97% (Disler, et al., 1996; Yoshioka, et al., 2004). Fat-suppressed fast spin echo sequences can also show good results with sensitivity as high as 100% and specificity of 68% for articular cartilage lesions related to knee osteoarthritis (Yoshioka, et al., 2004). The advantage of fast spin echo techniques is that they can used to evaluate meniscal and ligamentous tears, whereas SPGR techniques are limited to cartilage imaging (Potter, et al., 1998).

Even with this increased knowledge of cartilage-sensitive sequences, the clinical use of MRI for overall knee evaluation still has poor sensitivity, especially for superficial chondral lesions. For 1.5T MRI, the sensitivity was 13% for grade 1 lesions, 23% for grade II, 64% for grade III, and 73% for grade IV lesions (Figueroa, et al., 2007). The corresponding sensitivities for 3.0T MRI were 29%, 62%, 63%, and 74%, respectively (von Engelhardt, et al., 2007). In the first study, chondral lesions were classified according to depth as recommended by the International Cartilage Repair Society (ICRS) (Brittberg & Winalski, 2003). The ICRS classification is presented in detail in Table 4. In the latter study, the lesions were classified according to the Bachmann classification (Bachmann, et al., 1997), which is basically similar to the ICRS classification in grading the depth of the lesions. Detection of deep lesions is most important because they may become symptomatic and require treatment (Curl, et al., 1997; Kettunen, et al., 2005). Preoperative diagnosis of these lesions could allow for appropriate preparations for the potentially forthcoming cartilage repair procedure. Basic repair methods can be performed in most facilities, but more advanced techniques are centralised to few hospitals in Finland (Vasara, et al., 2006).

Higher magnetic field strengths may be beneficial for imaging cartilage, but only limited evidence supports this assumption. Experimental evaluation of artificial articular cartilage injuries in pig knees indicates that diagnostic performance of a conventional high-field 1.0T MRI system is superior to a low-field 0.18T system for detecting deeper chondral lesions (Woertler, et al., 2000). In another study comparing image quality of 1.5T MRI to 3.0T MRI, the 3.0T MRI had a better signal-to-noise ratio and subjectively better delineation of the cartilage. A severe limitation of the study was that it compared only image quality and not diagnostic validity (Schoth, et al., 2008). In the aforementioned study of Krampla and coworkers, the diagnostic validity of 1.0T, 1.5T, and 3.0T field strengths was also compared for chondral lesions, and no differences in sensitivities or specificities were detected (Krampla, et al., 2009). Wong and coworkers reported in a small, retrospective series of 19 patients that the sensitivity of 3.0T MRI was slightly higher than that of 1.5T MRI (76% versus 71%) in diagnosing knee chondral lesions (Wong, et al., 2009). The specificity was 95% for both field strengths. In a recent study using 1.5T and 3.0T MRI with fast spin echo sequences in a larger sample of 200 symptomatic patients, no differences were detected between sensitivities (71% for 3.0T and 69% for 1.5T MRI), but the specificity was slightly higher for the 3.0T system (85.9% versus 78%) (Kijowski, et al., 2009). The sensitivities for the different grades of chondral

lesions were not statistically different. A 1.5T MRI had a sensitivity of 41% for cartilage softening, 50% to 82% for partial thickness lesions, and 95% for full thickness lesions. The corresponding sensitivities for 3.0T MRI were 42%, and 49% to 85%, 98%. There is no evidence from clinical studies to support a superior diagnostic validity of 3.0T MRI compared with lower field systems. The undisputed advantage of 3.0-T systems is that the imaging procedure is faster.

Bone bruises represent trabecular bone marrow oedema and are frequently seen in MRIs of an injured knee, especially in association with osteochondral lesions, patellar dislocations, and ACL injuries (Bretlau, et al., 2002; Paakkala, et al., 2010; Yoon, et al., 2011). It is generally accepted that bone bruises in young adults are of traumatic origin and caused by compression forces to the bone. They usually resolve within 1 year from the injury (Bretlau, et al., 2002). More than 80% of ACL injuries have a concomitant bone bruise, most commonly in the lateral aspect of the tibial plateau or lateral femoral condyle (Yoon, et al., 2011). In primary traumatic patellar dislocations, practically all patients have bone bruises in the lateral femoral condyle and in the patella (Paakkala, et al., 2010). After a knee trauma that has led to bone bruising, the overlying cartilage may be seemingly uninjured. Nevertheless, a bone bruise may indicate that the overlying cartilage is substantially damaged (Johnson, et al., 1998). Of the potentially treatable, traumatic chondral lesions of the knee visible on routine MRI, almost all have associated focal subchondral oedema. It was suggested that a bone bruise might be an important diagnostic clue for detecting traumatic chondral lesions (Rubin, et al., 2000). A limitation of this study was that the presence of bone bruises was not recorded if there was no visible cartilage defect in MRI. In the study by Bretlau and coworkers, however, all bone bruises and associated injuries detected by MRI in acutely injured knees were reported. Four out of five patients with a bone bruise also had an osteochondral lesion and 100% of the patients with osteochondral lesions had a bone bruise (Bretlau, et al., 2002). Magnetic resonance imaging was used as the gold standard for detecting injuries, which is a limitation of the study, especially for chondral lesions for which MRI is generally not sensitive (Figueroa, et al., 2007; von Engelhardt, et al., 2007). The presence of a bone bruise also correlates strongly with femorotibial osteoarthritis (Oda, et al., 2008).

Magnetic resonance imaging studies have also been conducted with a contrast agent, a technique known as gadolinium-enhanced MRI or MR arthrography, which can be performed as direct MR arthrography (intra-articular injection of Gd-DTPA) or indirect MR arthrography (intravenous injection of Gd-DTPA). Although the sensitivity of MRI for chondral lesions may be increased by the use of contrast-agents (Gagliardi, et al., 1994; Kramer, et al., 1994), both of these MR arthrography methods are seldomly used in routine clinical practice. These methods make MRI more invasive and increase the risk for iatrogenic complications as well as the expense of the imaging process (Potter & Foo, 2006).

Magnetic resonance imaging can be used as an alternative to CT to diagnose AKP and patellar instability. As with CT imaging, MRI allows for comprehensive evaluation of patellar malalignments and kinetic MRI methods are also available. An advantage of MRI over CT is that cartilage injuries, bone bruises, and especially soft tissue structures like patellar tendinopathy, Hoffa's fat pad, and bursae can be evaluated. Other imaging methods for AKP include nuclear scintigraphy, which is useful in limited cases like in occult fractures and malignancies. Ultrasound is useful for diagnosing patellar tendinopathy (Christian, et al., 2006; Peers & Lysens, 2005).

Table 4. ICRS classification of articular cartilage injuries (Brittberg & Winalski, 2003)

Grade	Description
0	Normal
1	Superficial fibrillation, softening, fissures or lacerations
2	Defects less than 50% of the cartilage depth
3	Defects more than 50% but not to subchondral bone
4	Defects to the subchondral bone

6.4 General Treatment Principles of Meniscal Tears, Chondral Lesions and Anterior Knee Pain

6.4.1 Conservative Management

A detailed description of the management of knee injuries and AKP is beyond the scope of this dissertation and only some general principles are presented here. The basic aims for the treatment of knee disorders are to manage pain and other symptoms, maintain normal knee function, and improve the long-term prognosis of a disorder. A 1-month trial of conservative management is considered acceptable for minimally symptomatic small meniscal tears, as some of them may become asymptomatic. In general, however, meniscal tears require arthroscopic operation (Scotney, 2010). Anterior knee pain is initially treated conservatively. According to the most recent Cochrane review updated in 2009, physiotherapy can be considered to treat AKP but the evidence of its effectiveness is limited. Open and closed kinetic chain exercises were found to be equally effective (Heintjes Edith, et al., 2003). For full-thickness chondral lesions, especially in the patellofemoral compartment, conservative treatment and physiotherapy should be continued for a minimum of 3 to 6 months before surgery is considered. Physiotherapy should include strengthening of the quadriceps/vastus medialis muscle and a four-way

hip program in addition to reduction of overweight and activity modification (Gomoll, et al., 2010).

6.4.2 Arthroscopy and Arthrotomy

Knee arthroscopy is a minimally invasive technique that allows for the evaluation and treatment of intra-articular knee injuries and disorders. It became a mainstream technique in the 1970s and radically changed the treatment of various knee disorders, especially meniscal and cruciate ligament tears. Arthroscopy is indicated when the disorder is amenable to arthroscopic operation and conservative treatment is insufficient. Some of the common indications include knee-locking, knee instability (frequently in multiple ligament injuries), loose intra-articular bodies, symptomatic plicae, meniscal, ACL and LCL tears, and painful knee haemarthrosis associated with patellar dislocation or other injuries (Onyema, et al., 2011; Scotney, 2010). Basic cartilage repair procedures for small (<2–4 cm^2) lesions may also be performed arthroscopically. These techniques include debridement and chondroplasty, microfracture, and osteochondral autografts (Gomoll, et al., 2010; Kiviranta & Vasara, 2004). Arthroscopy may also be necessary when the diagnosis remains uncertain after a thorough physical examination and imaging and it is suspected that arthroscopically treatable lesions might still exist. Arthroscopy is also sometimes inevitable for prolonged knee symptoms (Onyema, et al., 2011). The current consensus is that diagnostic arthroscopies should be avoided if possible. Compared to open surgery, arthroscopy allows for minimal disruption of tissue, smaller skin scars, shorter recovery time, more rapid mobilisation, and it is cost-effective (Moore & Dalley, 2006; Onyema, et al., 2011; Rappeport, et al., 1996). Arthroscopy, however, also has some potential disadvantages. Even if minimally invasive, it causes short-term work disability, pain, and involves possible risks related to the operation itself such as unsuccessful treatment, vascular injuries or knee joint infection. It can be performed with general, regional, or local anaesthesia, each having their own risks (Onyema, et al., 2011). Sometimes no surgically treatable lesion is found in arthroscopy and in these cases it can be considered as an unnecessary diagnostic method that consumed health care resources.

Arthroscopy is considered the gold standard for diagnosing knee injuries and disorders as it allows for direct view of the knee joint (Casscells, 1971; Figueroa, et al., 2007). Nonetheless, its accuracy in the evaluation of chondral lesions and meniscal tears has been questioned (Hodler & Resnick, 1992; Quinn & Brown, 1991). Arthroscopy allows for evaluation of the cartilage surfaces, but reveals nothing about the possible lesions within the cartilage tissue which is a limitation (Van Breuseghem, 2004). In case that MRI detects lesions of this type the finding can be considered as a false positive as it cannot be confirmed at the arthroscopy.

Open knee surgery is currently rarely needed for treating knee injuries and AKP in young adult patients. Fractures of the knee region, however, may require open knee surgery. One of the other possible indications for arthrotomy in this population is the treatment of large (>2–4cm^2) traumatic chondral lesions with osteochondral allografts or autologous chondrocyte implantation (Gomoll, et al., 2010; Kiviranta & Vasara, 2004). Surgical treatment of traumatic chondral lesions has improved during the last two decades and new treatment methods for chondral lesions, such as autologous chondrocyte implantation, have evolved and show promising results (Brittberg, et al., 1994; Gomoll, et al., 2010; Kiviranta & Vasara, 2004; Peterson, et al., 2002; Vasara, et al., 2006). Surgical treatment can be considered in young adult patients when the symptoms are due to deep ICRS grade 3 to 4 chondral lesions and conservative treatment has failed to provide acceptable pain relief. The rehabilitation process following surgical repair, however, is demanding and long-lasting. In AKP patients, cartilage repair procedures may be performed when no source of pain other than deep patellofemoral chondral lesions is found (Gomoll, et al., 2010). For those patients who receive open knee surgery, both autologous chondrocyte implantation and osteochondral allografts are used. To optimize the healing environment for the repaired cartilage, mechanical deviations of the knee must be corrected. This is often performed by osteotomy or surgical adjustments of the tibial tuberosity location, medial patellofemoral ligament, and lateral soft tissues (Gomoll, et al., 2010).

7   Aims of the Study

The principal aims of this study were to investigate the epidemiology and MRI-based diagnostics of common knee injuries and AKP in a young adult population. The detailed aims of the study were to assess:

1) Diagnostic validity of 1.0T MRI in fresh traumatic chondral lesions of the knee in routine clinical practice (I).

2) Possible differences in diagnostic validity of MRI in meniscal tears related to acute knee trauma and in knee symptoms lasting over 6 months in young adults (II).

3) Diagnostic validity of MRI for patellar chondral lesions in nontraumatic AKP patients (III).

4) The association between clinical symptoms, physical findings, and patellar chondral lesions in young adults with nontraumatic AKP (III).

5) Incidence and risk factors for the need of inpatient care in knee injuries of young adult males (IV).

8 Materials and Methods

The study was performed at the Research Institute of Military Medicine, Central Military Hospital, Helsinki, Finland. The studies were approved by the medical ethics committee of the Central Military Hospital and by the Medical Ethics Committee of the Hospital District of Helsinki and Uusimaa. For the prospectively collected data, written informed consent was obtained from each subject.

8.1 Study Population

Study populations were conscripts performing their compulsory military service. All Finnish males are subject to compulsory military service at the age of 18 years, and service must be performed at the latest by the age of 30. The majority of conscripts are 19 years old at the beginning of their basic training. All conscripts are examined by a physician prior to military service and at the beginning of the service. The purpose of the examinations is to determine whether the subject is healthy enough to perform physically demanding military training. During the study period, approximately 80% of all potentially eligible males in Finland performed military service. Approximately 700 to 800 males a year are relieved from service before entry and the main reason for being excused from military service is chronic disease such as diabetes, asthma, and mental health problems. Musculoskeletal disorders are the main reason for premature discharge for those serving in the military (Taanila, et al., 2011). Because of the compulsory nature of the service, conscripts represent an extensive sample of the general population of young adult males in Finland.

A new batch of conscripts enters the service twice a year, in January and in July. The military service period ranges from a maximum of 362 days (officers and conscripts trained for particularly demanding duties) to 270 days (conscripts trained for work requiring special skills), with a minimum of 180 days (other rank-and-file duties). The military service begins with a basic training period of 8 weeks comprising increasing levels of walking, marching, bicycling, running, and other physical activities. The intensity of military training gradually increases, averaging 17 hours per week during the first 8-week period. In addition, conscripts participate in other physical training exercises, such as floorball, weight training, jogging, and circuit training for an average of 7 hours per

week. After the basic training period, conscripts are expected to have attained a physical level enabling them to march or ski a distance of 15 km on 2 consecutive days while carrying a rifle and full military pack weighing 25 kg and without losing their capability to engage in battle. The amount of moderate and high-intensity physical training is maintained at the same level in different companies over the following 4 months of service. The conscripts are expected to undergo approximately 450 hours of instructed physical training (19 hours per week) during the first 6 months of military service. Until the end of the service, combat training, marching, and other physical training activities are performed almost daily. Physical and combat training causes increased loads on the lower limbs and especially on the knees because kneeling and crawling are often included in the training activities. Young adults performing their compulsory military service are considered to be representative of how the general population reacts to the challenges of progressive physical exercise. Minor disorders are often provoked under these circumstances and knee pain may markedly interfere with the ability to complete military service.

8.1.1   Diagnostic Samples (I–III)

The diagnostic section of the dissertation deals with the three diagnostic challenges: fresh traumatic chondral lesions (I), fresh meniscal tears (II) and AKP (III). The study samples were based on the data of conscripts treated at the Central Military Hospital in Helsinki, Finland. The Central Military Hospital provided all of the surgical services for the conscripts at that time.

The sample of subjects with arthroscopically confirmed fresh traumatic chondral lesions of the knee comprised 32 conscripts. The age of the included patients ranged from 19 to 21 years (median, 19). Of these, 30 were men and 2 were women. The sample was collected retrospectively from the Central Military Hospital database containing 578 consecutive patients who had undergone MRI examination of the knee and subsequent arthroscopy during the 6-year period from March 1, 1997 to February 28, 2003. The primary inclusion criterion was a trauma-related, solitary or multiple, arthroscopically proven, fresh articular cartilage lesion of the knee joint. Other requirements were that MRI was performed as a part of routine clinical practice with routine protocols prior to arthroscopy and both MRI and arthroscopy were performed within 6 weeks of the trauma. Only patients younger than 25 years of age were included in the study to eliminate the possibility of osteoarthritic changes of the cartilage. Patients were excluded if there was no clear trauma or if the trauma had occurred more than 6 weeks prior to the arthroscopy. Patients with recurrent patellar dislocations or patellar chondral lesions (CMP) that were not assumed to be trauma-related were also excluded.

The samples of subjects with fresh and old meniscal tears included 82 patients (77 men, 5 women) with 27 meniscal tears related to acute knee trauma and 40 patients (39

men, 1 woman) with 14 meniscal tears related to chronic knee symptoms. The age of the subjects ranged from 18 to 25 years (median 20). The Central Military Hospital database of the patients who had undergone MRI examination of the knee and subsequent arthroscopy during the same 6-year period was used. Primary inclusion requirements were MRI performed as a part of routine clinical practice with routine protocols within 30 days prior to arthroscopy. A maximum interval between examinations of 30 days was allowed to ensure comparability between the findings in the MRI and arthroscopy. Patients were excluded in cases of an increase in knee symptoms or trauma between the time of the MRI and arthroscopy. All patients over 25 years of age or with previous surgical operations were excluded to ensure comparability between the groups and to minimize degenerative changes in the menisci. A total of 235 patients met these primary criteria and two groups were then formed based on the time of the injury and duration of the symptoms; the first group included fresh meniscal tears related to acute knee trauma and the second group included older meniscal tears related to chronic knee symptoms.

For the first group including those meniscal tears related to acute knee trauma, there were two additional inclusion criteria: the knee problem was caused by clear trauma and MRI had been performed no later than 1 month (30 days) after the trauma. To ensure that the tears were fresh, patients with a history of previous knee trauma or degenerative changes observed at arthroscopy were excluded. A total of 82 patients met the final inclusion criteria for this group and were accepted for the study sample.

For the second group including those with meniscal tears related to chronic knee symptoms, there were two additional exclusion criteria: knee symptoms had lasted for less than 6 months before MRI, and knee trauma had occurred during the 6 months preceding the MRI. In this group, a total of 40 patients met the final inclusion criteria and were accepted for the study sample.

The sample of subjects with nontraumatic AKP comprised 56 prospectively chosen conscripts (54 men, 2 women) with clinically diagnosed AKP and MRI examination followed by arthroscopy. Only one knee was examined in 21 patients, and both knees were examined in the remaining 35 patients. In bilateral cases, one knee was randomly selected for the study to ensure the independence of the observations. The age of the subjects ranged from 18 to 25 years and the median age was 19.5 years. The data were collected at the Central Military Hospital between the years 1999 to 2002. The main inclusion criterion was clinical diagnosis of nontraumatic, prolonged AKP. Exclusion criteria included a previous fracture, surgical procedure, or injury in the knee region. Arthroscopy was chosen only when the response to nonsurgical treatment was insufficient or differential diagnosis between patellar chondral lesions and other knee disorders required invasive methods. In cases for which arthroscopy was considered necessary, all patients were also examined with MRI. For subjects who had previously undergone MRI of the knee, the scan was repeated to minimize the delay between the MRI and the arthroscopy.

8.1.2   Epidemiological Sample (IV)

The epidemiological section of this dissertation is based on population-based data of Finnish young adult male conscripts. All 18- to 30-year old Finnish male conscripts performing their compulsory military service between the years 1998-2002 were included in the study. The incidence and risk factors for knee injuries leading to inpatient care were reported as well as the number of subsequent surgical operations and military service class changes indicative of longer-term notable disability. The total number of conscripts was 128,584 with a total exposure-time of 97,503 person-years. Of these, 1073 (1%) had a knee injury leading to at least one inpatient care admission.

8.2   Physical Examination Methods (I–III)

In the samples of fresh traumatic chondral lesions and fresh and old meniscal tears, the medical history of the former traumas, knee disorders, and symptoms was taken into account when selecting subjects into the study.

The sample of AKP patients was chosen according to clinical diagnosis of nontraumatic AKP syndrome. Physical examination was performed by an orthopaedic surgeon according to the standard policy of the institution. Examination included inspection; palpation; measurements of motion, muscle strength, limb lengths, and muscle girth; functional tests to assess walking gait, stationary running, hopping, and squatting; tests to detect mechanical or meniscal problems such as the McMurray test or Apley test; and evaluations of ligament stability, the extensor mechanism, and the popliteal space. The clinical symptoms and physical signs of AKP syndrome were then divided into three categories to assess their association with patellar chondral lesions: (1) diffuse pain in the anterior part of the knee as a single symptom, (2) typical clinical AKP syndrome without patellofemoral crepitus or pain on manipulation of the patella, and (3) typical clinical AKP syndrome with patellofemoral crepitus and/or pain on manipulation of the patella.

8.3   Imaging Methods (I–III)

All patients underwent MRI scans at the Central Military Hospital with a 1.0T scanner (Signa Horizon; GE Medical Systems, Milwaukee, WI). A standard knee coil with a field of view of 10 to 16 cm was used. The slice thickness was 3 to 4 mm, with a 0.5- or 1.0-mm intersection gap. The basic MRI protocol used in routine clinical practice for the overall knee injury examination included:

1. Sagittal proton density spin-echo with fat suppression
2. Sagittal T1-weighted spin-echo

3. Axial T2-weighted fast spin-echo with fat suppression
4. Coronal T2-weighted fast spin-echo with fat suppression

Other routinely used sequences to evaluate knee injury patients and all AKP patients were sagittal T2 and T2* GRE images, axial T1-weighted 3D fast SPGR images with fat suppression, and coronal proton density images with fat suppression. Of these, axial T1-weighted 3D fast SPGR was the most important routine sequence used to evaluate the patellar articular cartilage in AKP patients.

All MRIs were first evaluated by an experienced radiologist soon after the imaging process. All articular cartilage surfaces, bone bruises, menisci, cruciate ligaments, and other visible structures were registered into the medical records.

Plain radiographs, including anteroposterior, lateral, and sunrise views, were routinely obtained for the AKP patients before the physical examination by an orthopaedic surgeon.

8.4 Arthroscopies (I–III)

For all study subjects, arthroscopies were performed at the Central Military Hospital after MRI examination. Experienced orthopaedic surgeons performed all arthroscopies. All articular cartilage surfaces, menisci, cruciate ligament tears, and other structures were carefully examined under direct vision and with careful probing. In a prospective sample of patellar chondral lesions, special attention was paid to the patellar surface and the degree of fibrillation, fragmentation, and possible softening of the cartilage surface. Postoperative mobilization, and follow-up examinations were performed according to the standard practice of the institution when needed.

All arthroscopies were performed only when conservative treatment was considered insufficient or when differential diagnosis required invasive procedures. In samples of fresh traumatic chondral lesions and meniscal tears, the decision to perform arthroscopy was based on examination by an orthopaedic surgeon and subsequent MRIs. For the prospectively chosen sample of AKP patients, the initial treatment was nonsurgical, consisting mainly of activity restrictions or rest and nonsteroidal anti-inflammatory drugs when necessary. Before considering arthroscopy, a physiotherapist instructed and encouraged all patients to perform exercises such as lower extremity muscle strengthening, especially of the quadriceps.

For the sample of fresh traumatic chondral lesions, the median time from trauma onset to arthroscopy was 8 days (range, 2–40). For the sample of fresh meniscal tears, the median time between injury and MRI was 4.5 days (range, 0–30) and between MRI and arthroscopy 4 days (range, 0–29). For the sample of old meniscal tears, the median time delay between symptom onset and MRI was 3 years (range, 6 months–10 years), and the median time between MRI and arthroscopy was 20 days (range, 1–30). For the prospective sample of patients with AKP, arthroscopy was performed the first day

following the MRI examination except in seven cases, for which the time period between the MRI and arthroscopy ranged from 2 to 4 days.

8.5 Epidemiological Methods (IV)

8.5.1 Outcomes

The main outcome variables of the epidemiological analysis were 1) number and incidence of inpatient care admissions due to knee injuries in general and 2) number and incidence of inpatient care admissions due to knee injuries, as categorized into the specific ICD-10 diagnoses [ACL and PCL tears (S83.5), fresh and old meniscal tears (S83.2, M23.2), MCL and LCL tears (S83.4), traumatic chondral lesions (S83.3), and patellar dislocations (S83.0)]. Person-time injury-incidence rates, number of subjects with surgical operations, and military service class changes indicative of longer-term notable disability were reported. Risk factors analysed were conscript age, length of military service, weight, height, BMI, and physical performance, as measured with Cooper's 12-minute running test and muscle strength tests.

8.5.2 Data of Inpatient Care Admissions

During the study period all conscripts performing military service were required to use only the services of the primary military health-care units or the Central Military Hospital for medical treatment. All hospital and health-care unit admission information in Finland is collected in the National Hospital Discharge Register (NHDR). The NHDR data included all military conscripts admitted to primary military health-care units and the Central Military Hospital as inpatients from January 1, 1998, to December 31, 2002. Injuries to the conscripts during their leisure time or on vacation, as well as injuries occurring during military service were included. Information regarding inpatient care admissions due to knee injuries was collected by the NHDR with diagnoses coded according to the International Classification of Diseases (WHO, 1992, 10th revision). Both the main and the first secondary diagnoses were included. Information about any surgeries performed was also collected.

Coverage of the diagnosis in the Finnish NHDR between 1997 and 2002 was examined by Mattila et al. (Mattila, et al., 2008) by comparing patients with a confirmed cruciate ligament injury in the arthroscopy register of the Finnish Central Military Hospital to the data in the NHDR, and accuracy of the diagnosis in the Finnish NHDR between 1997 and 2002 was assessed by reviewing original medical reports, MRI, and arthroscopy files. The NHDR register coverage for cruciate ligament injuries was 92%, and the accuracy

was 89%. Previous studies demonstrated that the NHDR database is complete and highly accurate (Keskimäki & Aro, 1991; Salmela & Koistinen, 1987).

8.5.3   Disability Data

Data regarding longer-term disability (i.e., service class change) caused by knee injuries were obtained from the national register of the Finnish Defence Forces. Information regarding the ICD-10 diagnosis leading to a change of the service class was included in the register. Both the main diagnosis and the first secondary diagnosis, obtained from the register, were used in calculating the number of subjects requiring a change of the service class. Service class changes are usually recommended by the garrison physician when a knee injury causes disability and problems coping with military service for 2 or more weeks. A thorough clinical examination, including radiographs, and MRI and arthroscopy when needed, is performed before making a final decision to lower the service class, either to end military service prematurely, or to transfer the conscript to a physically less-demanding duty. A service class change resulting from a knee injury indicates a longer-term disability.

8.6   Statistical Methods of the Diagnostic Section (I–III)

Arthroscopic findings served as the gold standard when the diagnostic validity of MRI was analysed. Sensitivity, specificity, diagnostic accuracy, as well as positive and negative predictive values, were calculated with single table analysis. When the results for the different grades of chondral lesions were analysed, only sensitivity and accuracy were calculated because the number of true-negative and false-positive results in this setting is always 0. (Specificity = True-negative results/[False-negative results + False-positive results]). For same reason, diagnostic accuracy was identical with the sensitivity (Sensitivity = True-positives/[True Positives + False-negatives] and accuracy = [True-positives + True Negatives]/[True Positives + True negatives + False-positives + False-negatives]). The Fisher's exact test was used in two-way tables and 95% CI was analysed with the Wilson score method (Agresti & Coull, 1998).

8.6.1   Data of Fresh Chondral Lesions (I)

To analyse fresh traumatic chondral lesions found at MRI and arthroscopy, the data were classified according to the numeric grading system developed by Tyrrell et al (Tyrrell, et al., 1988) (Table 5). This system is similar to ICRS classification in that chondral lesions are graded according to their depth. Articular surfaces of the patella, femoral sulcus, medial and lateral femoral condyles, and medial and lateral tibial plateaus were included

in the analysis. Possible bone bruises seen in MRI were also taken into account as they may indicate damage to the overlying articular cartilage (Johnson, et al., 1998).

These data were collected in connection with normal clinical practice, and thus the orthopaedic surgeon received the original MRI reports before the arthroscopy. The exact grading of the chondral lesions was not included in the data. For the purposes of this study, the MRI data were re-evaluated by a musculoskeletal radiologist blinded to the prior results of arthroscopy or MRI. Sensitivity, specificity, and diagnostic accuracy of MRI for fresh traumatic chondral lesions were calculated. Bone bruises in MRI were primarily interpreted as a negative result for chondral lesions. As the underlying cartilage may be injured, however, the sensitivity, specificity, and diagnostic accuracy were also calculated to allow for such an interpretation.

Table 5. Depth of articular cartilage lesions according to grading scale developed by Tyrrell et al. (Tyrrell, et al., 1988).

Grade	Description
0	Normal
1	Moderate irregularity
2	Severe irregularity but not full thickness
3	Full-thickness loss

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8.6.2   Data of Meniscal Tears (II)

Generally used MRI criteria for meniscal tears are an internal tear line extending to the upper, lower, or apical surface of the meniscus, or a tear line splitting the meniscus into two or more pieces and showing partial dislocation of the meniscus (Crues, et al., 1987). These criteria were also used for samples with fresh and old meniscal tears. Due to the retrospective nature of the study, the arthroscopist was aware of the MRI report before surgery. The original MRI findings were reviewed and compared with the arthroscopic findings. Lateral and medial menisci of all the knees were evaluated and interpreted independently. The sensitivity, specificity, and diagnostic accuracy of MRI for both acute and chronic meniscal tears were calculated. To calculate the interobserver correlations and intraobserver agreement, the original MRI and arthroscopy records were reviewed twice by another radiologist with musculoskeletal training who was blinded to previous MRI and arthroscopy findings. Agreement was almost perfect when the kappa-value was 0.81 to 1.00, substantial at 0.61 to 0.80, moderate at 0.41 to 0.60, fair at 0.21 to 0.40, and poor at a kappa-value of less than 0.20 (Landis & Koch, 1977).

8.6.3 Data of Anterior Knee Pain and Patellar Chondral Lesions (III)

The MRI and arthroscopic findings of patellar chondral lesions in a prospective sample of nontraumatic AKP patients were recorded as showing either normal cartilage thickness or cartilage lesions of different depths or severity. Grading was based on the arthroscopic grading system by Shahriaree (Shahriaree, 1985), with 0 indicating normal; I, softening or a blister; II, fissuring; III, fragmentation and fissuring; and IV, full-thickness fissuring and exposed bone (Table 6). This grading system is a modification of the Outerbridge classification in which grade I represents softening and swelling of the cartilage, grade II/III represent fissure and fragmentation in an area less/more than 1.3 cm in diameter and grade IV represents erosion of cartilage down to bone (Outerbridge, 1961).

The images were initially evaluated according to a standard protocol for interpreting MRI findings by a musculoskeletal radiologist on duty. In addition, another musculoskeletal radiologist who was blinded to the previous MRI and arthroscopy findings then re-evaluated the images. These re-evaluations differed from the original interpretation in three cases, and thus a final decision was reached by consensus. Arthroscopy was performed by an experienced orthopaedic surgeon who evaluated the articular surfaces being blinded to the MRI findings.

When calculating the results for grade-I patellar chondral lesions, only arthroscopically detected grade-I lesions were taken into account as positive results (the gold standard) for patellar chondral lesions, and they were compared with the MRI results (with grade 0 on the images considered negative and grades I through IV considered positive). The results for grades II, III, and IV were calculated with arthroscopically detected grade-II, III, and IV lesions considered positive and compared with the MRI results (with grade 0 on the images considered negative and grades I through IV considered positive). Other internal derangements of the knee revealed by arthroscopy were also recorded and taken into account.

Possible PFM was evaluated on patellofemoral radiographs by measuring the lateral patellofemoral angle by drawing a line connecting the anterior aspects of the femoral condyles and a second line along the lateral facet of the patella (Figure 1) (Laurin, et al., 1978). The sulcus angle was measured between the lines extending from the deepest point of the intercondylar sulcus, both medially and laterally, to the tops of the femoral condyles. A sulcus angle >138˚ was considered to be shallow (Merchant, et al., 1974).

A line bisecting the sulcus angle was then compared with a line drawn from the apex of the sulcus angle through the lowest point of the articular ridge of the patella (the congruence angle) to detect possible patellar lateralization.

Table 6. Classification of patellar chondral lesions (CMP) according to the system described by Shahriaree (Shahriaree, 1985).

Grade	
I	Fibrillation
II	Fissure formation
III	Fragmentation
IV	Crater formation and eburnation

Slightly reformatted from Table I in original publication III (Pihlajamäki, et al., 2010).
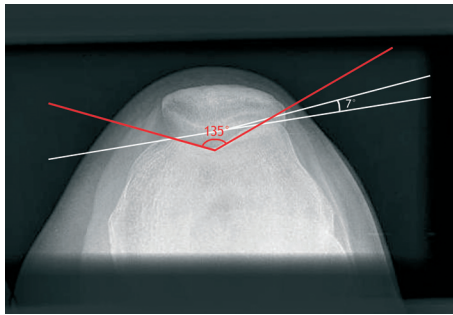
Figure 1. Patellofemoral radiograph of a left knee shows normal patellar anatomy. Lateral patellofemoral angle (white lines) opens laterally approximately 7˚ and sulcus angle is 135˚ (red lines).

8.7 Statistical Methods of the Epidemiological Section (IV)

For the epidemiological section of this study, the follow-up time for each conscript was calculated from entry into military service to the first inpatient care admission due to knee injury or to the end of the service if no hospitalisations occurred. Total exposure time for the population at risk was calculated from the total number of realized service days during the study period, which was obtained from the register. Total exposure time for the population at risk during the study period was 97,503 person-years. The person-time incidence rates for knee injuries leading to inpatient care were calculated by dividing the number of persons with a knee diagnosis by the total exposure time, and the 95% CIs were reported. Because subjects might have been at inpatient care multiple times for the same diagnosis, only first admissions were taken into account for calculating the incidence. The number of possible readmissions, surgical operations, and service class changes by diagnoses were also reported.

For the risk factor analysis, the height and weight of the conscripts were divided into quartiles. Age was divided into three groups matched by size. The BMI was calculated as weight in kilograms divided by the square of the height in meters (kg/m^2). Conscripts were then categorized as underweight, overweight, or obese based on the international classification according to BMI by the World Health Organization, as follows: BMI <18.5 was classified as underweight, 18.5–24.99 as normal, 25–29.99 as overweight, and ≥ 30 as

obese. Aerobic condition was determined based on the distance covered in a 12-minute Cooper running test and the results were divided in four categories as follows: <2200 meters (poor), 2200–2599 m (fair), 2600–2999 m (good), and ≥ 3000 m (very good). To measure strength, we used the Finnish Defence Force muscular strength test, which includes distance of horizontal jump without speed and number of sit-ups, push-ups, pull-ups, and back lifts performed in 1 minute, with values ranging from 0 to 3 points per movement. A total of 0–4 points was considered poor, 5–8 points as fair, 9–12 points as good, and 13–15 points as very good. Logistic regression was used to calculate risk factor analyses for knee injuries. First, logistic regression models adjusted by age and length of military service were constructed, each model including one of the possible risk factors. Only those risk factors significantly associated ($p<0.05$) with outcome were included in the final logistic regression model. Because of the strong interaction between BMI and weight, only BMI was included in the final logistic regression model. Odds ratios were calculated with a 95% CI. Statistical analyses were performed using SPSS 17.0 (IBM Corporation, NY) software for Windows.

9   Results

9.1   Clinical and Arthroscopic Diagnoses (I–III)

9.1.1   Fresh Traumatic Chondral Lesions (I)

A total of 192 articular cartilage surfaces in 32 knees with fresh traumatic chondral lesions were evaluated with MRI and arthroscopy. Arthroscopy revealed intact and normal surfaces in 147 (77%), and led to the classification of 12 chondral lesions (6%) as grade I, 21 (11%) as grade II, and 12 (6%) as grade III. Thus, the total number of damaged articular surfaces was 45 (23%). A sprain caused 40 (89%) of the lesions, contusion caused 3 (7%), and the combination of sprain and contusion caused 2 (4%). Of the 45 chondral lesions 19 (42%) were situated in the patellar surface, 12 (27%) in the lateral femoral condyle, 9 (20%) in the medial femoral condyle, 3 (7%) in the lateral tibial plateau, 2 (4%) in the medial tibial plateau, and 0 in the femoral sulcus. Lesions of multiple articular surfaces were found in 13 patients. Trauma to the knee resulted in first time acute patellar dislocation in 10 cases.

9.1.2   Meniscal Tears (II)

The total number of fresh meniscal tears identified by arthroscopy in 82 knees with acute knee trauma was 27 of which 12 were located in the medial meniscus and 15 in the lateral meniscus. Effusion or haemarthrosis was present in 64 knees (80%). The total number of old meniscal tears in 40 knees with chronic symptoms was 14; 9 were situated in the medial and 5 in the lateral menisci. Effusion or haemarthrosis was present in 2 of the 40 knees (5%).

9.1.3   Anterior Knee Pain and Patellar Chondral Lesions (III)

Arthroscopy confirmed the presence of patellar chondral lesions in 25 (45%) of the 56 knees with AKP and of these 8 (32%) were grade I, 9 (36%) were grade II, 8 (32%) were

grade III, and none were grade IV. Synovial plicae were found in 25 (45%) of the knees, meniscal tear in 4 (7%), femorotibial chondral lesion in 4 (7%) and normal anatomy with no abnormal arthroscopic findings in 6 (11%).

Diffuse AKP was the only symptom in 8 knees. A typical clinical presentation of AKP (etc. pain in the anterior aspect of the knee in prolonged sitting and other typical symptoms such as mild catching or giving-way sensations in walking) was present in 48 knees. In physical examination of the 48 knees, patellofemoral crepitus or pain on patellar manipulation was absent in 12 knees and present in 36 knees.

There was no association between the severity of patellar chondral lesions observed with arthroscopy and the clinical symptoms of AKP syndrome (p = 0.83). All arthroscopic findings (one or more per knee) and their association with the clinical symptoms and physical signs are shown in Table 7.

Table 7. Symptoms and Physical Signs, and Arthroscopic Findings

Symptoms and/or Physical Signs	Patellar Chondral Lesion	Synovial Plica	Meniscal Rupture	Femo-rotibial Chondral Lesion	Normal Findings	Total Number of Findings
Diffuse anterior knee pain as single symptom (n=8 patients)	1	4	0	0	3	8
Typical clinical symptoms without patellofemoral crepitus or pain on manipulating of patella (n=12)	6	7	0	0	0	13
Typical clinical symptoms with patellofemoral crepitus and/or pain on manipulating of patella (n=36)	18	14	4	4	3	43
Total	25	25	4	4	6	64

Slightly reformatted from Table III in original publication III (Pihlajamäki, et al., 2010).

9.2   Radiographs in Anterior Knee Pain (III)

Plain radiographs were obtained for 43 knees with AKP, and 36 of them showed normal findings (Table 8). Patellar subluxation or lateralization was found in six knees, and a flat sulcus angle was found in three knees, Osgood-Schlatter's disease was detected in one knee, and surface irregularity of the patellar facets was seen in one knee. Subsequent arthroscopy revealed patellar chondral lesions in 14 of the 36 knees with normal radiographic findings.

Table 8. Radiographic and Arthroscopic Findings

	Findings on Plain Radiographs	Patellar chondral lesion in the same knee
Normal radiographic findings	36	14
Subluxation/lateralization	6	4
Flat sulcus angle	3	2
Osgood-Schlatter disease	1	1
Surface irregularity of patellar facets	1	0

Slightly reformatted from Table IV in original publication III (Pihlajamäki, et al., 2010).

9.3 Diagnostic Validity of MRI (I–III)

9.3.1 Fresh Chondral Lesions (I)

Routine clinical practice MRI detected fresh traumatic chondral lesions with an overall sensitivity of 36% (95% CI, 23% to 50%), a specificity of 91% (95% CI, 86% to 95%), and a diagnostic accuracy of 78% (95% CI, 72% to 83%) when arthroscopy was used as the gold standard. Of the articular surfaces, 143 were identically graded on arthroscopy and MRI. When MRI results were compared with arthroscopy results, 24 surfaces differed by 1 grade, 17 surfaces differed by 2 grades, and 8 surfaces differed by 3 grades (Table 9). Grade I lesions (Figure 2) were detected by MRI with a sensitivity of only 17% (95% CI, 5% to 45%). Deeper (grade II) lesions were detected with a sensitivity of 32% (95% CI, 15% to 54%), and the deepest (grade III) lesions (Figure 3) were detected with a sensitivity of 57% (95% CI, 33% to 79%).

Of 45 cases with damaged articular surfaces, MRI revealed only a bone bruise in 7 (16%), and of the 147 healthy articular surfaces, MRI showed bone bruises in 20 cases (14%). When a bone bruise was interpreted as a positive result (i.e., among chondral lesions), the MRI findings showed a sensitivity of 51% (95% CI, 37% to 65%), a specificity of 77% (95% CI, 69% to 83%), and a diagnostic accuracy of 71% (95% CI, 64% to 77%). When both a bone bruise and chondral lesion were indicated by MRI, only the chondral lesion was included in the calculations, because it was regarded as a more severe condition. This combination was observed in 3 patients, each with a grade III lesion and a bone bruise in the lateral femoral condyle.

Table 9. MRI and Arthroscopy Results for Fresh Traumatic Chondral Lesions in 32 Knees

MRI	Arthroscopy				
	Grade 0	Grade I	Grade II	Grade III	Grade IV
Grade 0	114	8	11	3	136
Grade I	7	1	2	0	10
Grade II	4	1	2	2	9
Grade III	2	0	2	6	10
Bone bruise	20	2	2	3	27
Total	147	12	19	14	192

Slightly reformatted from Table 2 in original publication I (Kuikka, et al., 2006).
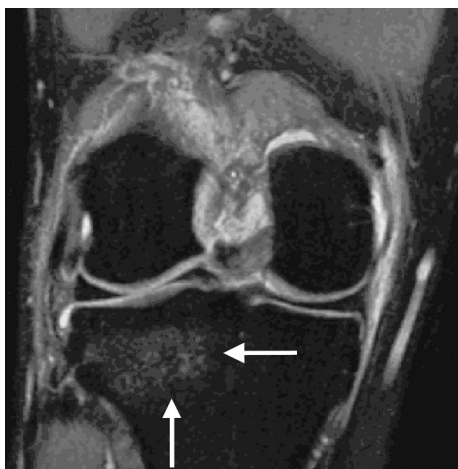
Figure 2A. Coronal T2-weighted MRI scan of a right knee 1 day after injury. A bone bruise is visible in the lateral condyle of the tibia (arrows). The articular cartilage seems normal and intact.

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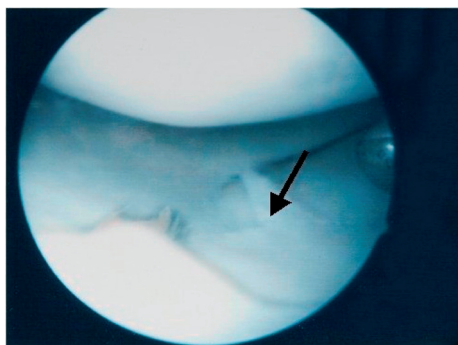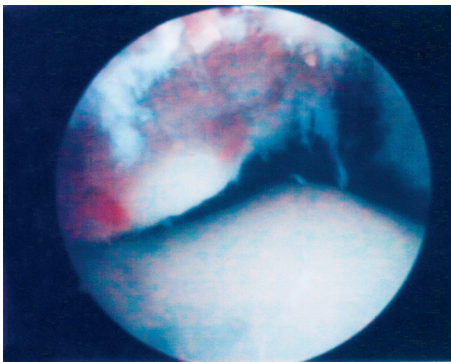

Figure 2B. The same knee 6 days after injury. Moderate irregularity (grade I) of the articular cartilage is visible in the lateral tibial condyle (arrow). Rupture of a lateral meniscus can also be seen.

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Figure 3A. T2-weighted axial MRI scan of a right knee 4 days after injury. A chondral lesion extends down to the subchondral bone in the medial facet of the patella (arrows), interpreted to be grade III.

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Figure 3B. The same knee 12 days after injury. Subchondral bone is exposed in the medial facet of the patella, and the lesion is also interpreted to be grade III on arthroscopy.

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9.3.2 Fresh and Old Meniscal Tears (II)

MRI detected fresh meniscal tears related to acute knee trauma (figure 4) with an overall sensitivity of 67% (95% CI, 48%–81%), a specificity of 93% (95% CI, 87%–96%), and a diagnostic accuracy of 88% (95% CI, 83%–93%). For fresh medial meniscal tears, the sensitivity was 92% (95% CI, 65%–99% and the specificity 87% (95% CI, 77%–93%). Sensitivity for fresh lateral meniscal tears was lower, 47% (95% CI, 25%–70%), and specificity was higher, 99% (95% CI, 92%–100%).

For old meniscal tears related to chronic knee symptoms (figure 5), the overall sensitivity was 64% (95% CI, 39%–84%), the specificity 91% (95% CI, 82%–96%), and the diagnostic accuracy 86% (95% CI, 77%–92%). Old medial meniscal tears were detected with a sensitivity of 89% (95% CI, 57%–98%) and a specificity of 87% (95% CI, 71%–95%).

For old lateral meniscal tears, the sensitivity and specificity were 20% (95% CI, 4%–63%) and 94% (95% CI, 81%–98%), respectively. Detailed results for the diagnostic validity of 1.0T MRI in detecting meniscal tears of the knee are presented in Tables 10 to 12, in which group A refers to fresh meniscal tears related to acute knee trauma and group B refers to old meniscal tears related to chronic knee symptoms.

Overall (both menisci) sensitivities and specificities did not significantly differ between the two groups (difference for sensitivities, P = .94; for specificities, P = .93). Further, statistical analysis performed independently for the lateral (difference for sensitivities, P = .47; for specificities, P = .88) and medial menisci (difference for sensitivities. P = .96; for specificities, P = .999) also revealed no significant difference between groups. The kappa-values for interobserver agreement between readers show moderate agreement (0.56 and 0.58; Table 13), and the results for intraobserver agreement showed substantial or almost perfect agreement (0.70 and 0.85; Table 14).

Table 10. Single Table Analysis for Both Menisci in Group A

MRI	Arthroscopy		
	Positive	Negative	Total
Positive	18	10	28
Negative	9	127	136
Total	27	137	164

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Table 11. Single Table Analysis for Both Menisci in Group B

MRI	Arthroscopy		
	Positive	Negative	Total
Positive	9	6	15
Negative	5	60	65
Total	14	66	80

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Table 12. Diagnostic Validity of 1.0 Tesla MRI for Meniscal Ruptures

| Location | Parameter | Values (With 95% CI) Expressed as Percentages | |
		Group A	Group B
Medial Meniscus	Sensitivity	92 (65–99)	89 (57–98)
	Specificity	87 (77–93)	87 (71–95)
	Diagnostic accuracy	88 (79–93)	88(74–95)
Lateral Meniscus	Sensitivity	47 (25–70)	20 (4–63)
	Specificity	99 (92–100)	94 (81–98)
	Diagnostic accuracy	89 (80–94)	85 (71–93)
Both Menisci	Sensitivity	67 (48–81)	64 (39–84)
	Specificity	93 (87–96)	91 (82–96)
	Diagnostic accuracy	88 (83–93)	86 (77–92)

Slightly reformatted from Table 3 in original publication II (Kuikka, et al., 2009).

Table 13. κ Values for Interobserver Agreement Between Readers

	κ Index	Interpretation
Group A, both menisci	0.58	Moderate agreement
Group B, both menisci	0.56	Moderate agreement
All patients, both menisci	0.57	Moderate agreement

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Table 14. κ Values for Intraobserver Agreement Between Readers

	κ Index	Interpretation
Group A, both menisci	0.70	Substantial agreement
Group B, both menisci	0.85	Almost perfect agreement
All patients, both menisci	0.76	Substantial agreement

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Figure 4A. A 19-year-old conscript sustained a trauma to the left knee in a football game. Sagittal T2-weighted MRI scan of the left knee 6 days after injury showing a displaced tear of the lateral meniscus accompanied with empty anterior meniscal recess (arrow) and posteriorly displaced torn meniscus (arrowhead).

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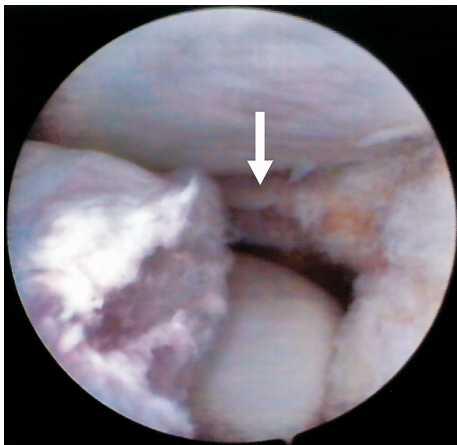
Figure 4B. Arthroscopy 9 days after injury reveals a large bucket-handle–type tear in the discoid lateral meniscus.

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Figure 5. An 18-year-old conscript sustained a bending injury to the left knee in a soccer game. Magnetic resonance imaging 9 months after injury demonstrated a large tear of the medial meniscus. A sagittal T2-weighted magnetic resonance image demonstrated high signal lines extending to the inferior meniscal surfaces (arrows). Arthroscopy 5 weeks after MRI revealed a bucket–handle type tear of the medial meniscus.

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9.3.3 Patellar Chondral Lesions Associated with Anterior Knee Pain (III)

Magnetic resonance imaging detected patellar chondral lesions in 15 of the 25 affected knees. The positive predictive value of MRI was 75% (95% CI, 53% to 89%), the negative predictive value was 72% (95% CI, 56% to 84%), the sensitivity was 60% (95% CI, 41% to 77%), the specificity was 84% (95% CI, 67% to 93%), and the diagnostic accuracy was 73% (95% CI, 60% to 83%). Magnetic resonance imaging detected one of eight grade-I lesions (Figure 6), resulting in a sensitivity of only 13% (95% CI, 2% to 49%) for this grade. For more severe grade II to III lesions combined, the sensitivity was 83% (95% CI, 59% to 94%). All eight of the grade III lesions were detected (Figure 7), resulting in sensitivity of 100% (95% CI, 68% to 100%). Magnetic resonance imaging and arthroscopy findings for the different grades of patellar chondral lesions are presented in Table 15. The kappa value for the overall measure of agreement across the five levels was 0.368 ($p < 0.001$).

**Table 15. Magnetic Resonance Imaging and Arthroscopic Findings in 56 knees**

MRI	Arthroscopy					
	Grade 0	**Grade I**	**Grade II**	**Grade III**	**Grade IV**	**Total**
Grade 0	26	7	3	0	0	36
Grade I	1	0	0	1	0	2
Grade II	2	1	5	3	0	11
Grade III	2	0	1	4	0	7
Grade IV	0	0	0	0	0	0
Total	31	8	9	8	0	56

Slightly reformatted from Table II in original publication III (Pihlajamäki, et al., 2010).


Figure 6A. A nineteen-year-old man reported chronic activity-related anterior knee pain in the left knee. Physical examination revealed patellofemoral crepitus. An axial, fat-suppressed T1-weighted 3D SPGR MRI of the knee showed intact cartilage surfaces (arrows).

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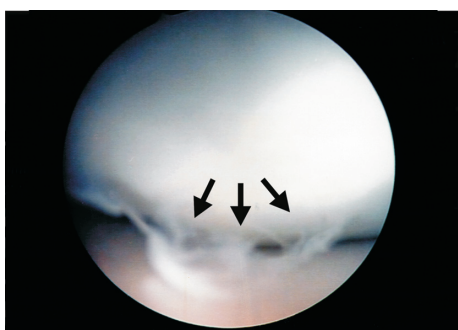
Figure 6B. Subsequent arthroscopy showed changes suggestive of grade-I patellar chondral lesions on both facets of the patella (arrows). Probing revealed softening of the cartilage. On the femoral side, the cartilage surfaces were normal, and gliding of the patella in the sulcus was unobstructed.

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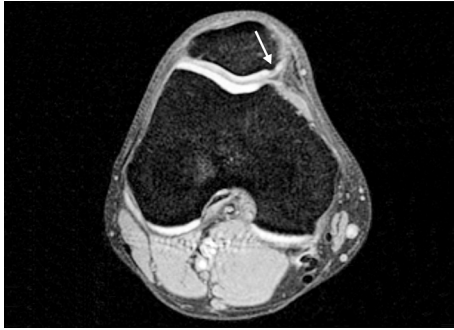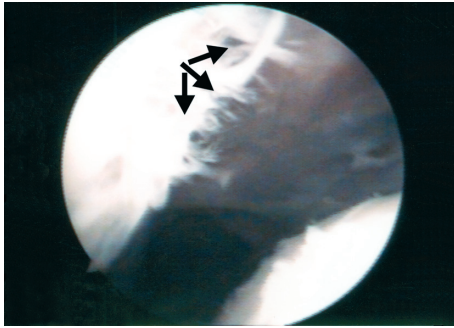
Figure 7A. A twenty-one-year-old man with chronic, activity-related anterior knee pain in both knees. Pain was also worsened while sitting sitting with the knees flexed. An axial, fat-suppressed T1-weighted 3D FSPGR MRI of the right knee shows mediocentral, grade II cartilage lesion of the patella. Subchondral bone is intact.

Figure 7B. Arthroscopy one day after the MRI showed mediocentral, grade III patellar chondral lesions (fragmentation and fissuring). The diameter of the lesion is only 0.5 cm. Lesion does not reach the subchondral bone. The fragmented areas of cartilage were trimmed by shaving. Also small medial synovial plica was detected and resected.

9.4   Incidence of Knee Injuries Needing Inpatient Care (IV)

The total number of subjects with a knee injury leading to at least one inpatient care admission was 1073 (1% of all conscripts), and the person-based incidence rate was 11 cases per 1000 person-years (95% CI:10.4–11.7). There were 298 subjects (28% of the primary admissions) admitted to inpatient care for old meniscal tear, 236 cases (22%) for acute patellar dislocation, 214 (20%) for fresh meniscal tear, 208 (19%) for ACL/PCL tear, 99 cases (9%) for MCL/LCL tear, and 18 (2%) for fresh chondral lesion. The detailed person-time incidence rates of inpatient care admissions are presented in Table 16.

Table 16. Incidence (per 1000 person-years) of inpatient care admissions due to knee injuries among 128,584 conscripts in 1998–2002 in Finland.

	Cases	Incidence*	95% CIs**
Men			
Old meniscal tear	298	3.1	2.7 to 3.4
Patellar dislocation	236	2.4	2.1 to 2.7
Fresh meniscal tear	214	2.2	1.9 to 2.5
ACL/PCL tear	208	2.1	1.9 to 2.4
MCL/LCL tear	99	1.0	0.8 to 1.2
Fresh chondral lesion	18	0.2	0.1 to 0.3
Total	1073	11.0	10.4 to 11.7

* Cases per 1000 person-years
**Confidence Intervals

Slightly reformatted from Table 1 in original publication IV (Kuikka, et al., 2011)

Mean time from the beginning of military service to the first inpatient care admission was 126 days. Twenty-five percent of the injuries occurred during the basic training period (first 8 weeks, days 1–56), 49% during the special and team training period (days 57 to 180), and 26% during the leadership period (days 180 to 365). The corresponding numbers were 13%, 57%, and 31% for old meniscal tears, 43%, 34%, and 23% for patellar dislocations, 22%, 54%, and 24% for fresh meniscal tears, 18%, 51%, and 31% for cruciate ligament tears, 32%, 53%, and 15% for collateral ligament tears, and 10%, 60%, and 30% for fresh chondral lesions. The three most common injuries during the first 8 weeks were patellar dislocation (47% of the cases), fresh meniscal tear (16%), and old meniscal tear (14%). The corresponding numbers for days 57–180 were 32% for old meniscal tears, 21% for fresh meniscal tears, and 20% for patellar dislocations. During days 180–365, 33% of the injuries were old meniscal tears, 24% were patellar dislocations, and 19% were cruciate ligament tears.

9.5 Readmissions, Disability, and Need for Surgery (IV)

The readmission status and number of surgical operations of any kind for each subject admitted to inpatient care are presented in Table 17. Consecutive admissions were required in approximately 30% of all cases after the first admission. Surgery was required in 59% of the cases, and knee injuries led to a longer-term notable disability requiring a service class change in 32% of the cases. Readmission was required in 45% of subjects admitted to inpatient care for ACL/PCL tears, with more than half of the primary cases resulting in a service class change. There were also many inpatient care admissions and further readmissions for patellar dislocation, but only 23% of the cases necessitated a

service class change. A service class change resulted in approximately one-third of the cases with meniscal tears and fresh chondral lesions, but in only 11% of cases of MCL/LCL tears. Surgery was required for 83% of subjects hospitalised for old meniscal tears, 62% for fresh meniscal tears, 67% for ACL/PCL tears, 44% for fresh chondral lesions, 31% for patellar dislocations, and 28% for MCL/LCL tears.

Table 17. Readmission status, service class changes and need for surgical operations among Finnish conscripts with knee injury in 1998–2002.

	Primary admission (N of subjects)	Cases requiring readmission	Service class change	Cases requiring surgery
Old meniscal tear	298	70 (23%)	91 (31%)	248 (83%)
Patellar dislocation	236	84 (36%)	55 (23%)	73 (31%)
Fresh meniscal tear	214	60 (28%)	66 (31%)	133 (62%)
ACL/PCL tear	208	94 (45%)	110 (53%	140 (67%)
MCL/LCL tear	99	10 (10%)	11 (11%)	28 (28%)
Fresh chondral lesion	18	3 (17%)	6 (33%)	8 (44%)
Total	1073	321 (30%)	339 (32%)	630 (59%)

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9.6 Risk Factors for Knee Injuries Needing Inpatient Care (IV)

Risk factor analyses were performed with logistic regression. Older age was a significant risk factor for inpatient care admission due to knee injury (OR 1.7; 95% CI: 1.3–2.2; Table 18). Obesity was also significantly associated with inpatient care for knee injuries, and subjects with BMI ≥ 30 had an OR of 1.6 (95% CI: 1.03–2.5 compared with subjects with BMI < 25. Subjects with the highest level of muscular strength had 1.6 (95% CI: 1.2–2.4) times the risk of inpatient care for knee injury compared with those in the lowest quartile. There was no association between the results of the 12-min running test, underweight, height and inpatient care admission for knee injury.

Final logistic regression models (Table 19) were used to determine the risk factors for inpatient care admissions for specific ICD-10 knee diagnoses. Obesity was found to be a statistically significant risk factor for inpatient care admission due to patellar dislocation and MCL/LCL tears, with an OR of 2.0 (95% CI: 1.1–3.5) for admission due to patellar dislocation, and an OR of 3.1 (95% CI: 1.4–7.0) for admission due to MCL/LCL tear. Higher weight was an independent risk factor for meniscal tears. For inpatient care admission due to a fresh meniscal tear, the heaviest weight quartile had an OR of

2.6 (95% CI: 1.4–5.0) and for admission due to an old meniscal tear the heaviest weight quartile had an OR of 1.8 (95% CI: 1.1–2.8). The risk for old meniscal tears in the oldest age group was 2.4 times (95% CI: 1.7–4.5) greater than that of the youngest age group. The highest muscle strength quartile showed an increased risk for both fresh meniscal tears and ACL/PCL tears.

Table 18. Logistic regression predicting inpatient care admissions due to knee injuries among 128,584 Finnish conscripts in 1998–2002.

Predictor	Odds Ratio	95% CI for Odds Ratio	
		Lower	Upper
Age			
18 to 19	1		
20	1.0	0.9	1.3
21–30	1.7	1.3	2.2
Length of military service			
180 days	1		
270 days	1.5	0.9	2.4
360 days	1.3	1.03	1.5
Underweight			
No	1		
Yes	0.7	0.4	1.1
Overweight and obesity			
No	1		
Overweight	1.0	0.8	1.3
Obesity	1.6	1.03	2.5
Muscle strength			
lowest quartile	1		
second quartile	1.0	0.7	1.3
third quartile	1.1	0.8	1.5
highest quartile	1.6	1.2	2.4

Slightly reformatted from Table 3 in original publication IV (Kuikka, et al., 2011)

Table 19. Multivariate logistic regression model of specific knee diagnoses among 128,584 Finnish conscripts in 1998–2002. Only significant variables are shown.

Predictor	Odds Ratio	95% CI for Odds Ratio	
		Lower	Upper
Patellar Dislocation			
Overweight and obesity			
No	1		
Overweight	1.1	0.8	1.7
Obesity	2.0	1.1	3.5
Age			
18 to 19	1		
20	1.4	1.01	2.0
21-30	1.1	0.6	1.9
MCL/LCL tear			
Overweight and obesity			
No	1		
Overweight	0.9	0.4	2.0
Obesity	3.1	1.4	7.0
Fresh Meniscal Tear			
Weight			
lightest quartile	1		
second quartile	1.8	0.97	3.4
third quartile	1.9	0.99	3.5
heaviest quartile	2.6	1.4	5.0
Muscle strength			
lowest quartile	1		
second quartile	1.0	0.4	2.5
third quartile	2.2	0.8	6.0
highest quartile	3.5	1.04	12.2
Old Meniscal Tear			
Age			
18 to 19	1		
20	1.2	0.8	1.7
21-30	2.4	1.5	3.6
Weight			
lightest quartile	1		
second quartile	1.2	0.8	1.9
third quartile	1.9	1.2	2.9
heaviest quartile	1.8	1.1	2.8
ACL/PCL tear			
Muscle strength			
lowest quartile	1		
second quartile	1.2	0.5	2.9
third quartile	1.7	0.7	3.8
highest quartile	2.6	1.04	6.5

Slightly reformatted from Table 4 in original publication IV (Kuikka, et al., 2011)

10   Discussion

10.1   Diagnostics (I–III)

10.1.1   Fresh Chondral Lesions (I)

In the sample of fresh traumatic chondral lesions, the sensitivity of 1.0T MRI used in routine clinical practice was only 36% whereas the specificity was 91%. Sensitivity was associated with the lesion grade and was only 17% for superficial lesions and moderately better, 57%, for full-thickness lesions.

A limitation of our study was the relatively small number of patients examined. Another limitation was that data covering several years were collected retrospectively in connection with normal clinical practice. Arthroscopy was used as gold standard when the diagnostic validity of MRI was analysed. As described in the literature review above, however, there are some concerns regarding its accuracy in the evaluation of chondral lesions. The field of view may be limited and possible hidden injuries within the articular cartilage can only be evaluated by probing (Hodler & Resnick, 1992; Van Breuseghem, 2004).

In the present study sprains were the most common cause of chondral lesions of the knee, and the patellar surface and the lateral femoral condyle were the most common lesion locations. It is noteworthy that one-third of the patients had acute traumatic patellar dislocations, which may increase the amount of chondral lesions in these surfaces (Sallay, et al., 1996).

Our study included only fresh traumatic chondral lesions of young adult patients with no osteoarthritic changes in the knee joint. This distinguishes our study from the previous literature. Most of the previous studies investigating the diagnostic validity of MRI for articular cartilage defects have focused on older patients with more osteoarthritic changes (Bredella, et al., 1999; Disler, et al., 1996; Felson, 1988; Handelberg, et al., 1990; Hodler, et al., 1992; Potter, et al., 1998; Recht, et al., 1993; Riel, et al., 1999). Magnetic resonance imaging of chronic osteoarthritis is somewhat different from that of fresh chondral lesions. For traumatic chondral lesions, it is clinically important to detect cartilage shear or a displaced flap that may clinically mimic the symptoms of meniscal tears. Even more

crucial is the detection of full-thickness lesions or osteochondral injuries as they may be amenable to repair (Potter & Foo, 2006). Chronic severe osteoarthritis frequently generates bone marrow oedema visible in MRI. As compared to bone bruises associated with traumatic chondral lesions, bone bruises in osteoarthritis are more often observed on both sides of the weight-bearing joint (Potter & Foo, 2006). Whether this leads to the radiologist paying more attention to the articular cartilage surfaces of the area and further increases the sensitivity of MRI for osteoarthritis, however, is not known.

In knee injuries, MRI planes and sequences are generally selected for overall knee examination and good visualization of possible ligamentous and meniscal tears. Traumatic chondral lesions often receive less attention in the selection of MRI protocol. This can explain why the overall sensitivity of MRI for fresh traumatic chondral lesions in this study was poor, only 36%. The interpretation of bone bruises detected by MRI in our study as a positive finding improved the sensitivity of MRI, but led to a deterioration of the specificity and diagnostic accuracy. Bone bruises on MRI may indicate damage to the articular cartilage (Johnson, et al., 1998).

As expected, superficial grade I lesions were detected with a very poor sensitivity (17%), whereas sensitivity improved modestly to 57% for full-thickness lesions. Even if routine 1.0T MRI was more sensitive for deeper lesions, its diagnostic validity can be considered insufficient even for the full-thickness lesions. A valid diagnosis is especially important for deep lesions as they may become symptomatic and require treatment (Curl, et al., 1997; Kettunen, et al., 2005) In young adults, surgical repair of full-thickness traumatic chondral lesions may be indicated if nonsurgical treatment fails to provide adequate pain relief (Gomoll, et al., 2010).

The results of many other studies using routine MRI protocols allowing for overall knee injury evaluation were similar to our findings. Friemert and coworkers used 1.5T MRI and reported a sensitivity of only 33% and specificity of 99% for chondral lesions in patients with knee pain of variable origin (Friemert, et al., 2004). In the study by Disler et al. (n=47, mean age, 36 years), standard 1.5T MRI sequences provided a sensitivity of only 29% to 38%, whereas the specificity was 97% (Disler, et al., 1996). These results are further supported by recent results of the conventional use of 1.5T and 3.0T MRI in clinical practice. Figueroa and Calvo reported a sensitivity of 13% for superficial chondral lesions and of 73% for full thickness lesions with the 1.5T MRI (Figueroa, et al., 2007). The corresponding sensitivities of 3.0T MRI were 29% and 74%, with a specificity of 95% (von Engelhardt, et al., 2007). Also, 3.0T MRI and low-field 0.2T MRI with sequences allowing for comprehensive knee evaluation achieved similar results in deep lesions. The sensitivity of low-field 0.2T MRI for non-fresh, full thickness articular cartilage lesions is reported to be 72%, with a specificity of 100% and accuracy of 92% (Riel, et al., 1999).

These routine protocols may also show very good diagnostic validities for chondral lesions. Bredella et al. included 130 patients (age range 23-72, mean 41 years) who had undergone both 1.5T MRI and arthroscopy for suspected internal knee derangement.

The sensitivity of axial and coronal fat-suppressed T2-weighted fast spin-echo combined with sagittal T2 spin-echo was 94%, with a specificity 99% and accuracy of 98% (Bredella, et al., 1999). The sensitivity of fat suppressed fast spin echo sequences in osteoarthritis may be as high as 100%. In this study, however, the specificity was substantially lower, 68% (Yoshioka, et al., 2004). Kijowski and coworkers reported no differences between sensitivities of 1.5T MRI and 3.0T MRI using fast spin echo sequences (71% for 3.0T and 69% for 1.5T MRI (Kijowski, et al., 2009). The specificity was slightly higher for the 3.0T system (85.9% versus 78%). Sensitivities were similar for different grades of chondral lesions. The sensitivity of 1.5T MRI was 41% for cartilage softening, 50% to 82% for partial thickness lesions, and 95% for full thickness lesions. Corresponding sensitivities of the 3.0T MRI were 42, 49% to 85%, and 98%.

It is not clear why the sensitivity of MRI in some of these studies was markedly higher than that in the present study. Increasing MRI field strength makes fat suppression more homogeneous and improves visualization of the articular cartilage (Schoth, et al., 2008; Stoller, 2007). As described in detail in the literature review above, increasing the field strength may not improve the diagnostic validity of MRI for chondral lesions (Kijowski, et al., 2009; Krampla, et al., 2009). There are other potentially more remarkable differences than MRI field strength, however, between the studies comparing the diagnostic validity of MRI. Differences between subjects, methodology, MRI sequences, gold standards, as well as grading of the chondral lesions, and especially the proportion of deep and superficial chondral lesions in the study material may significantly affect the results, making comparison of the results very challenging. A comparison of the diagnostic validity of MRI in the present study to that the previous literature indicates that sensitivity was higher in many of the previous studies. Rather similar results (i.e., insufficient sensitivity for valid diagnosis) with the MRI sequences used in routine clinical practice have likewise been reported, some of them only after the original publication of our article and even with the new 3.0T MRI systems (Figueroa, et al., 2007; von Engelhardt, et al., 2007). Biases, such as a selection or publication bias must also be taken into account, especially in cases when the diagnostic validity or other outcome of the study is poorer than that achieved in experimental or in state-of-the-art studies authors may be disinclined to submit their manuscript for publication or publication may be more easily rejected. The best results achieved, however, may significantly differ from those in real-world clinical practice (Lubowitz & Poehling, 2006).

The present study showed that routine clinical use of 1.0T MRI is not sensitive but is specific for the diagnosis of fresh traumatic chondral lesions. Sensitivity improved only modestly for deeper lesions. We hypothesized that 1.0T MRI could be used to replace diagnostic arthroscopy for the diagnosis of fresh traumatic chondral lesions. Our results failed to support this hypothesis due to the low sensitivity obtained with MRI. Almost half of the full-thickness cartilage lesions remained undiagnosed following preoperative MRI. Despite negative MRI findings, arthroscopy may reveal lesions amenable to

cartilage repair procedures. Maintaining the readiness and instrumentation available for at least for basic cartilage repair procedures at the time of arthroscopy is therefore advisable.

10.1.2 Fresh and Old Meniscal Tears (II)

The purpose of the present study was to investigate whether there is difference in diagnostic validity of MRI between meniscal tears related to acute knee trauma and meniscal tears related to chronic knee symptoms. No statistically significant difference was detected. Sensitivity was clearly lower, however, for lateral meniscal tears.

The patient material in the present study was very homogenous with regard to age, race, nationality, general health, and sex. MRI examinations were performed at a single facility with a standardized protocol. A reliable comparison of the diagnostic validity of MRI between acute and chronic meniscal tears can be performed only if the patients and methods are similar within the groups. No comparative studies of this type are found in the previous literature. Degeneration occurs with aging and weakens the meniscal structures, making them susceptible to injuries (Negendank, et al., 1990; Noble & Hamblen, 1975). As the median age of the patients in the present study was 20 years with a maximum age of 25 years, we expected no degenerative changes to be present, which distinguishes our study from many others.

The study is limited, however, by the retrospective data collection. Another limitation is that it is possible that patients with chronic symptoms and false-negative MRI results were treated nonsurgically at a higher rate than the acute group, thereby skewing the statistics. Still, it is unlikely that patients with long-lasting symptoms and false-negative MRI results would become asymptomatic during the physically demanding military service. As the availability of arthroscopy was good, it was performed despite negative MRI findings if the knee pain was prolonged and resulted in difficulties in performing duties required for military training. MRI field strength in the present study was 1.0T. As described in detail in the review of the literature section, recent clinical studies demonstrated that the diagnostic validity of 1.0T, 1.5T, and 3.0T MRI for meniscal tears is similar (Grossman, et al., 2009; Krampla, et al., 2009; Oei, et al., 2003).

Multicentre studies and meta-analyses revealed that, in general, the diagnostic validity of MRI for meniscal tears is good. The pooled sensitivity of MRI varies from 91% to 93% for medial meniscal tears and 69% to 79% for lateral meniscal tears. The pooled specificity varies from 81% to 88% for medial meniscal tears and from 93% to 96% for lateral meniscal tears (Crawford, et al., 2007; Fischer, et al., 1991; Mackenzie, et al., 1996; Oei, et al., 2003). These meta-analyses comprised a large number of studies and a variety of methods and samples were used. In general, there was no special attention paid to the freshness of the lesions. As a result, the intervals between the onset of the symptoms and MRI varied widely and tended to be rather long.

There are few published studies investigating acute meniscal tears using MRI. In acutely injured knees, sensitivity as low as 25% is reported for the lateral meniscal tears (Kinnunen, et al., 1994). Kinnunen and coworkers, however, reported 88% sensitivity for medial meniscal tears. A small study by Munshi et al. (Munshi, et al., 2000) reported an MRI sensitivity of 50% for medial meniscal tears and 88% for lateral meniscal tears in acute knee haemarthrosis patients. The specificities in these two studies ranged from 80% to 86% for medial meniscal tears and from 73% to 97% for lateral meniscal tears. Higher MRI sensitivity in traumatic knee haemarthrosis has also been reported, 94% for lateral and 83% for medial meniscal tears (Adalberth, et al., 1997) In that study, however, specificities were very poor – only 27% and 29%, respectively.

Lundberg et al (Lundberg, et al., 1996) studied 69 patients with acute traumatic knee haemarthrosis who were evaluated by 1.5T MRI a mean of 3 days after traumatic onset with arthroscopy being performed shortly thereafter. The authors reported a sensitivity of 74% and a specificity of 66% for medial meniscal tears, and a sensitivity of 50% and a specificity of 84% for lateral meniscal tears. The diagnostic validity of MRI for meniscal tears was lower than the mean results documented in the literature (Crawford, et al., 2007; Fischer, et al., 1991; Mackenzie, et al., 1996; Oei, et al., 2003).

Lundberg and coworkers suggested that this is due to properties associated with acutely injured knees, such as haemarthrosis or catabolic processes of the meniscal tissue. Our results suggest that effusion or haemarthrosis do not weaken the diagnostic validity of MRI. Effusion or haemarthrosis was present in most (80%) of the knees with acute injury, but in only a very small number (5%) of knees with chronic symptoms.

Although the freshness of the meniscal tears in the aforementioned studies (Adalberth, et al., 1997; Kinnunen, et al., 1994; Lundberg, et al., 1996; Munshi, et al., 2000) was equal to that of the sample including acute meniscal tears in our data, the previous authors did not investigate chronic tears. Whether there is real association between the freshness of the injury and decreased diagnostic validity of MRI, however, is not clear. In the present study, using comparable materials and methods, we found no statistically significant difference in the MRI results between meniscal tears related to acute knee trauma and meniscal tears related to chronic knee symptoms. The intraobserver agreement reported in this study was substantial to almost perfect, indicating that the same observer interpreted the images similarly over time. Interobserver agreement was slightly lower, showing moderate agreement.

Previous results suggesting that a lower diagnostic validity of MRI in acute traumas may be explained by factors other than the properties associated with acutely injured knees, such as interobserver variability, sequence or sample selections, or other variability between the studies. The diagnostic validity of MRI in acutely injured knees varied between studies, and in relation to menisci examined (medial or lateral), and acute setting did not necessarily lead to a lower diagnostic validity of MRI (Adalberth, et al., 1997; Kinnunen, et al., 1994; Munshi, et al., 2000). Even if many of the MRI studies

of acutely injured knees have reported poorer than average diagnostic validities, poor results were also reported in studies not limited to acute knee injuries and performed with commonly used field strengths (1.0T to 3.0T) (Krampla, et al., 2009).

Magnetic resonance imaging can be as accurate as clinical examination for meniscal tears (Rose & Gold, 1996). Although our study did not deal with clinical examination, the relatively poor overall MRI sensitivity for meniscal tears indirectly emphasizes its value. MRI sensitivity for medial meniscal tears in the present study was good; 92% for acute meniscal tears and 89% for old meniscal tears. For lateral meniscal tears, the corresponding sensitivities were very low, from 47% to 20%, respectively. The poor sensitivity for lateral meniscal tears in the present study also led to a decrease in the overall sensitivity for both groups. There were no statistically significant differences in relation to symptom duration. The decreased MRI sensitivity for tears of the lateral meniscus is well known and demonstrated in the literature (Crawford, et al., 2007; Fischer, et al., 1991; Kinnunen, et al., 1994; Lundberg, et al., 1996; Mackenzie, et al., 1996; Oei, et al., 2003; Rose & Gold, 1996). Very low sensitivities (25%) for lateral meniscal tears are reported both for acute knee injuries (Kinnunen, et al., 1994) and for patients with knee pain lasting 3 months or more (35%) (Rose & Gold, 1996). It is not clear why overall MRI sensitivity for lateral meniscal tears was so low in the present study. De Smet and Mukherjee reported that lateral meniscal tears are more likely missed if the tear involves only one third of the meniscus or is located in the posterior horn (De Smet & Mukherjee, 2008). They also reported that lower sensitivity for the lateral meniscal tears was associated with concomitant ACL tears. This finding was not statistically significant, however, possibly due to the relatively small patient sample. Other hypothesized causes for the lower MRI sensitivity in diagnosing lateral meniscal tears include oblique visualization of the posterior horn of the lateral meniscus due to its anatomy, the magic angle effect, and arterial pulsation artefacts (De Smet & Mukherjee, 2008).

The specificity in the present study was slightly lower for medial meniscal tears than for lateral meniscal tears (87% vs. 94%–99%). Visualization of the posterior horn of the medial meniscus is limited in arthroscopy and the diagnosis of longitudinal tears in the inferior surface of the menisci is based on probing. Some of the "false" positive MRI findings may be attributed to inadequate visualization of this area in arthroscopy. Arthroscopy is considered to be the gold standard, and the specificity of MRI decreases with an increase in the number of "false" positive findings. The precise location of the tears was not registered in the present study, so it is not known whether the results were affected by the location of the lesions or by other factors presented above. The diagnostic validity of MRI is thought to be strongly affected by the menisci involved and independent evaluation of the menisci is far more informative than evaluation of both menisci together.

In conclusion, MRI has similar diagnostic validity for meniscal tears in acute knee trauma and for knee symptoms lasting over 6 months in young adults. This study also

suggests that the diagnostic validity of MRI for meniscal tears is not weakened by effusion or haemarthrosis.

Magnetic resonance imaging showed relatively poor overall sensitivity for meniscal tears in both groups. For clinical practice, this finding reveals that up to one-third of meniscal tears failed to be detected by MRI in young adults, regardless of the age of the tear. The overall specificity was good, indicating a small number of false-positive findings. However, there was a substantial difference in the diagnostic validity of MRI between lateral and medial meniscal tears. As many as 9 of 10 of the medial meniscal tears were detected by MRI, whereas lateral meniscal tears were missed in more than half of the cases, regardless of the duration of the symptoms. In clinical practice, arthroscopy should be considered if justified by the patient's symptoms despite negative MRI findings, especially in cases of clinically suspected lateral meniscal tears.

10.1.3 Patellar Chondral Lesions Associated with Anterior Knee Pain (III)

In the 56 knees with AKP, there were patellar chondral lesions in 25 (45%) . Twenty-five patients also had pathological plicae and only 6 knees had normal arthroscopic findings. The presence of retropatellar crepitus or pain on patellar manipulation was not associated with the higher proportion of patellar chondral lesions in patients with typical clinical AKP symptoms. Neither was an association found between the severity of chondral lesions and clinical symptoms and signs of the subjects. The routine MRI protocol used in AKP patients showed a sensitivity of 13% for superficial patellar chondral lesions, which was significantly higher (83%) for more severe lesions.

The present study has several strengths, such as the prospective design and the homogeneity of the study population. In addition, the age group studied here is optimal because individuals in this age group do not normally show degenerative chondral changes such as osteoarthritis (Felson, 1988). Further, this relatively large group of skeletally mature young adults underwent a uniform examination and treatment for AKP according to the policy of one institution. The standard methods and protocols of the institution were used for the evaluation of clinical symptoms, plain radiographs, MRI, and arthroscopic findings. Magnetic resonance imaging was usually performed on the day prior to the arthroscopy to avoid possible bias caused by any delay. As mentioned in the Material and Methods section above, a total of 91 knees were examined but, in cases of bilateral findings, only one knee was randomly selected for the study. This limited the number of the knees in the present study, but, on the on the other hand, ensured the independence of the observations.

According to our results, patients with diffuse AKP as the sole symptom very rarely have patellar chondral lesions. Only one of eight of these patients had patellar chondral lesion in arthroscopy. Half of the patients with AKP combined with other typical clinical symptoms had patellar chondral lesions, regardless of the presence or absence

of patellofemoral crepitus and/or pain on manipulation of the patella. Leslie and Bentley found that 58% of the patients with corresponding symptoms and retropatellar crepitus had patellar chondral lesions (chondromalacia), which is similar to our results (Leslie & Bentley, 1978). Leslie and Bentley suggested that patellofemoral crepitus is one of the signs most indicative of patellar chondral lesions. Niskanen and coworkers studied the validity of clinical tests for detecting patellar chondral lesions in a sample of 100 consecutive patients undergoing arthroscopy for various knee problems (Niskanen, et al., 2001). The best sensitivity was reported for the patellar tracking test in which the patella was moved up and down and compressed against the femoral groove. Pain in this test resulted in a sensitivity of 56% and a specificity of 55%. For patients with patellar pain or otherwise suspected patellar chondral lesions, the sensitivity of this test was slightly higher, 67% (Niskanen, et al., 2001).

Based on both the present data and these previous studies (Leslie & Bentley, 1978; Niskanen, et al., 2001), it is clear that painful patellar compression or retropatellar crepitus are far from pathognomonic tests and have poor diagnostic validity for detecting patellar chondral lesions. In the present study, the presence of pain in patellar compression or retropatellar crepitus was not associated with the higher proportion of patellar chondral lesions if the symptoms were otherwise similar.

An important finding of the present study was the lack of an association between the severity of patellar chondral lesions and the clinical symptoms and signs. These findings are contradictory to the observations of Kettunen et al., who reported that patients with more severe cartilage lesions of the patellofemoral joint had more subjective symptoms and functional limitations than those without lesions or with small cartilage lesions (Kettunen, et al., 2005). On the other hand, our results are supported by the finding that chondral lesions are asymptomatic even with direct probing (Dye, et al., 1998). Several other knee pathologies can cause pain to the anterior aspect of the knee and new theories have challenged the traditional views of the origins of the pain (Dye, 2005; Houghton, 2007; Kodali, et al., 2011; Llopis & Padron, 2007). A medial synovial plica of the knee was as common an arthroscopic finding as patellar chondral lesions in the present study and was detected in nearly half of the knees. Pathologic medial synovial plicae may impinge between the medial femoral condyle and patella, eventually leading to cartilage damage or synovitis due to repetitive contact forces (Christoforakis, et al., 2006; Llopis & Padron, 2007; Lyu & Hsu, 2006; Munzinger, et al., 1981). The severity of symptoms, however, is not proportional to the size of the plica and the relationship between the plica and AKP is controversial (Jee, et al., 1998; Llopis & Padron, 2007). Even if synovial plicae may be a source of AKP, their presence should be cautiously evaluated as the cause of the symptoms (Llopis & Padron, 2007).

Only 6 of the 56 symptomatic knees had normal arthroscopic findings. Pain in these knees might be explained by the tissue homeostasis theory (Dye, 2005). According to Dye, increased loading of the patellofemoral joint leads to a loss of tissue homeostasis

in the surrounding innervated tissues and causes pain in the anterior aspect of the knee. Only in the most severe cases is the loss of tissue homeostasis characterized by arthroscopically visible damage such as chondral lesions (Dye, 2005).

T2-weighted or other sequences that allow for the evaluation of meniscal and ligament tears exhibit variable sensitivities for patellar chondral lesions. In the study by McCauley and coworkers, the diagnostic validity of MRI with T2-weighted axial plane images showed a sensitivity of 72% and a specificity of 87% for patellar chondral lesions. For axial proton density images, the corresponding figures were 62% and 78%. The combination of these sequences resulted in 86% sensitivity and 74% specificity (McCauley, et al., 1992). Murphy evaluated only severe grade III and IV patellar chondral lesions using T2*-weighted 3D gradient-echo MRI and reported good sensitivity (83%), similar to our results (Murphy, 2001). It must be noted, that even 100% sensitivity is sometimes achieved with T2-weighted spin-echo pulse sequences in the sagittal and axial planes and a 3D fast sequence in the sagittal plane. This combination can lead to a number of false negative findings, however, and the specificity is only 50% (Handelberg, et al., 1990).

Better diagnostic validity of MRI for chondral lesions may be achieved with the use of sequences specifically designed for cartilage imaging. Fat-suppressed 3D SPGR sequences are now routinely used in MRI examination when chondral lesions are considered a possibility. In routine evaluation of AKP patients, these sequences should be obtained in the axial plane. This allows for good visualization of the articular cartilage surfaces of the patellofemoral joint and especially the patellar facets. The 3D SPGR technique requires a long acquisition time and is not optimal for the visualization of menisci, ligaments, and subchondral bone (Potter, et al., 1998). As symptoms of AKP may be confused with those of meniscal tears, it is important that routine knee MRI also includes some meniscal-sensitive sequence in the sagittal plane, such as T2* GRE or proton density spin-echo with fat suppression. For these reasons, the routine knee imaging protocol for AKP patients in this study included an axial fat suppressed 3D SPGR sequence and a sagittal T2* GRE sequence. With this protocol, the overall MRI sensitivity for chondral lesions of all grades in the present study was 60% and the specificity was 84%.

Disler et al. used fat suppressed 3D SPGR imaging to evaluate chondral lesions in all articular cartilage surfaces of the knee. Two readers evaluated the images and the sensitivity for chondral lesions in combined surfaces ranged from 75% to 85%. The specificity was 97% regardless of the reader (Disler, et al., 1996). For patellar chondral lesions, the sensitivity varied from 87% to 100% and the specificity ranged from 92% and 100%. In detecting osteoarthrotic chondral lesions, sensitivities for this sequence ranged from 96% to 97% (Recht, et al., 1993; Yoshioka, et al., 2004). The reference standard for MRI results were anatomic sections of cadaveric knees in Recht's study and arthroscopy findings in Yoshioka's study.

The results of the present study demonstrate that the evaluation and comparison of the diagnostic validity of MRI is far more informative when the results are analysed

independently for the different grades. The relatively low sensitivity of 60% in this study is partly explained by the fact that sensitivity was only 13% for grade I chondral lesions. This finding indicates that superficial patellar chondral defects cannot be validly detected by MRI even when an SPGR sequence allowing for visualization of the cartilage is included in the routine protocol. For grade II and III lesions, the sensitivity was considerably higher (83%). For grade III lesions including fragmentation of the cartilage, MRI detected all of the lesions and sensitivity was 100%. Our results clearly indicated that the highest sensitivity occurred for the deepest lesions. This finding is consistent with previous findings (Figueroa, et al., 2007; Gagliardi, et al., 1994; Murphy, 2001; von Engelhardt, et al., 2007).

Gagliardi et al. examined 27 AKP patients with 1.5T MRI obtained in axial plane images with T1-, T2 spin echo, proton-density, and fat suppressed 2D SPGR sequences (Gagliardi, et al., 1994). They graded the patellar chondral lesions using the same system that we used (Shahriaree, 1985). The sensitivity of MRI for grade-I patellar chondral lesions was 0%. For grade-II and III lesions, the sensitivity was 13% for proton-density sequences, 20% for SPGR and T1 sequences, and 47% for T2-weighted imaging. For grade-IV lesions, the sensitivity ranged from 50% (SPGR imaging) to 75% (T1-weighted, T2-weighted, and proton-density-weighted imaging. Specificities for all grades and sequences were high, between 91% and 100% (Gagliardi, et al., 1994). The sensitivities reported by Gagliardi et al. (1994) for all of the sequences that they used were lower than the sensitivities found in the present study.

A recent study of conventional clinical practice use of 3.0T MRI including 3D T1-weighted gradient echo sequence in axial plane showed an overall sensitivity for patellar chondral lesions of 87% and a specificity of 89%. A high proportion of the lesions in this location were deep, grade III to IV lesions. In addition, grade I lesions were considered to indicate a disease-negative status. When the sensitivity of knee chondral lesions was presented according to lesion severity, the sensitivity was 29% for grade I lesions, 62% for grade II, 63% for grade III, and 74% for grade IV presenting full-thickness lesions (von Engelhardt, et al., 2007). These results are consistent with our results and demonstrate that increasing the field strength may not be beneficial for the diagnosis of articular cartilage lesions.

Skyline views are a routine method of AKP imaging. The main purpose is to evaluate possible patellar malalignment. Of the various suggested malalignments, only patellar subluxation is increased in patients with AKP as compared to healthy controls (Haim, et al., 2006). Patellar subluxation, however, does not seem to be associated with arthroscopically detected patellar chondral lesions (Leslie & Bentley, 1978). In the present study, only 16% (7 of 43) of the knee radiographs in AKP patients showed some malalignment. No conclusion can be drawn regarding the association between the reported malalignments and patellar chondral lesions due to their small number. In addition, skyline radiographs are a very rough method to evaluate patellar malalignment.

Computed tomography, MRI or kinetic CT allow for the detection of more subtle cases of malalignment (Christian, et al., 2006). Although patellar malalignment may not be associated with AKP or patellar chondral lesions, it may affect the outcome of cartilage repair procedures and even account for premature failure of the repair (Gomoll, et al., 2010; Potter & Foo, 2006). Patellar chondral lesions are an off-label indication for autologous chondrocyte implantation. which has become an option for treatment of all but the smallest chondral lesions in the patellofemoral compartment (Gomoll, et al., 2010).

The association between clinical symptoms and physical signs, and possible patellar chondral lesions was assessed in young adults with AKP syndrome. The findings of the present study support earlier reports that patellar chondral lesions cannot be distinguished from other causes of AKP based only on symptoms and signs on physical examination. Arthroscopic examinations revealed patellar chondral lesions in less than half of all subjects. The presence of retropatellar crepitus or pain on manipulation of the patella was not associated with a higher proportion of patellar chondral lesions in patients with typical clinical AKP symptoms. There was also no association found between the severity of chondral lesions and clinical symptoms and signs among the subjects. Thus, these symptoms and signs are not helpful when considering whether the patient might have deep chondral lesions possibly amenable to surgical repair. Pathological synovial plicae were as common a finding as patellar chondral lesions. Of the 56 six knees, arthroscopy revealed pathology in 50.

Another aim of this study was to investigate the diagnostic validity of MRI for patellar chondral lesions in AKP patients. We used a routine MRI protocol that allows for overall knee examination as well as visualization of the patellar cartilage. Our hypothesis was that MRI could be used to confirm the diagnosis of chondromalacia patellae at least in the case of more severe, deeper chondral lesions. For superficial patellar chondral lesions the sensitivity was insufficient, only 13%. For more severe lesions, 1.0T MRI may be considered a valid diagnostic tool as the sensitivity was substantially higher, 83%.

10.2 Epidemiology of Knee Injuries (IV)

10.2.1 Incidence of Knee Injuries Needing Inpatient Care

The overall person-time incidence rate for knee injuries requiring inpatient care in the present study was 11 per 1000 person-years. The most common injuries were meniscal tears, patellar dislocation, and cruciate ligament tears.

There are several strengths in the present study. It involved a population of 128,584 conscripts with a total exposure time of nearly 100,000 person-years. Due to the compulsory nature of military service, these subjects represent ordinary young adult

males of Finland. All conscripts were required to use only the services of the primary military health-care units and Central Military Hospital for medical treatment. The NHDR database from which the data were obtained is complete and highly accurate (Keskimäki & Aro, 1991; Mattila, et al., 2008; Salmela & Koistinen, 1987). These factors together allowed us to include knee injuries requiring inpatient care during the follow-up time with very high accuracy and coverage. To our knowledge, there are no published studies reporting the accurate incidence rates of hospitalised knee injuries. Among Finnish military conscripts, the overall incidence rate of injury-related inpatient care admissions is 94 per 1000 person-years (Mattila, et al., 2006). The sample population of the previous study and that of the present study are congruent, and suggest that more than one-tenth of all injuries leading to hospitalisation are knee injuries.

There are also weaknesses in the present study. Despite the fact that all hospitalised injuries were taken into account, data on less severe injuries were lacking. In the US Army, it is estimated that only 1 of every 20 military injuries results in hospitalisation (Jones, et al., 2000). As presented earlier in the review of the literature section, re-analysis of previous reports of Finnish conscripts suggests that the patient-based incidence of acute knee injuries treated at the garrison clinics on an outpatient basis is approximately 130 per 1000 person-years (Taanila, et al., 2009, 2010). This is more than 10-fold higher than the incidence of hospitalised knee injuries in the present study.

Kannus and coworkers reported a cumulative incidence rate of 11 knee injury patients per 1000 persons per year in a study of outpatient visits at the primary health care units in the Orivesi region, Finland (Kannus & Järvinen, 1989). The incidence rate reported in their study was substantially lower than the corresponding statistics for conscripts treated as outpatients at the garrison clinics (Taanila, et al., 2010). When taking into account that approximately 1 of 10 knee injuries treated at the primary care units requires surgical consultation, the incidence rate reported by Taanila and coworkers was more consistent with our study than that reported by Kannus and coworkers (Kannus & Järvinen, 1989; Taanila, et al., 2010). The study population of Kannus and coworkers was relatively old, which evidently decreased the incidence rate of knee injuries and may explain the result. The incidence rates reported from special health care units are generally markedly lower than that in our study. For acute traumatic knee haemarthrosis treated in Turku University Hospital, the cumulative incidence is 0.5 per 1000 inhabitants annually (Sarimo, et al., 2002). Traumatic knee haemarthrosis thus represents only a small proportion of all knee injuries requiring inpatient care in Finland. In a UK population, the cumulative person-based incidence rate for knee injuries treated at the orthopaedic trauma unit was as low as 0.4 cases per 1000 persons annually (Clayton & Court-Brown, 2008). Both inpatient and outpatient care were taken into account and the age of the patient ranged from 12 to 89 years. The authors pointed out that the incidence reported is a clear underestimate as knee injuries were frequently referred to knee surgeons instead of the orthopaedic trauma unit. General population-based data from the US show a cumulative incidence rate of

1.2 cases per 1000 persons annually for ligamentous and meniscal injuries of the knee treated at an orthopaedic knee injury clinic (Miyasaka, et al., 1991). The age distribution of the population was not reported but it can be assumed that the average age of the patients was older than in the present study. This is probably the most likely explanation for the low incidence rates reported in the UK and US studies compared with the results of the present study. There may also be other differences between the countries, such as insurance policy differences, higher number of patients using private health care units in UK or US, or differences in the physical activity level of the populations. Also, rather than reporting the exact person-time (i.e., first admission due to knee injury, death or moving out of the area as a censoring event), most of the authors (Clayton & Court-Brown, 2008; Kannus & Järvinen, 1989; Miyasaka, et al., 1991; Sarimo, et al., 2002) reported a cumulative annual incidence that assumes that a person is at risk for the whole study period. This somewhat lowers the incidence rate.

In the present study, the incidence rate per 1000 person-years for hospitalised old meniscal tears was 3.1, for fresh meniscal tears 2.2, for patellar dislocations 2.4, for cruciate ligament tears 2.1, for collateral ligament tears 1.0, and for fresh chondral lesions 0.2 cases. There is a very limited amount of comparable data in the literature. The aforementioned studies (Clayton & Court-Brown, 2008; Miyasaka, et al., 1991; Sarimo, et al., 2002) reported remarkably lower incidence rates for all of the specified knee diagnoses in comparison with the present study. In a cohort of Finnish adolescents and a young adult population, an event-based incidence rate of 0.61 (males, 0.97) per 1000 person-years for cruciate ligament injuries leading to hospitalisation was reported (Parkkari, et al., 2008). The incidence was lower than in our study. Parkkari and coworkers reported a hazard ratio of 4.0 for cruciate ligament injuries in males participating in organized sports more than 4 times per week and this may explain the higher injury incidence rate during military service (Parkkari, et al., 2008). An incidence of 0.77 hospitalised primary traumatic patellar dislocations per 1000 person-years was reported in the Finnish conscript population (Sillanpää, et al., 2008). The present study reported a markedly higher incidence that can be explained by the inclusion of recurrent dislocations and dislocations without remarkable trauma in the study.

The most common ICD-10 diagnosis in subjects admitted to inpatient care was old meniscal tear (28%), followed by acute patellar dislocation (22%), fresh meniscal tear (20%), ACL/PCL tear (19%), MCL/LCL tear (9%), and fresh chondral lesions (2%). Minor knee distortions without damage to a particular structure were observed in 34% of the cases studied by Majewski. Anterior cruciate ligament tear was the most common specific knee diagnosis (20%), followed by medial meniscus tear (11%), chondral lesion (11%), MCL tear (8%), contusion injury due to direct trauma (6%), lateral meniscus tear (4%), and patellar dislocation (3%) (Majewski, et al., 2006). Only specified ICD-10 diagnoses were included in our analysis. The relative frequency of meniscal tears and patellar dislocations was clearly higher in our study, whereas the proportion of ACL tears and

chondral lesions was lower. Majewski's study was performed in a sports injury clinic and included only athletic knee injuries, which might explain the higher percentage of ACL injuries (Parkkari, et al., 2008). In our study, all hospitalised injuries occurring during leisure time and not associated with military or sports training were also included. The registry data used in our study, however, did not include information regarding whether the knee injury occurred during sports, military exercises, or vacations. Taanila et al. (Taanila, et al., 2009) examined this issue in Finnish conscripts. Musculoskeletal disorders were included in their analysis and the knee joint was the second most common injury location (18%). The majority of injuries occurred during actual military service (91%), followed by during vacations (9%), and on the way to vacation or back to the garrison (0.5%). The most common cause of knee injury was training in combat gear, followed by marching and other physical exercises. The number of chondral lesions increases with age (Curl, et al., 1997), which may explain the lower proportion of these lesions in the present study. Chondral lesions are not always reported as a separate diagnosis (Kiviranta & Vasara, 2004) and the number of chondral lesions in the present study should be considered a clear underestimate.

This study is the largest performed and reported to date of the incidence and risk factors for knee injuries that can be generalised to the young adult male population between the ages of 18 and 30 years, i.e., the group in which most knee injuries occur (Gianotti, et al., 2009; Kannus & Järvinen, 1989; Majewski, et al., 2006) and in which participation in sports is common. The incidence rates of knee injuries needing inpatient care in this population have not been comprehensively reported. Young adults serving compulsory military service are representative of the general population and are thus an excellent indicator of how this population reacts to the challenges of progressive physical exercise. This study demonstrates that the incidence of knee injuries needing inpatient care is high in the young adult male population involved in physical training, and causes a significant burden to hospitals. Overall person-time incidence rate of knee injuries requiring inpatient care in the present study was 11 per 1000 person-years, which indicates that more than 1 of 100 young adult male conscripts will be admitted to inpatient care each year due to knee injury. This incidence is remarkably high compared with the results presented in older general populations in Finland, UK, and US (Clayton & Court-Brown, 2008; Kannus & Järvinen, 1989; Miyasaka, et al., 1991). The findings in Finnish young adults, conscripts, and knee haemarthrosis patients are more logically consistent with the results of the present study (Parkkari, et al., 2008; Sarimo, et al., 2002; Sillanpää, et al., 2008; Taanila, et al., 2010).

10.2.2 Readmissions, Disability, and Need for Surgery

Among all young adult male conscripts hospitalised with knee injuries, as many as one-third will undergo a service class change due to long-term disability. Almost two-thirds of all hospitalised subjects require surgery.

The majority of subjects admitted to inpatient care for old meniscal tears required surgery. Subjects with fresh meniscal tears and ACL/PCL tears also were usually treated surgically, whereas those with fresh chondral lesions, patellar dislocations, and MCL/LCL tears rarely underwent surgery. Majewski et al. (Majewski, et al., 2006) reported that 87% of clinically diagnosed ACL tears required surgery and the corresponding percentages were 85% of lateral meniscus, 84% of medial meniscus, 78% of PCL, 59% of MCL, and 49% of LCL). The proportions of injuries treated surgically reported by Majewski et al (2006) were generally higher than those in the present study. Almost all ACL tears were treated surgically in Majewski's study and it seems likely that surgery was considered more eagerly for athletes than for ordinary young adult males in the present study.

One important and novel finding of the present study was that up to one-third of all subjects admitted to inpatient care exhibited such a severe decline in physical performance that a service class change was warranted. A service class change was deemed necessary for more than half the subjects with ACL/PCL tears. The decision for a service class change is not made easily and is therefore considered a reliable indicator of more severe injury with longer-term disability. The present study included both traumatic and nontraumatic, primary, and recurrent patellar dislocations. Approximately one-fifth of the patellar dislocations in the present study led to a service class change, indicating longer-term notable disability and one-third required surgery. In the study of Sillanpää and coworkers, the proportion of service class changes was similar, but surgery was required twice as often when only primary traumatic patellar dislocations were taken into account (Sillanpää, et al., 2008).

To our knowledge, no other studies in the literature have reported similar disability rates of different knee injuries. Information gained in the present study will help clinicians in predicting the prognosis of different knee injuries. A long-term follow-up study would be beneficial to determine whether knee injuries leading to a service class change cause permanent disability or persistent symptoms.

10.2.3 Risk Factors for Knee Injuries Needing Inpatient Care

Older age and obesity are the most important risk factors for inpatient care admission for knee injury. Obesity was a significant independent risk factor for patellar dislocation and MCL/LCL tears. Although higher weight was an independent risk factor for meniscal tears, BMI was not. The overall risk for inpatient care admissions due to knee injuries and particularly due to old meniscal tears increased with age.

Data regarding the association between physical fitness, or anthropometric properties, such as height, weight or BMI and knee injuries needing inpatient care has been severely lacking before the present study. Previous studies demonstrated that older age, up to 26 years, increases the risk for discharge from the US Army due to disabling knee injuries (Sulsky, et al., 2000). Obesity is a risk factor for disabling knee pain and inpatient care admission due to lower limb injury (Mattila, et al., 2007; Webb, et al., 2004). In the present study, running test results were not associated with knee injuries. Instead, better muscle strength was a statistically significant risk factor for knee injuries in general and specifically for fresh meniscal tears and cruciate ligament injuries. Those with better muscle strength may participate in more vigorous sports activities, which increases the risk for knee injuries and especially the risk for cruciate ligament tears (Haapasalo, et al., 2007; Parkkari, et al., 2008). In addition, conscripts with better muscle strength may be required to perform more physically challenging tasks during military service for which the risk of knee injury may be higher. An earlier study assessing Finnish conscripts reported that good muscular fitness increases the risk for injury-related inpatient care admissions in general, and excellent aerobic condition increases the risk for lower limb injury leading to inpatient care (Mattila, et al., 2007). In contrast, however, the risk for musculoskeletal injuries treated at the garrison clinics as outpatients and also the risk for medical discharge from the military service is reported to increase if the running test results are poor. Overall results of the muscular strength tests are not associated with these outcomes (Taanila, et al., 2011; Taanila, et al., 2010). The reasons for these contradictory results are not clear and require further research. The risk factor variables in the present study were measured during the first weeks of military service, therefore it is possible that weight or physical performance changed during the subsequent service time.

The multivariate analysis in the present study indicated that the risk for patellar dislocations is 2-fold in obese (BMI > 30) subjects. No significant association was detected between height, weight, or physical fitness and risk of inpatient care admissions due to patellar dislocations. A previous univariate analysis demonstrated that higher height and weight increase the risk when only primary traumatic patellar dislocations are taken into account (Sillanpää, et al., 2008). To our knowledge, there are no previous studies reporting risk factors for collateral ligament tears. A new important finding of the present study was that obesity is associated with inpatient care due to MCL/LCL tears and it increases the risk 3-fold. In the present study, heavier subjects had a higher risk for meniscal tears. Weight is also reported to be a risk factor for meniscal tears in a UK population (Baker, et al., 2002). Older age as a risk factor for old meniscal tears is a logical finding, as aging weakens the meniscal structures (Negendank, et al., 1990). Nevertheless, there has been lack of data actually showing that the risk increases with aging.

This study adds to the knowledge of the poorly known, intrinsic and potentially modifiable risk factors for knee injuries requiring inpatient care and can be generalised

onto the young adult male population of Finland. An important new finding was that obesity is a significant risk factor for inpatient care of knee injuries and especially of collateral ligament tears and patellar dislocations. Older age is associated with increased risk for inpatient care admission due to knee injury and thus entering military service at a younger age, e.g., between 18–20, might be beneficial. The association between knee injuries and muscle strength, as well as the prevention of knee injuries, requires further research.

11 Conclusions

The principal aims of the present study were to investigate the epidemiology and MRI-based diagnostics of common knee injuries and AKP in the young adult population. The study population comprised young adult conscripts performing their compulsory military service. Except for the knee injury under study, all were generally healthy and able to perform military service. Due to the compulsory nature of military service, male conscripts included in this study are highly representative of ordinary Finnish young adults. The findings can thus be generalised to the physically active, young adult male population.

1) Data from patients with fresh traumatic chondral lesions indicated that although routine clinical use of 1.0T MRI is not sensitive, it is specific for the diagnosis of fresh traumatic chondral lesions. Sensitivity improved only modestly for deeper lesions. Almost half of the full-thickness cartilage lesions were undiagnosed by preoperative MRI. Despite negative MRI findings, arthroscopy may reveal lesions amenable to cartilage repair procedures. Readiness and available instrumentation for basic cartilage repair procedures at the time of arthroscopy is therefore advisable (I).

2) Data of meniscal tears revealed that MRI has a similar diagnostic validity for meniscal tears in acute knee trauma and knee symptoms lasting over 6 months in young adults. Our results also suggest that neither effusion nor haemarthrosis are associated with the diagnostic validity of MRI. The diagnostic validity of MRI substantially differed between lateral and medial meniscal tears. As many as 9 of 10 of the medial meniscal tears were detected in MRI, whereas lateral meniscal tears were missed in more than half of the cases, regardless of the duration of the symptoms. Clinically, arthroscopy should be considered despite negative MRI findings if justified by the patient's symptoms, especially in cases of suspected lateral meniscal tears (II).

3) Routine MRI protocol used in the prospective sample of patients with AKP included a cartilage-specific T1-weighted 3D SPGR sequence and allowed for an overall, clinically rational knee examination. The MRI sensitivity for superficial patellar chondral lesions was insufficient, only 13%. For more severe lesions, however, 1.0T MRI may be a valid diagnostic tool as the sensitivity was substantially higher, 83% (III).

4) The AKP data also provided complementary evidence that patellar chondral lesions cannot be distinguished from other causes of AKP based only on symptoms and signs on physical examination. Arthroscopic examinations revealed patellar chondral lesions

in less than half of all subjects. Pathological synovial plica was a consistently common finding, although association with the symptoms cannot be assessed. Arthroscopy revealed pathological findings in 50 of 56 knees. The presence of retropatellar crepitus or pain on patellar manipulation was not associated with a higher proportion of patellar chondral lesions in patients with typical clinical AKP symptoms. No association was found between the severity of chondral lesions and clinical symptoms and signs. Thus, these symptoms and signs are not helpful when considering whether the patient might have deep chondral lesions possibly amenable to surgical repair (III).

5) Epidemiological data revealed the incidence of inpatient care admissions due to knee injuries in the largest-ever sample that can be generalised onto the physically active young adult male population. The overall person-time incidence rate for knee injuries requiring inpatient care admission in the present study was remarkably high, 11 per 1000 person-years. Each year more than 1 of 100 young adult males will be admitted to inpatient care due to knee injury during their conscription. The incidence rates of hospitalised knee injuries in this population have not been comprehensively reported earlier.

Clinically relevant data regarding the proportions of surgical treatment and longer-term disability associated with hospitalised knee injuries were reported. Nearly two-thirds of the knee injuries needing inpatient care led to surgical treatment and as many as one-third led to longer-term notable disability. To our knowledge, no other studies in the literature have reported corresponding information for knee injuries requiring inpatient care. A long-term follow-up study would be beneficial to determine whether knee injuries leading to a service class change cause permanent disability or persistent symptoms.

This thesis also adds to the body of knowledge of poorly known, intrinsic, and potentially modifiable risk factors of knee injuries requiring inpatient care. The most important risk factors were older age and obesity. Obesity was a significant independent risk factor for patellar dislocation and MCL/LCL tears. Higher weight, but not BMI, was a risk factor for meniscal tears. Older age increased the overall risk for inpatient care admission and especially the risk for old meniscal tears. The association between knee injuries and muscle strength as well as the prevention of knee injuries warrants further research (IV).

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Paavo Kuikka

13 References

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14 Original Publications

Sensitivity of Routine 1.0-Tesla Magnetic Resonance Imaging Versus Arthroscopy as Gold Standard in Fresh Traumatic Chondral Lesions of the Knee in Young Adults

Paavo-Ilari Kuikka, B.M., Martti J. Kiuru, M.D., Ph.D., M.Sc., Maria H. Niva, M.D., Ph.D., Heikki Kröger, M.D., Ph.D., and Harri K. Pihlajamäki, M.D., Ph.D.

Purpose: The purpose of this study was to evaluate the sensitivity, specificity, and accuracy of routine 1.0-Tesla magnetic resonance imaging (MRI) versus arthroscopy in detecting fresh traumatic chondral lesions of the knee. **Methods:** Over a period of 6 years, 578 consecutive military personnel underwent MRI before arthroscopy of the knee. Of these, 32 patients with arthroscopically proven fresh traumatic chondral lesions of the knee were chosen for further analysis. A supplementary condition was that arthroscopy was performed no later than 6 weeks after the onset of trauma. The original MRIs and hospital records were re-evaluated and the chondral lesions were graded and compared with arthroscopic findings. The arthroscopic results served as the gold standard when the sensitivity, specificity, and accuracy of MRI were calculated. **Results:** The age of the patients ranged from 19 to 21 years (mean, 19.6 years). MRI detected cartilage defects with a sensitivity of 36% (95% confidence interval [CI], 23% to 50%), specificity of 91% (95% CI, 85% to 95%), and diagnostic accuracy of 78% (95% CI, 72% to 83%). MRI results were affected by the grade of the chondral lesions. **Conclusions:** This study shows that routine 1.0-T MRI is not sensitive but is specific and somewhat accurate in detecting fresh traumatic articular cartilage lesions. The hypothesis of this study was that 1.0-T MRI could replace diagnostic arthroscopy in the diagnosis of fresh traumatic chondral lesions. Our results fail to support this hypothesis because of the poor sensitivity obtained with MRI. **Level of Evidence:** Level II, development of diagnostic criteria. **Key Words:** Knee—Injury—Trauma—Articular cartilage—Arthroscopy—Magnetic resonance imaging.

Traumatic chondral lesions of the knee are common in physically active young adults, but the accurate numbers and localizations are not well known. In the detection of trauma-related lesions, magnetic resonance imaging (MRI) of the knee joint is routine practice. According to the literature, MRI has a good sensitivity and specificity when menisci and ligament injuries of the knee are examined.[1-3] In earlier studies, however, MRI of cartilage has produced varying results when compared with arthroscopy, with sensitivity ranging from 18% to 100%, specificity ranging from 50% to 100%, and accuracy ranging from 81.5% to 98%.[4-14] To our knowledge, studies reporting on MRI of fresh traumatic chondral lesions of the knee are lacking in the literature.

Knee arthroscopies are often performed because of injury, pain, or swelling of the knee joint. Sometimes, no surgically treatable lesion is found, in which case arthroscopy is considered an unnecessary diagnostic method. Being invasive, arthroscopy causes an inability to work, pain, and stress for the patient while also

creating risks related to anesthesia and surgery. Furthermore, unnecessary arthroscopies consume already limited health care resources.

Occasionally, only chondral lesions with no ligamentous or meniscal injuries are found on arthroscopy. We might argue that early discovery of chondral lesions by MRI would alert the surgeon to a state of readiness, and corrective surgery during arthroscopy could be performed if necessary. Within the past few years, treatment methods for cartilage defects have significantly improved.[15] There is evidence that, with aging, chondral lesions in physically active young adults can lead to osteoarthritis.[16]

The aim of this study was to evaluate the sensitivity, specificity, and accuracy of routine 1.0-Tesla MRI versus arthroscopy in detecting fresh traumatic chondral lesions of the knee. The hypothesis of this study was that 1.0-T MRI could replace diagnostic arthroscopy in the diagnosis of fresh traumatic chondral lesions.

METHODS

A retrospective search of our hospital database was conducted. The search identified 578 consecutive patients who had undergone MRI examination of the knee and subsequent arthroscopy during a 6-year period, from March 1, 1997, to February 28, 2003.

The primary inclusion criteria for this study consisted of trauma-related, solitary or multiple, arthroscopically proven fresh chondral lesions of the knee. There were 2 further requirements: arthroscopy had to have been performed no later than 6 weeks after the onset of trauma, and MRI examination had to have been conducted before arthroscopy. Furthermore, to eliminate cases with osteoarthritic changes in the cartilage, only patients aged under 25 years were included in the study.

There were 4 exclusion criteria. We excluded patients if the pain in the knee did not result from any clear trauma, if the pain originated from trauma that occurred more than 6 weeks before arthroscopy, if they had disease-derived chondromalacia patellae, or if they had recurrent dislocation of the patella. Exceptions to the criteria were patients with a dislocation of the patella that occurred for the first time and was directly attributable to trauma.

All patients underwent MRI scans on a 1.0-T scanner (Signa Horizon; GE Medical Systems, Milwaukee, WI). A knee coil with a field of view of 10 to 16 cm was used. The slice thickness was 3 to 4 mm, with a 0.5- or 1.0-mm intersection gap. Sagittal proton density spin-echo sequence images with fat suppression (repetition time [TR] of 3,400 ms and echo time [TE] of 17 ms, with 2 signals averaged and a 256 × 256 [516] matrix) and sagittal T1-weighted spin-echo sequence images (TR of 680 ms and TE of 11 ms, with 2 signals averaged and a 256 × 256 [512] matrix) were obtained. T2-weighted fast spin-echo sequences with fat suppression were obtained in the axial images (TR of 2,560 ms and TE of 85 ms, with 2 signals averaged and a 256 × 256 [512] matrix) and in the coronal images (TR of 4,000 to 4,600 ms and TE of 72 to 90 ms, with 2 signals averaged and a 256 × 256 [512] matrix).

All patients first underwent MRI and then arthroscopy within 2 to 40 days from trauma. The mean time from trauma onset to arthroscopy was 13.4 days. Six articular surfaces in each knee were evaluated: patella, femoral sulcus, medial and lateral femoral condyles, and medial and lateral tibial plateaus.

The MRIs were evaluated by an experienced radiologist soon after the imaging process. Because of the retrospective nature of this study and in accordance with the normal policy of our department, the arthroscopist received the MRI results before the operation. However, the exact grading of the chondral lesions did not emerge from the data. For the purposes of this study, the MRIs were re-evaluated retrospectively by a musculoskeletal radiologist, blinded to the prior results of arthroscopy or MRI.

The cartilage lesions found at MRI and arthroscopy were classified according to their depth, by use of the numeric grading system developed by Tyrrell et al.[17] (Table 1). The arthroscopic results served as the gold standard when the specificity, sensitivity, and diagnostic accuracy of MRI were calculated with single-table analysis. Bone bruises (bone contusions) detected by MRI were primarily interpreted as a negative result. Bone bruises, which are occasionally detected on MRIs of an injured knee, result from compression forces to the bone and may leave the overlying cartilage seemingly uninjured. However, it has been suggested that a bone bruise on MRI may indicate dam-

TABLE 1. *Depth of Articular Cartilage Lesions According to Grading Scale Developed by Tyrrell et al.[17]*

Grade	Description
0	Normal
1	Moderate irregularity
2	Severe irregularity but not full thickness
3	Full-thickness loss

TABLE 2. *MRI and Arthroscopy Results for Chondral Lesions in 32 Knees*

| MRI	Arthroscopy				
	Grade 0	Grade I	Grade II	Grade III	Total
Grade 0	114	8	11	3	136
Grade I	7	1	2	0	10
Grade II	4	1	2	2	9
Grade III	2	0	2	6	10
Bone bruise	20	2	2	3	27
Total	147	12	19	14	192

age to the overlying articular cartilage.[18] Therefore, because an injury was considered possible, sensitivity, specificity, and diagnostic accuracy were also calculated to allow such interpretation. Ninety-five percent confidence intervals (CIs) were calculated by use of the Poisson approximation.[19]

RESULTS

Thirty-two consecutive military personnel met the inclusion criteria and were selected for further detailed analysis. Of these, 30 were men and 2 were women. Their ages ranged from 19 to 21 years, and the mean age was 19.6 years.

Altogether, 192 articular cartilage surfaces in 32 knees were evaluated with MRI and arthroscopy. On arthroscopy, 147 (76.6%) of these surfaces were considered intact and normal, and 12 chondral lesions (6.3%) were classified as grade I, 21 (10.9%) as grade II, and 12 (6.3%) as grade III. The total number of damaged articular surfaces was 45 (23.4%). Of the lesions, 40 (88.9%) were caused by a sprain, 3 (6.7%) by a contusion, and 2 (4.4%) by a combination of a sprain and a contusion.

MRI detected cartilage defects with an overall sensitivity of 35.6% (95% CI, 23.2% to 50.2%), specificity of 91.2% (95% CI, 85.5% to 94.8%), and diagnostic accuracy of 78.1% (95% CI, 71.8% to 83.4%) when arthroscopy was used as the gold standard. Of the articular surfaces, 143 were identically graded on arthroscopy and MRI when a bone bruise seen on MRI was considered a negative result. When MRI results were compared with arthroscopy results, 24 surfaces differed by 1 grade, 17 surfaces differed by 2 grades, and 8 surfaces differed by 3 grades (Table 2). Grade I lesions (Fig 1) were detected with MRI, although the sensitivity and diagnostic accuracy were only 16.7% (95% CI, 4.7% to 44.8%). Deeper (grade II) lesions were detected with a sensitivity and diagnostic accuracy of 31.6% (95% CI, 15.4% to 54.0%), and the
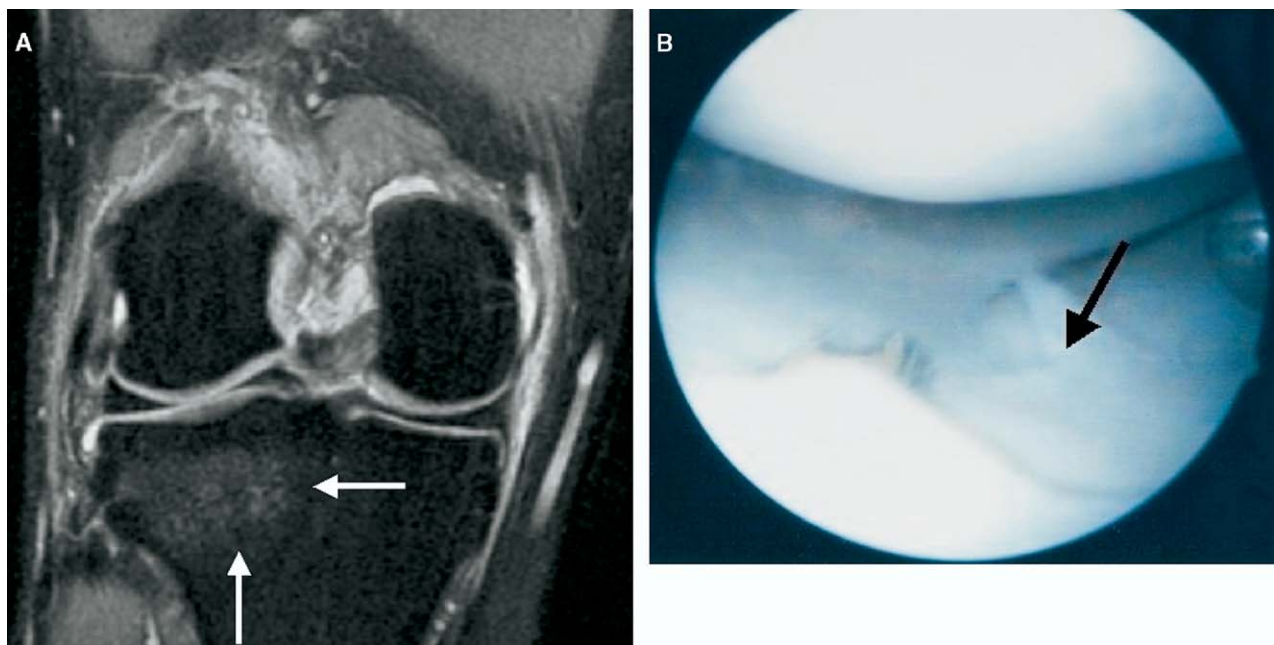
FIGURE 1. (A) Coronal T2-weighted MRI scan of a right knee 1 day after injury. A bone bruise is visible in the lateral condyle of the tibia (arrows). The articular cartilage seems normal and intact. (B) The same knee 6 days after injury. Moderate irregularity (grade I) of the articular cartilage is visible in the lateral tibial condyle (arrow). Rupture of a lateral meniscus can also be seen.
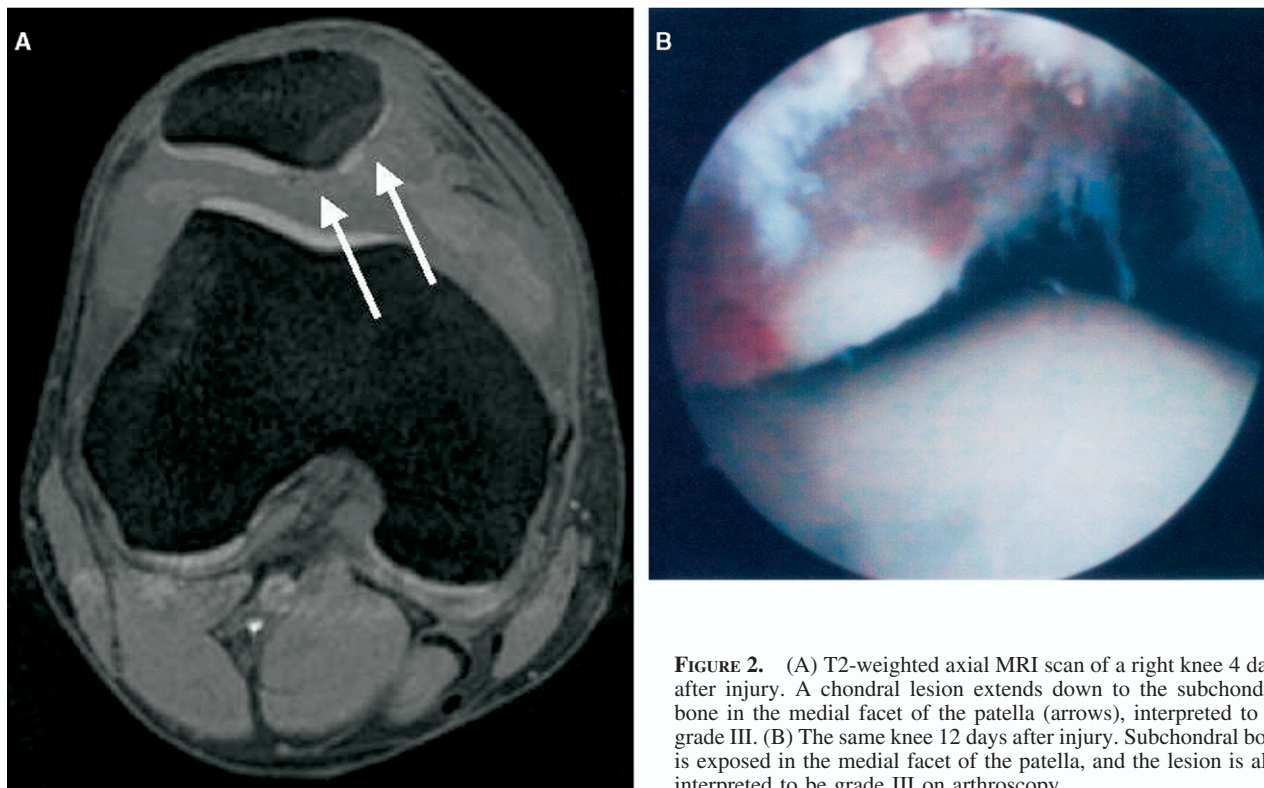
Figure 2. (A) T2-weighted axial MRI scan of a right knee 4 days after injury. A chondral lesion extends down to the subchondral bone in the medial facet of the patella (arrows), interpreted to be grade III. (B) The same knee 12 days after injury. Subchondral bone is exposed in the medial facet of the patella, and the lesion is also interpreted to be grade III on arthroscopy.

deepest (grade III) lesions (Fig 2) were detected with a sensitivity and diagnostic accuracy of 57.1% (95% CI, 32.6% to 78.6%). When the results for the different grades of chondral lesions were calculated, the specificity could not be determined, because the data regarding the healthy articular surfaces were lacking, and thus the number of true-negative results and false-positive results was 0 (Specificity = True-negative results/[False-negative results + False-positive results]). Due to the lack of true-negative and false-positive results, the sensitivity and diagnostic accuracy attained were identical.

In 7 (15.6%) of the 45 damaged articular surfaces, the only MRI finding was a bone bruise, and of the 147 healthy articular surfaces, MRI showed bone bruises in 20 cases (13.6%). When a bone bruise was interpreted as a positive result (i.e., chondral lesion), the MRI findings showed a sensitivity of 51.1% (95% CI, 37.0% to 65.0%), specificity of 76.9% (95% CI, 69.4% to 83.0%), and diagnostic accuracy of 70.8% (95% CI, 64.1% to 76.8%). When a combination of bone bruise and chondral lesion was indicated by MRI, only the latter was included in the calculations, because it was considered a more severe condition. This combination was ascertained in 3 patients, each

showing a combination of a grade III lesion and a bone bruise in the lateral femoral condyle.

Of the 45 chondral lesions, 19 were situated in the patellar surface, 12 in the lateral femoral condyle, 9 in the medial femoral condyle, 3 in the lateral tibial plateau, 2 in the medial tibial plateau, and 0 in the femoral sulcus. Thirteen patients had lesions in multiple articular surfaces. Trauma to the knee had resulted in first acute patellar dislocations in 10 cases.

DISCUSSION

This study shows that routine 1.0-T MRI, though lacking in sensitivity, is specific and somewhat accurate when examining fresh traumatic chondral lesions. The most common cause of chondral lesions of the knee was a simple sprain, and the most common locations for lesions were the patellar surface and the lateral femoral condyle. It is noteworthy, however, that our study included 10 acute traumatic patellar dislocations, increasing the number of lesions especially on these surfaces.

It seemed clear that MRI was more sensitive in detecting deep chondral lesions. As expected, grade I lesions were detected with a very poor sensitivity and

diagnostic accuracy (16.7%), whereas grade III lesions were detected with only slightly better values (sensitivity and diagnostic accuracy of 57.1%). In this study specificity could not be determined when calculating results for the different grades of chondral lesions. Clinically, detecting deep lesions is important, because they are likely to become symptomatic and require treatment.[20,21] Contrary to our expectations, our results suggest that the sensitivity of 1.0-T MRI fails to suffice even for the deepest lesions. Riel et al.,[7] comparing the results of 0.2-T MRI with those of arthroscopy in nonfresh, full-thickness cartilage lesions, reported a sensitivity of 72%, specificity of 100%, and accuracy of 92% for MRI. In our study, in contrast, the sensitivity, specificity, and diagnostic accuracy were 35.6%, 91.2%, and 78.1%, respectively. However, our study also took into account the more superficial lesions, which can partly explain the poorer results that we achieved.

Interestingly, if the bone bruises detected by MRI in our study were interpreted as a positive result, the sensitivity of MRI improved, whereas the specificity and diagnostic accuracy deteriorated. It has been suggested that bone bruises on MRI may indicate damage to articular cartilage.[18]

Patients selected into this study were young military personnel aged 19 to 21 years. Except for the present knee injury, they were all healthy and able to perform military service. Thus the subject sample included in this study was very homogeneous. Because osteoarthritic changes are very rare in young persons,[22] it can be assumed that fresh-looking chondral lesions detected here were caused by the present trauma, not osteoarthritis. This distinguishes our study from many others. Similar studies of fresh chondral lesions of the knee in young adults do not exist in the literature. Most of the previous studies investigating chondral lesions have focused on older patients,[5,7,11-14,23] and it is well known that the prevalence of knee osteoarthritis increases with age.[22]

The MRI field strength used routinely at our hospital, as well as in this study, was 1.0 T. Similar studies with 1.0-T MRI have not been published before. Most of the previous studies have used 1.5-T field strength.[4,5,9-14] The study of Handelberg et al.[5] concentrated mainly on patellar cartilage lesions, and MRI showed a sensitivity of 100%, specificity of only 50%, and accuracy of 81.5%. Disler et al.[12] found in their study of 47 patients (mean age, 36 years) that the fat-suppressed spoiled gradient-echo (SPGR) imaging sequence of 1.5-T MRI had a clearly higher sensitivity than the standard MRI sequences (75% to 85% v 29% to 38%),

whereas the specificity was 97% for both standard and SPGR sequences. Their results for the standard sequences compared well with our results. In addition, Friemert et al.[4] documented similar results with 1.5-T MRI sequences used routinely for the detection of meniscal and ligamentous injuries. In their sample of 86 patients with knee pain of variable origin, the sensitivity of MRI was only 33% whereas the specificity was 99%. However, better results with routine clinical sequences have also been achieved. In their study of 130 patients, Bredella et al.[11] detected cartilage abnormalities with a sensitivity of 93%, specificity of 99%, and accuracy of 98% for 1.5-T MRI when arthroscopy was used as the gold standard. The better results achieved with SPGR sequences by Disler et al. were consistent with the findings of Potter et al.,[13] who reported a sensitivity of 87% and specificity of 94% for fast spin-echo images. Furthermore, Recht et al.[14] reported similar results for fat-suppressed SPGR sequences in a study of 10 cadaveric knees, aged 70 to 89 years at the time of death, indicating a sensitivity of 96%, specificity of 95%, and accuracy of 95% for MRI in detecting chondral lesions. Recht et al. further compared the MRI results with the anatomic sections.

Still, comparing our results with those obtained with other field strengths is not reliable, because the differences may derive from factors other than field strength, such as selection bias. MRI field strength affects the homogeneity of fat suppression; the higher the field strength is, the more homogeneous and better the fat suppression is. Without fat suppression sequences, interpretation of cartilage is more difficult and less sensitive.

A limitation of our study was the relatively small number of patients examined. Furthermore, because of the rarity of these fresh traumatic chondral lesions, data covering several years were collected retrospectively in connection with normal clinical practice. Given the retrospective nature of the study, the nongraded MRI results were available at the time of arthroscopy, which may have influenced the arthroscopy results. Still, this is the true situation in clinical practice, and the orthopaedic surgeon was unaware that the results would be used in a study in the future.

Arthroscopy is usually considered the gold standard for articular defects. Nonetheless, its accuracy in the evaluation of cartilaginous disorders has been questioned.[24,25] Admittedly, arthroscopy only allows visual inspection of the cartilage surface and reveals nothing about the midsubstance of the tissue, which may contain hidden defects.[26] Although MRI can reveal possible damage even to inner tissue layers, the

gold standard of arthroscopy may override such evidence as a false-positive finding. A strongly weighted preference to one technology may distort the results and should be considered a limitation in this study as well.

Besides arthroscopy, anatomic sections have been used as the gold standard for articular cartilage lesions. As already discussed, Recht et al.[14] reported a sensitivity of 96%, specificity of 95%, and accuracy of 95%. Hodler et al.[23] compared MRI findings of 75 randomized articular surfaces in 20 cadaveric knees (mean age at the time of death, 73.8 years) with anatomic sections and showed a sensitivity of 71.4%, specificity of 68.6%, and accuracy of 70% for MRI.

MRI studies can also be conducted by use of a contrast agent, a technique known as gadolinium (Gd–diethylenetriamine penta-acetic acid [DTPA])–enhanced MRI or MR arthrography. This may be performed as direct MR arthrography (intra-articular injection of Gd-DTPA) or indirect MR arthrography (intravenous injection of Gd-DTPA). Although it has been shown that the sensitivity of MRI increases with intra-articular injection of Gd-DTPA,[27] both of these MR arthrography methods are very seldom used in routine clinical MRI of the knee. In addition, in fresh traumas there is usually intra-articular blood that serves as a natural contrast agent, rendering intra-articular Gd-DTPA injection unnecessary. Moreover, some investigators believe that intra-articular MR arthrography should be avoided in fresh traumas that might involve intra-articular fractures.

Various MRI methods in different patient groups have been previously studied. The variety of methods and patient groups, as well as the use of different grading scales and gold standards for chondral lesions, makes reliable comparison of the studies challenging. When comparing our results with those of previous studies, it seems that, even though most of the previous studies achieved a better sensitivity and accuracy for MRI in chondral lesions of the knee, similar results with the standard or routine MRI sequences have also been reported.

CONCLUSIONS

This study shows that routine 1.0-T MRI is not sensitive but is specific and somewhat accurate in detecting fresh traumatic articular cartilage lesions. The hypothesis of this study was that 1.0-T MRI could replace diagnostic arthroscopy in the diagnosis of fresh traumatic chondral lesions. Our results fail to support this hypothesis because of the poor sensitivity obtained with MRI.

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1   **Magnetic Resonance Imaging in Acute Traumatic and Chronic Meniscal Tears of the**

2   **Knee – A Diagnostic Accuracy Study in Young Adults**

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6   Paavo-Ilari Kuikka,*† MB, Petri Sillanpää,† MD, PhD, Ville M. Mattila,† MD, PhD, Maria

7   H. Niva,† MD, PhD, and Harri K. Pihlajamäki,†‡ MD, PhD

8   From the †Centre for Military Medicine, Helsinki, Finland, and the ‡Department of

9   Orthopaedic Surgery, Central Military Hospital, Helsinki, Finland

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36 **ABSTRACT**

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38 **Background:** No previous research has investigated the diagnostic validity of magnetic

39 resonance imaging for acute versus chronic meniscal tears using comparable materials and

40 methods.

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42 **Hypothesis:** There is no difference in the diagnostic validity of magnetic resonance imaging

43 for acute versus chronic meniscal tears in young adults.

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45 **Study Design:** Cohort study (diagnosis); Level of evidence, 2.

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47 **Methods:** A total of 628 young adult military personnel underwent magnetic resonance

48 imaging and arthroscopy of the knee over a 6-year period. Inclusion criteria were met by 82

49 patients with acute knee trauma (magnetic resonance imaging within 30 days from trauma)

50 and 40 patients with chronic knee symptoms (symptoms lasting over 6 months before

51 magnetic resonance imaging). The original magnetic resonance imaging and arthroscopy

52 records were reviewed twice by a musculoskeletally trained radiologist, blinded to previous

53 magnetic resonance imaging and arthroscopy findings. Interobserver correlations and intraob-

54 server reliability were calculated and reported. Arthroscopy served as the gold standard when

55 calculating the diagnostic values of magnetic resonance imaging for acute and chronic

56 meniscal tears.

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58 **Results:** The median age of the patients was 20 years (range, 18-25). Magnetic resonance

59 imaging detected acute meniscal tears with sensitivity of 67%, specificity of 93%, and

60 diagnostic accuracy of 88% and chronic meniscal tears with 64%, 91%, and 86%,

61 respectively. There was no statistically significant difference in magnetic resonance imaging

62 results between the 2 groups.

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64 **Conclusions:** The diagnostic validity of magnetic resonance imaging is similar for meniscal

65 tears in acute knee trauma and in knee symptoms lasting over 6 months in young adults. The

66 results also suggest that effusion or hemarthrosis do not weaken the diag- nostic validity of

67 magnetic resonance imaging. The magnetic resonance imaging sensitivity achieved in the

68 present study was relatively poor, but the specificity was good for both acute and chronic

69   meniscal tears. Despite negative magnetic resonance imaging findings at the acute stage of

70   knee trauma, patient monitoring and readiness for arthroscopy should be considered if

71   justified by the patient's symptoms.

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INTRODUCTION

Fifteen percent of physical activity–related injuries are found in the knee, and the risk of sustaining a knee injury is especially high in the age group of 15 to 25 years. [7] Meniscal tears represent approximately 15% of all sports-related knee injuries and almost 25% of knee injuries involving surgery. [12] Noninvasive imaging modalities are often useful and important after knee trauma to identify which patients have meniscal tears. Using reliable methods also ensures appropriate selection of physically active young adults for arthroscopic management of meniscal tears.

Magnetic resonance imaging is widely used for noninvasive evaluation of the knee joint, and many clinicians consider it reliable in detecting internal knee derangements. This method is a powerful diagnostic tool when ligamentous and meniscal injuries of the knee are examined. [11, 16, 19]

However, a lower diagnostic validity for intra-articular lesions has been reported when only acute knee injuries are included. [10] The authors of that study suggest that MRI's low diagnostic validity in acute knee injuries may be attributed to the paramagnetic properties of blood remains and catabolic processes. However, the conflicting reports may derive from differences in the MRI methods, sample selection, or other dissimilarities between the previous studies. No previous research has investigated the diagnostic validity of MRI for acute versus chronic meniscal tears using comparable materials and methods.

The purpose of this study was, therefore, to evaluate whether the diagnostic validity of routine MRI is essentially equal for assessment of both acute traumatic and chronic meniscal tears of the knee joint in young adults. We hypothesized that there is no difference in the diagnostic validity of MRI for acute versus chronic meniscal tears in young adults.

MATERIALS AND METHODS

A retrospective search of the database of the Central Military Hospital of Finland was conducted. The selected sample included 628 consecutive patients who had undergone both MRI examination and arthroscopy of the knee during a 6-year period. The patient population consisted of young military conscripts, cadets, and officers.

The main inclusion criterion for this study was an MRI examination followed by arthroscopy of the same knee within 30 days to ensure comparability between

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109 examinations. A total of 354 patients met this criterion. Patients were excluded if they

110 had undergone previous surgical procedures of the knee (43 patients), MRI was

111 performed after arthroscopy (1 patient), knee symptoms increased markedly between MRI

112 and arthroscopy (1 patient), or any knee trauma occurred between MRI and arthroscopy

113 (0 patients). Patients who underwent a special MRI examination (eg, gadolinium-

114 enhanced) were excluded (69 patients). Furthermore, all patients over the age of 25 years

115 (5 patients) were excluded to ensure comparability between the groups.

116 After excluding a total of 119 patients according to the above criteria, 2 groups were

117 formed of the remaining 235 patients on the basis of the freshness of the injury; group A

118 included acute traumatic meniscal tears and group B, chronic meniscal tears.

119 For group A, there were 2 additional inclusion criteria: the knee problem had been caused

120 by clear trauma and MRI had been performed no later than 1 month (30 days) after the onset

121 of trauma (108 patients). To ensure freshness of the tears, we then excluded patients with a

122 history of previous knee trauma (25 patients). Additionally, patients with degenerative

123 changes revealed at arthroscopy were excluded (1 patient). A total of 82 patients met the

124 final inclusion criteria for group A and were thus accepted for further detailed analysis.

125 For group B, there were 2 additional exclusion criteria: knee symptoms had lasted for less

126 than 6 months before MRI, and knee trauma had occurred during the 6 months preceding

127 MRI (195 patients). In this group, a total of 40 patients met the final inclusion criteria for

128 further analysis.

129 Magnetic resonance imaging scans were performed on a 1.0-T scanner (Signa Horizon, GE

130 Healthcare, Milwaukee, Wisconsin). A knee coil with a field of view of 10 to 16 cm was

131 used. The slice thickness was 3 to 4 mm, with a 0.5- or 1.0-mm intersection gap. Axial and

132 coronal T2-weighted fast spin- echo sequences with fat suppression as well as sagittal T1-

133 weighted and proton density spin-echo sequence images with fat suppression were obtained

134 routinely. Sagittal T2-weighted images, coronal proton density images with fat suppression,

135 and axial 3-dimensional T1-weighted fast spoiled gradient- echo images with fat suppression

136 were also commonly used.

137 All the MRI findings were originally interpreted by an experienced radiologist soon

138 after the imaging process. Magnetic resonance imaging criteria for a meniscal tear were an

139 internal tear line extending to the upper, lower, or apical surface of the meniscus, or a tear

140 line splitting the meniscus into 2 or more pieces and showing partial dislocation of the

141 meniscus. These are commonly used MRI criteria for meniscal tears based on criteria

142 presented by Crues et al. [4] Crues et al[4] noted that a meniscal tear can be diagnosed only

143 when the intrameniscal area of high signal intensity extends to the articular surface.

144   In agreement with the normal policy of the department, and as noted in this retrospective

145 study, the arthroscopist had received the original MRI results before the operation. For the

146 purposes of the present study, the original MRI statements were reviewed and compared with

147 the arthroscopic findings. The lateral and medial menisci of all the knees were evaluated and

148 interpreted as independent cases. The arthroscopic results served as the gold standard when

149 the sensitivity, specificity, and diagnostic accuracy of MRI for both acute and chronic

150 meniscal tears were calculated with single-table analysis. The Wilson score method was

151 used to calculate the 95% confidence intervals (CIs). [2]

152

153 For calculating the interobserver correlations and intraobserver agreement, the original MRI

154 and arthroscopy records were reviewed twice by a second musculoskeletally trained

155 radiologist, blinded to previous MRI and arthroscopy findings. Agreement was interpreted

156 to be almost perfect with a kappa-value of 0.81 to 1.00, substantial with 0.61 to 0.80,

157 moderate when 0.41 to 0.60, fair when 0.21 to 0.40, and poor with a kappa-value of less than

158 0.20. [9]

159

160 **RESULTS**

161

162 Group A comprised 82 patients (77 men and 5 women, 164 menisci) who met the inclusion

163 criteria and were accepted for further detailed analysis. The median age of the patients was 20

164 years (range, 18-25). The median time between onset of injury and MRI examination was

165 4.5 days (range, 0-30), and the median time delay between MRI and arthroscopy was 4 days

166 (range, 0-29). The total number of meniscal tears identified by arthroscopy was 27 (Table 1);

167 12 were located in the medial meniscus and 15 in the lateral meniscus. Effusion or

168 hemarthrosis was present in 64 knees. In group A, MRI detected acute meniscal tears with

169 an overall sensitivity of 67% (95% CI, 48%-81%), specificity of 93% (95% CI, 87%-96%),

170 and diagnostic accuracy of 88% (95% CI, 83%-93%) (Figure 1).

171   Group B comprised 40 patients (39 men, 1 woman, 80 menisci) who met the inclusion

172 criteria for further analysis. The median age of the patients was 20 years (range, 18-25).

173 The median time between onset of symptoms and MRI was 3 years (range, 6 months–10

174 years), while the median delay between MRI and arthroscopy was 20 days (range, 1-30).

175 The total number of meniscal tears in this group was 14 (Table 2); 9 were situated in the

176   medial and 5 in the lateral menisci. Effusion or hemarthrosis was present in 2 knees. In

177   group B, MRI detected chronic meniscal tears with an overall sensitivity of 64% (95% CI,

178   39%-84%), specificity of 91% (95% CI, 82%-96%), and diagnostic accuracy of 86% (95%

179   CI, 77%-92%) (Figure 2).

180   More detailed results for the diagnostic validity of 1.0-T MRI in detecting meniscal tears of

181   the knee are presented in Table 3 separately for groups A and B. No statistically significant

182   difference was found between the overall (both menisci) sensitivities or specificities in the

183   2 groups (difference for sensitivities, $P = .94$; for specificities, $P = .93$). Neither was the

184   difference statistically significant between the 2 groups when statistical analysis was made

185   independently for lateral (difference for sensitivities, $P = .47$; for specificities, $P = .88$) and

186   for medial menisci (difference for sensitivities. $P = .96$; for specificities, $P = .999$).

187   The kappa- values presented in Table 4 for interobserver agreement between readers

188   show moderate agreement (0.56 and 0.58), and the results presented in Table 5 for

189   intraobserver agreement show substantial or almost perfect agreement (0.70 and 0.85).

190

191   **DISCUSSION**

192

193   The principal finding of the present study was in concordance with our hypothesis; there

194   was no statistically significant difference in the diagnostic validity of MRI results between

195   the meniscal tears in acute knee trauma and in knee symptoms lasting over 6 months in

196   young adults. Magnetic resonance imaging detected meniscal tears with a relatively poor

197   overall sensitivity, whereas the specificity was good in both groups. The observation that the

198   sensitivity for lateral meniscus was clearly lower than that for the medial meniscus in both

199   groups is important to clinicians.

200   Several systematic meta-analyses have investigated the use of MRI in the diagnosis of

201   meniscal tears. [11, 16, 19] However, no previous studies comparing the diagnostic validity of

202   MRI between acute and chronic meniscal tears exist in the literature.

203   Only a few studies have been published investigating fresh meniscal tears by means

204   of MRI. The study of Lundberg et al[10] included 69 patients with acute traumatic knee

205   hemarthrosis, evaluated at an average of 3 days after the onset of trauma by 1.5-T MRI,

206   and arthroscopy was performed shortly afterward. The authors reported sensitivity of 74%

207   and specificity of 66% for medial meniscal tears, and sensitivity of 50% and specificity of

208   84% for lat- eral meniscal tears. Another small study concerning acute traumatic knee

209   hemarthrosis by Munshi et al[13] reported a sensitivity of 50% and a specificity of 86% for

210 detecting medial meniscal tears, and a sensitivity of 88% and   a specificity of 73% for

211 detecting lateral meniscal tears. The results of these 2 studies were   lower   than the

212 average overall results on meniscal tears previously documented in the literature. [11, 16, 19] One

213 study about traumatic knee hemarthrosis reported higher MRI sensitivities (94% for the

214 lateral and 83% for the   medial meniscus). [1]   In that study, however, specificities were

215 extremely poor—only 29% and 27%, respectively. Although the freshness of the meniscal

216 tears in the   studies of Lundberg et al[10]   and Adalberth et al[1]   was equal to group A in

217 our study, they did not investigate any chronic tears. A reliable comparison of the diagnostic

218 validity of MRI between acute and chronic meniscal tears can be performed only if the

219 materials and methods are similar for both groups. In addition, the study groups should be

220 homogeneous with respect to their age and health status. This kind of comparative study

221 does not exist in the previous literature. In the present study, using comparable materials and

222 methods, we found that there was   no statistically significant difference in the MRI

223 results   between acute traumatic meniscal tears and chronic tears. Lundberg et al[10]

224 suggested that the low diagnostic validity of MRI in acute knee injuries with

225 hemarthrosis may be attributed to the shifting paramagnetic properties of the blood

226 remains and the catabolic processes in meniscal and chondral tissues during the

227 hemoglobin degradation process. However, our results also suggest that effusion or

228 hemarthrosis do not weaken the diagnostic validity of MRI. Effusion or hemarthrosis was

229 present in most of the knees in group A but in only a very small number of knees in group B.

230 Mackenzie et al[11]   reassessed the diagnostic performance statistics of 22 studies with sample

231 sizes between 35 and 1014 and reported sensitivity of 93%, specificity of 84% and

232 accuracy of 89% for medial meniscal tears on MRI. The sensitivity for lateral meniscal tears

233 was somewhat lower (76%), whereas the specificity and accuracy were slightly higher,

234 94% and 91%, respectively. For both menisci, the results were 89%, 92%, and 91%,

235 respectively. The meta-analysis by Rappeport et al[19]   included 20 studies on suspected

236 meniscal tears with a total of 3171 patients. For the meniscal tears, the sensitivity of MRI

237 ranged from 71% to 100%, typically exceeding 85%, and the specificity ranged from

238 37% to 100%, frequently exceeding 90%. A more recent meta-analysis by Oei et al[16]

239 included 29 studies investigating MRI of the menisci and the cruciate ligaments of the

240 knee. Each study was conducted between 1991 and 2000 and comprised over 30 patients.

241 The pooled weighted sensitivity for the medial meniscal tears was 93.3% and the pooled

242 weighted specificity was 88.4%. For the lateral meniscal tears, the results were 79.3%

243 and 95.7%, respectively. These meta-analyses consisted of a large number of studies using a

244 variety of methods and samples, and generally, no special attention was paid to the

245 freshness of the lesions. Thus the intervals between the onset of the symptoms and MRI

246 varied widely and tended to be rather long.

247 In the multicenter analysis (n = 1094) by Fischer et al,[6] the overall sensitivity was 93%

248 for medial menisci and 69% for lateral menisci and the specificity was 84% and 94%,

249 respectively. However, results varied clearly between different centers, with the sensitivity

250 ranging from 80% to 94% for medial menisci and 66% to 86% for lateral menisci the

251 specificity varied from 58% to 85% and 87% to 96% respectively.

252

253 As noted above, most of the numerous diagnostic studies published have shown that MRI

254 allows good diagnostic performance in detecting meniscal tears. However, clearly poorer

255 results for the diagnostic validity of MRI have also been reported in studies not limited to

256 acute tears, with the lowest reported sensitivity for medial meniscal tears being 62%,[24] and

257 67% for lateral meniscal tears. [17] For both menisci, Niitsu et al[14] reported a sensitivity of

258 48%. The lowest specificities were reported by Raunest et al, [20] who found a specificity of

259 37% for medial meniscal tears, 69% for lateral meniscal tears, and 57% for both menisci.

260 The overall intraobserver agreement reported in this study ranged from substantial to almost

261 perfect, meaning that the same observer was able to interpret the images in a similar

262 manner repeatedly. The interobserver agreement was slightly lower, showing moderate

263 agreement.

264 Magnetic resonance imaging scans were performed on a 1.0-T scanner, which can be

265 considered a limitation because there are higher field strengths available today. However,

266 according to a comprehensive meta-analysis by Oei et al, [16] higher magnetic field strengths do

267 not significantly improve the diagnostic performance of MRI in meniscal tears. This finding

268 was confirmed in the study by Riel et al, [21] for example, and in the recently published study

269 by Sampson et al. [23]

270 Riel et al[21] reported sensitivity, specificity, and accuracy of 93%, 97%, and 95% for tears

271 of the medial meniscus and 82%, 96%, and 93% for tears of the lateral meniscus with use

272 of a 0.2-T scanner. Both the sensitivity and specificity were similar or slightly better with the

273 0.2-T MRI scanner as compared with the 3-T MRI scanner used by Sampson. However,

274 Ramnath et al[18] achieved slightly better results, particularly for the lateral meniscus, with

275 a sensitivity of 96% and a specificity of 89% for medial meniscal tears and a 94% sensitivity

276 and specificity for lateral meniscal tears. It should be noted that the availability of higher

277 field- strength scanners is still limited due to their higher costs.

278   The retrospective nature of this study can be considered as a limitation. The findings of the

279   MRI examination were available to the arthroscopist before the procedure, which may have

280   influenced the arthroscopy results. However, this is routine clinical practice, and the

281   orthopaedic surgeon was unaware that the results would be used in a study in the future.

282   The study has also noteworthy strengths. The homogeneity of our study population is

283   worth mention. The patients selected into this study comprised young military conscripts,

284   cadets, and officers aged 18 to 25 years. They had passed their entry medical examination to

285   military service as healthy and were able to perform physically demanding military training.

286   Degenerative changes of the menisci often originate in the third decade of life and increase

287   the susceptibility of menisci to injury. [15] As the maximum age of all patients included in this

288   study was 25 years, no degenerative changes were expected to be present.

289   It is possible that patients with chronic symptoms and false-negative MRI results were not

290   treated surgically at a higher rate than the acute group, thereby skewing the numbers.

291   However, it is unlikely that patient with a false-negative MRI result would be asymptomatic

292   during the physically demanding military service. As the availability of arthroscopy was

293   good, the procedure was performed despite a negative MRI if the knee pain was prolonged

294   and resulted in difficulties in performing the military training. The decreased MRI

295   sensitivity for tears of the lateral meniscus has been reported, [3, 6, 8, 10-11, 16, 21] and was also

296   confirmed in the present study. Arthroscopy might be considered more often in cases with

297   clinically suspected lateral meniscal tears than medial meniscal tears despite the negative MRI

298   findings. De Smet and Mukherjee[5] researched possible reasons for lower MRI sensitivity

299   in lateral meniscal tears. They found that lateral meniscal tears are more likely to be missed

300   if the tear involves only one third of the meniscus or is located in the posterior horn.

301   Rose and Gold[22] compared the accuracy of MRI to clinical examination in detecting

302   suspected meniscal tears and found that clinical examination was at least as accurate as MRI

303   for meniscal tears. Although our study did not deal with clinical examination, relatively

304   poor MRI sensitivity in meniscal tears indirectly emphasizes its value.

305   In conclusion, the diagnostic validity of MRI is similar for meniscal tears in acute knee

306   trauma and in knee symptoms lasting over 6 months in young adults. Our results also

307   suggest that effusion or hemarthrosis do not weaken the diagnostic validity of MRI. Magnetic

308   resonance imaging detected meniscal tears with a relatively poor overall sensitivity in both

309   groups. For clinical practice, this finding means that MRI failed to detect one third of the

310   meniscal tears in young adults regardless of the age of the tear. Despite negative MRI

311 findings, arthroscopy should be considered if justified by the patient's symptoms. However,

312 specificity was good in both groups, indicating a small number of false-positive findings.

313

314 **ACKNOWLEDGMENT**

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390 **FIGURE LEGENDS**

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392 **FIGURE 1.** A nineteen-year old conscript sustained a trauma to the left knee in a football

393 game. (A) Sagittal T2-weighted MRI scan of the left knee six days after injury showing a

394 displaced tear of the lateral meniscus accompanied with empty anterior meniscal recess

395 (arrow) and posteriorly displaced torn meniscus (arrowhead). (B) Arthroscopy nine days after

396 injury reveals a large bucket-handle type tear in the discoid lateral meniscus.

397

398 **FIGURE 2.** An eighteen year old conscript sustained a bending injury to the left knee in a

399 soccer game. MR image nine months after injury demonstrated a large tear of the medial

400 meniscus. A sagittal T2-weighted MR image demonstrated high signal lines extending to the

401 inferior meniscal surfaces (arrows). Arthroscopy five weeks after MRI revealed a bucket-

402 handle type tear of the medial meniscus.

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423 *Figure 1 A*

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433   *Figure 1B*
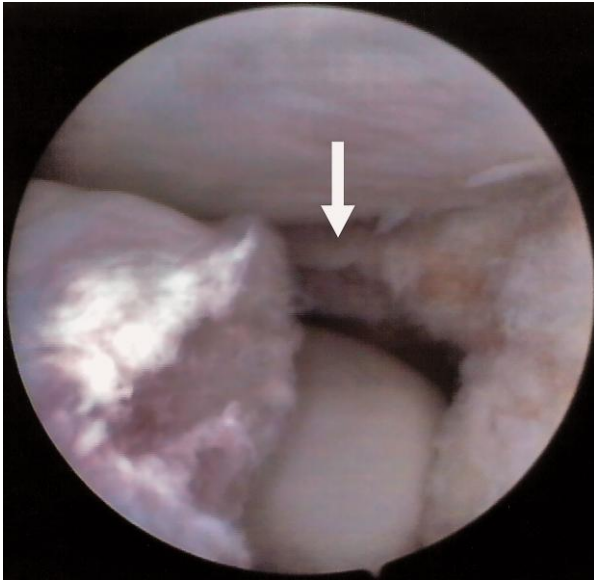
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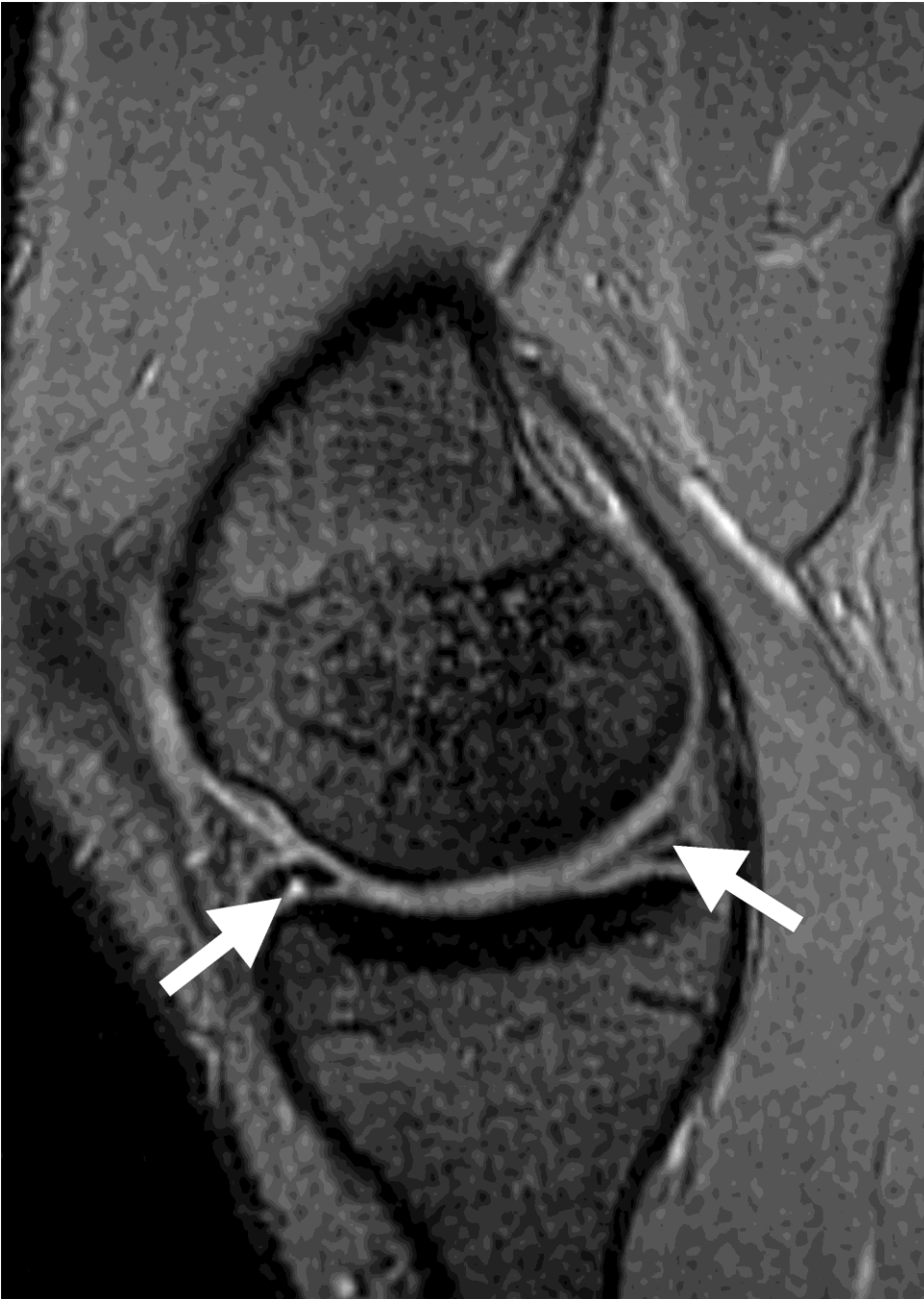
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Table 1.

Single table analysis for both menisci in group A

	Arthroscopy		
MRI	positive	negative	**total**
Positive	18	10	28
Negative	9	127	136
	27	137	164

460

Table 2.

Single table analysis for both menisci in group B

	Arthroscopy		
MRI	positive	negative	**total**
Positive	9	6	15
Negative	5	60	65
	14	66	80

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Table 3.

Diagnostic validity of 1.0-Tesla MRI in meniscal ruptures

Location	Parameter	Values and 95% CIs* are expressed in percentages	
		Group A	Group B
	Sensitivity	91.7 (64.6-98.5)	88.9 (56.5-98.0)
Medial Meniscus	Specificity	87.1 (77.3-93.1)	87.1 (71.2-94.9)
	Diagnostic accuracy	87.8 (79.0-93.2)	87.5 (73.9-94.5)
	Sensitivity	46.7 (24.8-69.9)	20.0 (3.6-62.5)
Lateral Meniscus	Specificity	98.5 (92.0-99.7)	94.3 (81.4-98.4)
	Diagnostic accuracy	89.0 (80.4-94.1)	85.0 (70.9-92.9)
	Sensitivity	66.7 (47.8-81.4)	64.3 (38.8-83.7)
Both Menisci	Specificity	92.7 (87.1-96.0)	90.9 (81.6-95.8)
	Diagnostic accuracy	88.4 (82.6-92.5)	86.3 (77.0-92.2)

*Confidence Intervals

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Table 4.

Kappa values for interobserver agreement between readers

	Kappa index	Interpretation
Group A, both menisci	0.58	moderate agreement
Group B, both menisci	0.56	moderate agreement
All patients, both menisci	0.57	moderate agreement

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Table 5.

Kappa values for intraobserver agreement between readers

	Kappa index	Interpretation
Group A, both menisci	0.70	substantial agreement
Group B, both menisci	0.85	almost perfect agreement
All patients, both menisci	0.76	substantial agreement

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Reliability of Clinical Findings and Magnetic Resonance Imaging for the Diagnosis of Chondromalacia Patellae

By Harri K. Pihlajamäki, MD, PhD, Paavo-Ilari Kuikka, MD, Vesa-Veikko Leppänen, MD,
Martti J. Kiuru, MD, PhD, and Ville M. Mattila, MD, PhD

*Investigation performed at the Centre for Military Medicine and the Department of Orthopaedic Surgery,
Central Military Hospital, Helsinki, Finland*

Background: This diagnostic study was performed to determine the correlation between anterior knee pain and chondromalacia patellae and to define the reliability of magnetic resonance imaging for the diagnosis of chondromalacia patellae.

Methods: Fifty-six young adults (median age, 19.5 years) with anterior knee pain had magnetic resonance imaging of the knee followed by arthroscopy. The patellar chondral lesions identified by magnetic resonance imaging were compared with the arthroscopic findings.

Results: Arthroscopy confirmed the presence of chondromalacia patellae in twenty-five (45%) of the fifty-six knees, a synovial plica in twenty-five knees, a meniscal tear in four knees, and a femorotibial chondral lesion in four knees; normal anatomy was seen in six knees. No association was found between the severity of the chondromalacia patellae seen at arthroscopy and the clinical symptoms of anterior knee pain syndrome (p = 0.83). The positive predictive value for the ability of 1.0-T magnetic resonance imaging to detect chondromalacia patellae was 75% (95% confidence interval, 53% to 89%), the negative predictive value was 72% (95% confidence interval, 56% to 84%), the sensitivity was 60% (95% confidence interval, 41% to 77%), the specificity was 84% (95% confidence interval, 67% to 93%), and the diagnostic accuracy was 73% (95% confidence interval, 60% to 83%). The sensitivity was 13% (95% confidence interval, 2% to 49%) for grade-I lesions and 83% (95% confidence interval, 59% to 94%) for grade-II, III, or IV lesions.

Conclusions: Chondromalacia patellae cannot be diagnosed on the basis of symptoms or with current physical examination methods. The present study demonstrated no correlation between the severity of chondromalacia patellae and the clinical symptoms of anterior knee pain syndrome. Thus, symptoms of anterior knee pain syndrome should not be used as an indication for knee arthroscopy. The sensitivity of 1.0-T magnetic resonance imaging was low for grade-I lesions but considerably higher for more severe (grade-II, III, or IV) lesions. Magnetic resonance imaging may be considered an accurate diagnostic tool for identification of more severe cases of chondromalacia patellae.

Level of Evidence: Diagnostic Level I. See Instructions to Authors for a complete description of levels of evidence.

Anterior knee pain is a very common disorder in adolescents and young adults[1,2]. However, the pathophysiology underlying anterior knee pain is controversial. It has been previously thought to be caused by chondromalacia patellae. Patellar tendinopathy, patellofemoral malalignment[2], or an imbalance in tissue homeostasis[3] have also been suggested to cause similar symptoms. The typical clinical symptoms of anterior knee pain syndrome include a deep-seated ache and retropatellar pain that worsens when climbing stairs, sitting with the knees flexed, and rising from a sitting position. Extending the knee against resistance may also cause pain, and a sense of insecurity may be felt during weight-bearing[4]. The importance of a reliable diagnosis is emphasized by the fact that the symptoms of anterior knee pain syndrome may re-

semble those of other conditions, such as a meniscal tear[5]. There is a substantial difference in the required treatment for these disorders, especially with regard to the potential need for surgical management. Physical signs of anterior knee pain, such as effusion, quadriceps wasting, and retropatellar crepitus, have been claimed to be more informative in the diagnosis of chondromalacia patellae[6]. However, none of these signs is considered specific for chondromalacia patellae[6].

Radiographs have not proven to be useful in the diagnosis of chondromalacia patellae until the disease is in the advanced stages[7,8]. A reliable diagnosis can be reached by using arthroscopy, as it allows a good view of the patellofemoral joint[9]. However, surgical treatment of chondromalacia patellae is indicated in <10% of patients[10], and the initial treatment of chondromalacia consists of a period of rehabilitation[11]. There is evidence that physical therapy can alleviate patellofemoral pain[12]. Arthroscopic smoothing of fibrillated and traumatized areas of articular cartilage has been used for grade-II, III, and IV chondromalacia, although the positive treatment outcomes may deteriorate over time[5,13]. If the arthroscopic examination does not reveal any arthroscopically treatable lesion, it may seem to be a costly diagnostic method unnecessarily consuming our limited health-care resources. Moreover, arthroscopy causes short-term functional disability, pain, and stress and involves risks related to anesthesia and surgery.

It would be beneficial if magnetic resonance imaging, which is a noninvasive diagnostic method, could confirm the diagnosis of chondromalacia patellae. It is a more comfortable procedure for the patient, and the risk of complications is lower than that associated with diagnostic arthroscopy. However, it is unclear whether magnetic resonance imaging can help to confirm the correct diagnosis of chondromalacia patellae in patients with anterior knee pain. In previous reports, the overall sensitivity of magnetic resonance imaging for the diagnosis of chondromalacia patellae has ranged between 26% and 100%, the specificity has ranged between 50% and 94%, and the diagnostic accuracy has ranged between 77% and 90%[14-19]. These studies have varied widely with regard to the imaging methods, patient samples, and grading systems utilized, which probably explains the different results. Several authors have reported that magnetic resonance imaging is more sensitive for detecting deep chondral lesions than it is for demonstrating superficial ones[15,18,20-22].

The purpose of the present study was to assess the correlation between clinical symptoms of anterior knee pain syndrome and chondromalacia patellae. We also assessed the reliability of 1.0-T magnetic resonance imaging, by comparing the results with those of arthroscopy, for the diagnosis of chondromalacia patellae in young adults. The hypothesis of this study was that magnetic resonance imaging would ensure the diagnosis of chondromalacia patellae at least in patients with more severe chondral lesions.

Materials and Methods

This prospective diagnostic study was performed during a three-year period at the authors' institution, which provided all surgical services for the entire armed forces of Finland at that time. All male citizens in Finland become eligible for mandatory military service at the age of eighteen years, and the majority of recruits are nineteen years old at the beginning of their basic training. The patients selected for this study were young military trainees who had been deemed healthy enough to pass the entry medical examination and were able to perform physically demanding military training. Physical and combat training for the recruits includes physical exercise causing increased loads on the lower limb and especially on the knees because kneeling and crawling are often included in the training activities. Combat training, marching, and other physical training activities were performed almost daily throughout the service period. Thus, anterior knee pain may interfere markedly with the performance of such military training and may threaten the ability to complete military service. Participation in this study was voluntary, and written informed consent was obtained from each patient. The study protocol was approved by the local ethics committee.

The inclusion criteria consisted of nontraumatic, prolonged anterior knee pain causing problems that interfered with military service. An orthopaedic surgeon performed physical examinations according to the standard policy of the institution. These examinations consisted of a systematic and methodical examination that included inspection; palpation; measurements of motion, muscle strength, limb lengths, and muscle girth; functional tests to assess walking gait, stationary running, hopping, and squatting; tests to detect mechanical or meniscal problems such as the McMurray test or Apley test; and evaluations of ligament stability, the extensor mechanism, and the popliteal space. Plain radiographs, including anteroposterior, lateral, and sunrise views, were made. The clinical symptoms of anterior knee pain syndrome were divided into three categories for assessment of their relationship with chondromalacia: (1) diffuse pain in the anterior part of the knee as a single symptom, (2) typical clinical anterior knee pain syndrome without patellofemoral crepitus or pain on manipulation of the patella, and (3) typical clinical anterior knee pain syndrome with patellofemoral crepitus and/or pain on manipulation of the patella. The exclusion criteria included a previous fracture, surgical procedure, or injury in the knee region.

The initial treatment for all patients experiencing anterior knee pain was nonoperative, consisting mainly of activity restrictions or rest and nonsteroidal anti-inflammatory drugs when necessary. In addition, before arthroscopy was considered, the patients were instructed and encouraged to perform exercises supervised by a physiotherapist. These included lower-extremity muscle strengthening with a concentration on the quadriceps. Arthroscopy was chosen when the response to nonoperative treatment was insufficient and when a reliable method was needed to verify the suspected diagnosis of chondromalacia patellae or to differentiate between chondromalacia patellae and other internal derangements of the knee. The only deviation from the standard policy of the institution was that magnetic resonance imaging of the knee was performed for all of the patients included in the study. Most patients underwent

the scan one day prior to the scheduled arthroscopy date. For patients who had already undergone magnetic resonance imaging of the knee as part of the normal clinical assessment and policy of the department, the scan was repeated for the purpose of the study to minimize the delay between the magnetic resonance imaging and the arthroscopy.

Plain radiographs, including anteroposterior, lateral, and sunrise views, were routinely made of all of the patients before the physical examination by an orthopaedic surgeon. In order to evaluate possible anatomic deviations of the patellofemoral joint, the following measurements and assessments were performed. On the sunrise radiographs, the patellar angle was measured between a line connecting the anterior aspects of the femoral condyles and a second line drawn along the lateral facet of the patella[23]. The sulcus angle was measured between lines extending from the deepest point of the intercondylar sulcus, medially and laterally, to the tops of the femoral condyles. A line bisecting the sulcus angle was compared with a line drawn from the apex of the sulcus angle through the lowest point of the articular ridge of the patella (the congruence angle) to detect possible lateralization of the patella. The sulcus angle was considered to be flat if it was <138°[24].

The magnetic resonance imaging performed for all patients prior to the knee arthroscopy was carried out with a 1.0-T scanner (Signa Horizon; GE Medical Systems, Milwaukee, Wisconsin) with a standard knee coil and a field of view of 10 to 16 cm. The slice thickness was 3 to 4 mm, with a 0.5 or 1.0-mm intersection gap. Sagittal T1 and T2*-weighted images, coronal proton density images with fat suppression, and axial three-dimensional T1-weighted fast spoiled gradient-recalled images with fat suppression were obtained routinely.

A musculoskeletal radiologist on duty initially evaluated the images with use of a standard protocol for interpreting magnetic resonance images. For the purpose of this prospective study, another musculoskeletal radiologist (M.J.K.) who was blinded to the previous magnetic resonance imaging and arthroscopy findings then reevaluated the images. These reevaluations differed from the original interpretation in three cases, and a decision was reached by consensus. The magnetic resonance images were recorded as showing either normal cartilage thickness or a loss of cartilage. Grading of chondromalacia with use of the magnetic resonance imaging was based on the arthroscopic grading system described by Shahriaree[11], with 0 indicating normal; I, softening or a blister as indicated by high signal intensity and swelling of the cartilage; II, fissuring; III, fragmentation and fissuring; and IV, full-thickness fissuring and exposed bone (Table I).

Arthroscopy was performed during the first day following the magnetic resonance imaging examination except in seven cases, in which the time period between the magnetic resonance imaging and arthroscopy ranged from two to four days. The experienced orthopaedic surgeon performing the arthroscopy evaluated the articular surfaces while blinded to the findings on the magnetic resonance imaging. The knees were examined systematically with use of a probe inserted into the knee joint. Under direct vision and with careful probing, special attention was paid to the patellar surface and the degree of fibrillation, fragmentation, and possible softening of the cartilage surface.

Chondral lesions identified by magnetic resonance imaging or arthroscopy were classified into four grades according to the system of Shahriaree[11] (Table I). All other internal derangements of the knee revealed by arthroscopy were recorded and taken into account. If deemed necessary on the basis of the arthroscopic findings, arthroscopic operations, postoperative mobilization, and follow-up examinations were carried out according to the standard practice of the institution.

Statistical Methods

To determine the validity of the 1.0-T magnetic resonance imaging for the diagnosis of chondromalacia patellae, the magnetic resonance imaging findings were compared with the arthroscopic findings, which served as the gold standard. A single table analysis was used to calculate the positive and negative predictive values as well as the sensitivity, specificity, and diagnostic accuracy of magnetic resonance imaging. The Fisher exact test was used in two-way tables. Ninety-five percent confidence intervals were calculated with the Wilson method. When the results were calculated for grade-I chondromalacia patellae, only arthroscopically detected grade-I lesions were taken into account as positive results (the gold standard) for chondromalacia, and they were compared with the magnetic resonance imaging results (with grade 0 on the images considered negative and grades I through IV considered positive). Results for grades II, III, and IV were calculated with arthroscopically detected grade-II, III, and IV lesions considered positive and compared with the magnetic resonance imaging results (with grade 0 on the images considered negative and grades I through IV considered positive).

Source of Funding

There was no external funding source for the investigation.

Results

Fifty-six patients (fifty-four men and two women) met the inclusion criteria for the present study. The median age of the patients was 19.5 years (range, eighteen to twenty-five years). Twenty-one patients had only one knee examined, and the remaining thirty-five had both knees examined. Altogether, ninety-one knees were examined but, in bilateral cases, one knee was randomly selected for the study in order to ensure the independence of the observations.

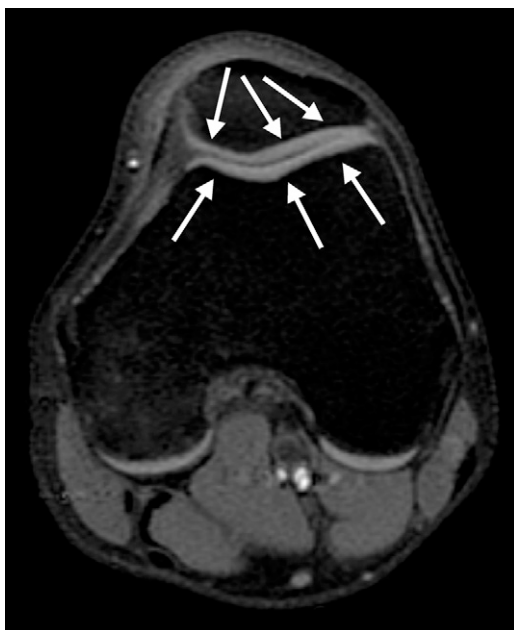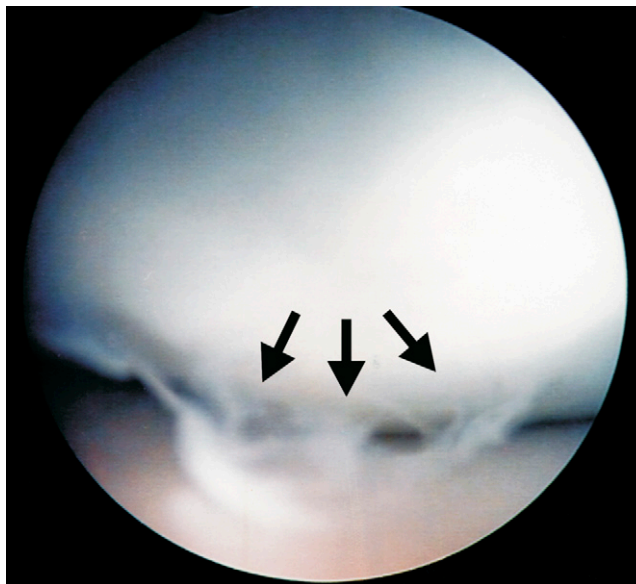| TABLE I Classification of Chondromalacia Patellae According to the System Described by Shahriaree[11]	
Grade	
I	Fibrillation
II	Fissure formation
III	Fragmentation
IV	Crater formation and eburnation

Fig. 1-A

Fig. 1-B

Figs. 1-A and 1-B A nineteen-year-old man reported chronic activity-related pain in the left knee. Clinical examination revealed patellofemoral crepitus suggestive of chondromalacia patellae. **Fig. 1-A** An axial fat-suppressed T1-weighted magnetic resonance image of the knee showed intact cartilage surfaces (arrows). **Fig. 1-B** Subsequent arthroscopy showed changes suggestive of grade-I chondromalacia on both facets of the patella (arrows). Probing revealed softening of the cartilage. On the femoral side, the cartilage surfaces were normal, and gliding of the patella in the sulcus was unobstructed.

All of the fifty-six patients were determined to have anterior knee pain on the basis of the clinical examination by an experienced orthopaedic surgeon. Arthroscopy confirmed the presence of chondromalacia patellae in twenty-five (45%) of the fifty-six knees. Twenty knees (36%) had signs of chondromalacia patellae on the magnetic resonance images (Figs. 1-A and 1-B). With regard to the detection of chondromalacia patellae, the positive predictive value of magnetic resonance imaging was 75% (95% confidence interval, 53% to 89%), the negative predictive value was 72% (95% confidence interval, 56% to 84%), the sensitivity was 60% (95% confidence interval, 41% to 77%), the specificity was 84% (95% confidence interval, 67% to 93%), and the diagnostic accuracy was 73% (95% confidence interval, 60% to 83%). Of eight patients with a grade-I lesion on arthroscopy, one had a true-positive finding on magnetic resonance imaging, so that magnetic resonance imaging had a sensitivity of 13% (95% confidence interval, 2% to 49%) for the detection of grade-I lesions. The number of true-positive magnetic resonance imaging findings was higher for grade-II, III, or IV lesions (fourteen of seventeen patients), and the sensitivity was 83% (95% confidence interval, 59% to 94%) for detection of those lesions. The results of magnetic resonance imaging and arthroscopy for the different grades of chondromalacia are presented in Table II. The kappa value for the overall measure of agreement across the five levels was 0.368 (p < 0.001).

Eight of the twenty-five arthroscopically confirmed cases of chondromalacia patellae were grade I, nine were grade II,

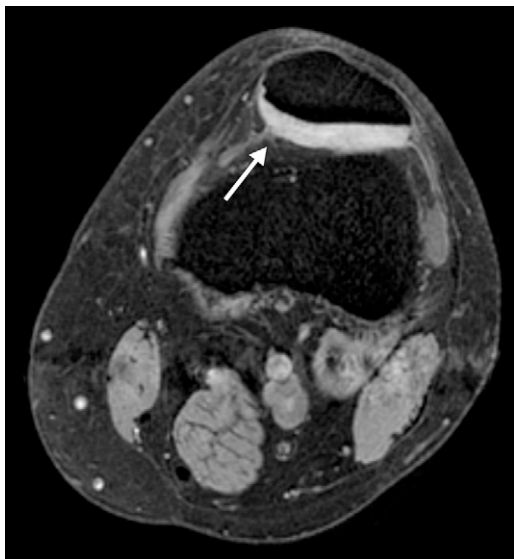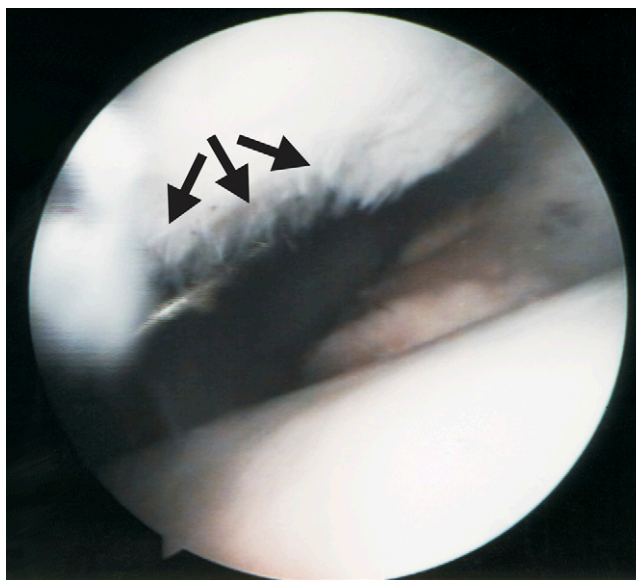| TABLE II Magnetic Resonance Imaging and Arthroscopic Findings in Fifty-six Knees						
Magnetic Resonance Imaging Grade	Arthroscopy Grade					
	0 (Negative)	I (Positive)	II (Positive)	III (Positive)	IV (Positive)	Total
0 (negative)	26	7	3	0	0	36
I (positive)	1	0	0	1	0	2
II (positive)	2	1	5	3	0	11
III (positive)	2	0	1	4	0	7
IV (positive)	0	0	0	0	0	0
Total	31	8	9	8	0	56

Fig. 2-A

Fig. 2-B

Figs. 2-A and 2-B A twenty-three-year-old man with activity-related swelling of both knees and patellofemoral pain since the start of military service. Plain radiographs demonstrated a flat sulcus angle in both knees. **Fig. 2-A** An axial fat-suppressed T1-weighted magnetic resonance image of the left knee showed some signal variation on the articular surface of the patella, including slight unevenness suggestive of the initial stage of grade-II cartilage defect formation (arrow). **Fig. 2-B** Arthroscopy showed smooth, even articular surfaces on the femoral aspect of the patellofemoral joint. The medial aspect of the patella showed grade-III cartilage damage, which also extended to the lateral aspect (arrows). The size of the damaged area is 2×2.5 cm, but the defect does not reach the subchondral bone. The fragmented areas of cartilage were trimmed by shaving.

eight were grade III, and none were grade IV (Figs. 2-A and 2-B). In eight knees, diffuse anterior pain was the only symptom. The typical clinical picture of anterior pain without patellofemoral crepitus or pain on manipulation of the patella was present in twelve knees, and the typical clinical picture of anterior pain with patellofemoral crepitus and/or pain on manipulation of the patella was found in thirty-six knees. No association was found between the severity of chondromalacia patellae seen on arthroscopy and the clinical symptoms of anterior knee pain syndrome (p = 0.83).

Of the fifty-six knees with anterior knee pain, twenty-five (45%) had a synovial plica; four, a meniscal tear; four, a femorotibial chondral lesion; and six, normal anatomy without any abnormal arthroscopic findings. All arthroscopic findings (one or more per knee) and their correlation with the clinical symptoms and physical signs are shown in Table III.

Plain radiographs were made of forty-three knees with anterior knee pain, and they showed normal findings in thirty-six of them (Table IV). Subluxation or lateralization of the patellae was found in six knees, a flat sulcus angle was found in three knees, Osgood-Schlatter disease was detected in one knee, and surface irregularity of the patellar facets was seen in one knee. The subsequent arthroscopy performed for the current study demonstrated chondromalacia patellae in fourteen of the thirty-six knees with normal radiographic findings.

TABLE III Symptoms and Physical Signs, and Arthroscopic Findings						
Symptoms and/or Physical Signs	Chondromalacia Patellae	Synovial Plica	Meniscal Rupture	Femorotibial Chondral Lesion	Normal Findings	Total Number of Findings
Diffuse anterior knee pain as single symptom (n = 8 patients)	1	4	0	0	3	8
Typical clinical symptoms without patellofemoral crepitus or pain on manipulation of patella (n = 12)	6	7	0	0	0	13
Typical clinical symptoms with patellofemoral crepitus and/or pain on manipulation of patella (n = 36)	18	14	4	4	3	43
Total	25	25	4	4	6	64

TABLE IV Radiographic and Arthroscopic Findings		
	Findings on Plain Radiographs	Arthroscopically Confirmed Chondromalacia Patellae in Same Knee
Normal radiographic findings	36	14
Subluxation/lateralization	6	4
Flat sulcus angle	3	2
Osgood-Schlatter disease	1	1
Surface irregularity of patellar facets	1	0

Discussion

The purposes of this study were to assess the correlation of clinical symptoms of anterior knee pain syndrome and chondromalacia patellae and to define the reliability of 1.0-T magnetic resonance imaging in the diagnosis of chondromalacia patellae in young adults. Our hypothesis was that magnetic resonance imaging would confirm the diagnosis of chondromalacia patellae at least in the case of more severe, deeper chondral lesions. In our study, chondromalacia patellae was found in less than half of the patients with anterior knee pain and 1.0-T magnetic resonance imaging was accurate in identifying more severe cases of chondromalacia patellae.

The principal finding of the present study was that there is no correlation between the presence of softened articular cartilage (chondromalacia patellae) and clinical symptoms of anterior knee pain syndrome. This finding is supported by previous reports in the literature that also alluded to the absence of pathognomonic symptoms[6]. According to our results, diffuse anterior knee pain as the sole symptom seems to exclude a diagnosis of chondromalacia patellae fairly reliably because the diagnosis was confirmed in only one of eight patients with that symptom alone. Chondromalacia patellae was seen in only half of the patients with typical clinical symptoms without patellofemoral crepitus or pain on manipulation of the patella. Our results correspond with those of Leslie and Bentley, who found that only 60% of patients with clinically diagnosed anterior knee pain and retropatellar crepitus had chondromalacia[6]. Thus, the association between symptoms and the identification of chondromalacia patellae with arthroscopy is not clear[3]. In addition, an important finding was the lack of an association between the severity of chondromalacia patellae and the clinical symptoms, which contradicted the observations reported by Kettunen et al., who reported that patients with more severe cartilage lesions of the patella or the femoral trochlea had more subjective symptoms and functional limitations than those without lesions or with small cartilage lesions[25]. The findings of the present study suggest that chondromalacia patellae cannot be distinguished by symptoms and signs on physical examination.

In addition to chondromalacia patellae (softening of the patellar articular cartilage), a medial synovial plica of the knee was a common arthroscopic finding in patients experiencing anterior knee pain. It was previously suggested that a medial synovial plica can cause symptoms, possibly by generating chondromalacia[26]. In the present sample, a medial synovial plica was detected arthroscopically in nearly half of the knees, but its association with symptoms must also be evaluated critically. Previous reports showed no correlation between the size of the plica and the severity of the symptoms[27,28] and that even smaller plicae may impinge on the adjacent cartilage of the femoral condyle[29]. Moreover, recent reports suggest that, although aspects of the pathomechanism of plica syndrome remain unclear, arthroscopic resection should be considered if incapacitating knee pain is accompanied by an arthroscopic finding of a medial plica of the knee[27,29,30].

In the study by Lee et al., the sensitivity of magnetic resonance imaging in detecting all of the grades of chondromalacia patellae was 57%[15], which is close to the sensitivity of 60% found in our study. Using T2-weighted magnetic resonance imaging, McCauley et al.[14] found a slightly higher sensitivity (72%), an almost equal specificity (87%), and a slightly higher accuracy (79%) compared with what we found in our study. Using T2-weighted magnetic resonance imaging, Handelberg et al.[19] reported an accuracy (82%) similar to that reported by McCauley et al. However, it has also been reported that T2-weighted magnetic resonance imaging may produce many false-negative results[20]. Other results in the literature have deviated more substantially from those in our study. The highest sensitivity (100%) was achieved with T2-weighted spin-echo pulse sequences in the sagittal and axial planes and with a three-dimensional fast sequence in the sagittal plane[19]. An almost equally high sensitivity (99%) was reported for three-dimensional spoiled gradient-recalled imaging with fat suppression after intravenous injection of contrast medium[31]. However, the combination that provided the highest sensitivity led to poorer specificity (50%). The highest specificity (94%) was achieved with spectral presaturation with inversion recovery sequences[16].

On the basis of the differences among the chondromalacia patellae grades, with a sensitivity of only 13%, grade-I chondral defects cannot be reliably detected with use of 1.0-T magnetic resonance imaging. The imaging sensitivity was considerably higher (83%) for grades II and III. Although no patients in the study had grade-IV chondromalacia patellae, our results clearly indicated that the sensitivity was highest for the deepest lesions. This finding is consistent with those presented previously[15,20,21]. Gagliardi et al., using the same chondromalacia patellae grading system[11] that we used, reported a sensitivity of 0% for grade-I chondromalacia patellae with all of their imaging sequences[20]. For grade-II and III lesions, the sensitivity was between 13% (proton-density-weighted magnetic resonance imaging) and 47% (T2-weighted imaging), and, for grade-IV lesions, it was between 50% (spoiled gradient-recalled imaging) and 75% (T1-weighted, T2-weighted, and proton-density-weighted imaging)[20]. The sensitivities reported by Gagliardi et al. for all of the sequences that they used were lower than the sensitivities found in the present study. Murphy

used T2*-weighted three-dimensional gradient-echo magnetic resonance imaging and reported results very similar to ours, with a sensitivity of 83% for grade-III and IV lesions[21]. Lee et al. reported a higher sensitivity—94% for grade-III and IV chondromalacia patellae with use of axial inversion recovery-fast spin-echo imaging[15]. However, on the basis of the present study, magnetic resonance imaging should be considered instead of arthroscopy for patients with prolonged anterior knee pain.

Plain radiographs have been considered inadequate for the identification of early cartilage damage[7,8]. However, it has been suggested that chondromalacia patellae might frequently be accompanied by subluxation of the patella or a flat sulcus angle[32,33]. Contrary results have been reported in studies concerning anterior knee pain[34] and arthroscopically diagnosed chondromalacia patellae[6]. Although our results seem to support the latter studies[6,34], no conclusion can be drawn from the abnormal findings reported here because of their small number. For example, although it may seem that chondromalacia patellae is accompanied by a flat sulcus angle, the very small number of cases with such an angle and the seemingly normal articular surfaces on these images do not support such a conclusion.

Our study has several noteworthy strengths, including the prospective design and the homogeneity of the study population. Our study sample consisted of young military trainees between eighteen and twenty-five years of age, who all were deemed healthy enough to pass their military entry medical examination. All were expected to have attained, after completion of their military basic training, a physical level enabling them to march or ski, while carrying a full military pack weighing 25 kg and a rifle, a distance of 15 km on two consecutive days while maintaining fitness for battle. Due to the compulsory nature of the military service, the study participants reflect the young adult male population of the country. Moreover, the age group that we studied is optimal because individuals in that group do not normally have degenerative chondral changes such as osteoarthritis. This relatively large group of skeletally mature young adults underwent a uniform examination and treatment for anterior knee pain according to the policy of one institution. The standard methods and protocols of the institution were used for the evaluation of clinical symptoms, plain radiographs, magnetic resonance images, and arthroscopic findings. Magnetic resonance imaging was ordinarily performed on the day prior to the arthroscopy to avoid possible bias caused by any delay.

The strength of the magnetic resonance imaging field used in the present study (1.0 T) may be considered a limitation, although it is unclear whether higher field strength might have resulted in a more reliable diagnosis of chondromalacia patellae. As mentioned in the Results section, a total of ninety-one knees were examined but, in cases of bilateral findings, only one knee was randomly selected for the study. This limited the number of the knees in the present study and can be considered a limitation.

In conclusion, chondromalacia patellae cannot be diagnosed on the basis of symptoms or with current methods of physical examination. The present study demonstrated no correlation between the severity of the chondromalacia patellae and the clinical symptoms of anterior knee pain syndrome. Thus, these symptoms should not be used as an indication for knee arthroscopy. The sensitivity of magnetic resonance imaging for the detection of grade-I lesions was low and could not confirm the diagnosis of chondromalacia patellae. However, the sensitivity of magnetic resonance imaging was considerably higher for the detection of more severe (grade-II or III) lesions, and 1.0-T magnetic resonance imaging may be considered an accurate diagnostic tool for the identification of more severe cases of chondromalacia patellae. In addition to chondromalacia patellae, a medial synovial plica of the knee was a common arthroscopic finding in young adult patients experiencing anterior knee pain. ■

Harri K. Pihlajamäki, MD, PhD
Paavo-Ilari Kuikka, MD
Vesa-Veikko Leppänen, MD
Martti J. Kiuru, MD, PhD
Ville M. Mattila, MD, PhD
Research Unit, Centre for Military Medicine, P.O. Box 50, FIN-00301 Helsinki, Finland. E-mail address for H.K. Pihlajamäki: Harri.Pihlajamaki@helsinki.fi

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Knee injuries related to sports in young adult males during military service – Incidence and risk factors

P.-I. Kuikka[1], H. K. Pihlajamäki[1], V. M. Mattila[1,2]

[1]*Centre for Military Medicine; and Department of Orthopaedic Surgery, Central Military Hospital, Helsinki, Finland,* [2]*Department of Orthopedics and Traumatology, Tampere University Hospital, Tampere, Finland*
Corresponding author: Paavo-Ilari Kuikka, MD, Centre for Military Medicine, Research Unit, PO Box 50, FIN-00301 Helsinki, Finland. Tel: +358 9 181 25814, Fax: +358 9 181 25827, E-mail: pikuikka@student.uef.fi

The population-based incidence and risk factors for knee injuries in young adults were assessed in Finnish male conscripts performing their compulsory military service (n = 128 584). The main outcome variables were (1) hospitalization due to knee injuries overall and (2) hospitalization due to knee disorders as categorized into specific International Classification of Diseases, tenth revision diagnoses (cruciate and collateral ligament tears, meniscal tears, traumatic chondral lesions, and patellar dislocations). Person-time injury-incidence rates were calculated by dividing the number of persons with a diagnosed knee injury by the total exposure time of 97 503 person-years. The number of subjects with surgical operations and military service class changes indicative of longer term notable disability are also reported. Risk factor analyses were performed by logistic regression. The person-based incidence of hospitalizations for knee injury was 11 cases per 1000 person-years [95% confidence interval (CI): 10.4–11.7]. The most important risk factors were higher age (odds ratio 1.7; 95% CI: 1.3–2.2) and obesity (odds ratio 1.6; 95% CI: 1.03–2.5). Two thirds of all subjects hospitalized for knee injuries had surgery, and one third had longer term notable disability. These findings indicate that knee injuries cause a significant burden of hospitalizations, often leading to surgery and longer term disability.

Knee injuries are frequently seen in the everyday clinical practice of orthopedic surgeons and general practitioners. The incidence of all knee injuries is greatest in patients under 30 years of age and especially in males (Kannus & Jarvinen, 1989; Majewski et al., 2006; Gianotti et al., 2009). In the general population, the incidence is suggested to be 11 cases per 1000 person-years (Kannus & Jarvinen, 1989). In most of the previous incidence rate studies, however, only specific knee diagnoses, such as tears of the anterior cruciate ligament (ACL; Anderson et al., 2001; Bodor, 2001; Parkkari et al., 2008) were evaluated, or the study sample comprised a definite, restricted sample of a special subpopulation, such as a sports team or patient catchment of a specialized clinic. Comprehensive studies with population-based sample are scarce, and thus data of overall incidence rates of knee injuries are difficult to generalize for application in clinical practice.

Majewski et al. (2006) conducted a comprehensive 10-year study of the epidemiology of knee injuries in sports. Almost half of the injuries were sustained by those aged 20–29. The most common injury was a knee sprain without clearly identifiable internal derangement, and the most common diagnoses were ACL tear (20.3%), medial meniscus (MM) tear (10.8%),

chondral lesion (10.6%), medial collateral ligament (MCL) tear (7.9%), contusion injury due to direct trauma (5.5%), lateral meniscus (LM) tear (3.7%), and patellar dislocation (3.3%).

Participation in sports is a significant risk factor for knee injuries, and as many as half of all knee injuries occur during sports activities (Kannus & Jarvinen, 1989). As many as 40% of sports injuries are knee injuries (Majewski et al., 2006). The association between aerobic fitness and anthropometric properties of knee injuries is not well-known. A higher age increases the risk of disabling knee injuries among young men in the U.S. army (Sulsky et al., 2000). Higher age, obesity, and poor results in a running test are suggested to be risk factors for musculoskeletal injuries as a whole (Heir & Eide, 1996). Participation in sports, weak quadriceps muscle, and female sex are associated with ACL tears (Anderson et al., 2001; Bodor, 2001; Parkkari et al., 2008). Participation in sports, weak quadriceps muscle, and older age are known risk factors for meniscal tears (Baker et al., 2002, 2003; Canale ebST, 2003). Patellar dislocations typically occur in young adults during sports (Atkin et al., 2000). Risk factors for acute patellar dislocations are suggested to be higher height and weight (Sillanpaa et al., 2008). Overweight and older age

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predispose young adult males to deeper chondral lesions (Eskelinen et al., 2004).

Population-based studies of the incidence of knee injuries as well as the risk factors for those injuries in the literature are sparse. Therefore, we conducted a population-based study among Finnish conscripts to assess the incidence and risk factors for knee injuries leading to hospitalization.

Materials and methods

Study population

The study population comprised Finnish male conscripts performing their compulsory military service between the years 1998–2002. Military service is compulsory for all Finnish males, and thus conscripts represent an extensive sample from the general population of young adult males in Finland. Approximately 80% of all males in Finland perform military service. Chronic diseases such as diabetes, asthma, and mental health problems are the main reasons for exemption from military service. Before entering military service, all conscripts had to pass a medical examination performed by a physician. Health status was re-checked by a physician also during the first week of service, indicating that conscripts were healthy young men. In case that medical examination revealed knee injuries or previous operations that cause severe disability, the conscript was discharged from the service. The age of the conscripts varies between 18 and 30 years (median, 20 years). A new batch of conscripts enters twice a year, in January and in July. The mandatory military service period ranges from a maximum of 362 days (officers; conscripts trained for particularly demanding duties) to 270 days (conscripts trained for work requiring special skills), with a minimum of 180 days (other rank-and-file duties).

Military service begins with a basic training period of 8 weeks consisting of increasing levels of walking, marching, bicycling, running, and other physical activities. The intensity of military training gradually increases, averaging 17 h per week. Moreover, conscripts participate in other physical training exercises, such as floorball, weight training, jogging, and circuit training for 7 h per week on average. Over the following 4 months of service (special and team training period), the amount of moderate and high-intensity physical training is maintained at the same level in different companies. During the first 6 months of military service, conscripts are expected to complete approximately 450 h of instructed physical training (19 h per week). More specific details of the military service in Finland have been published previously (Mattila et al., 2007b; Taanila et al., 2009).

Hospitalization data

During military service, all conscripts are required to use only the services of the primary military health-care units and Central Military Hospital when in need of medical treatment. Information from all hospital and health-care unit admissions in Finland is collected to the National Hospital Discharge Register (NHDR). The coverage and accuracy of the NHDR is good (Salmela & Koistinen, 1987; Keskimaki & Aro, 1991; Mattila et al., 2008). These factors together allow for extensive and very reliable documentation of all hospitalizations due to knee injuries during the military service.

Data obtained from the NHDR included all military conscripts admitted alive to primary military health-care units and the Central Military Hospital as inpatients from January 1, 1998, to December 31, 2002. Injuries that occurred during the conscript's leisure time or on the way to a vacation or returning to the garrison, as well as those occurring during military service were included. Information of hospitalizations due to knee injuries was collected from the NHDR with diagnoses coded according to the International Classification of Diseases, tenth revision (ICD-10; WHO, 1992). Inclusion criteria were hospitalization with main or secondary diagnose of ACL and posterior cruciate ligament (PCL) tears (S83.5), fresh and old meniscal tears (S83.2, M23.2), MCL and lateral collateral ligament (LCL) tears (S83.4), traumatic chondral lesions (S83.3), and patellar dislocations (S83.0). Information about surgical operations was also collected.

Disability data

Data concerning longer term disability (service class change) caused by knee injuries were obtained from the national register of the Finnish Defense Forces. The register contains information regarding ICD-10 diagnoses leading to a service class change. Register contained main diagnose and one secondary diagnose, and both were taken into account when calculating number of subjects with service class change.

When a knee injury causes disability and problems coping with military service for approximately 2– 3 weeks or more, a service class change is considered by the garrison physician. A final decision is made only after thorough clinical examination, including radiographs, and magnetic resonance imaging (MRI) and arthroscopy when needed. When the service class is lowered, military service is prematurely interrupted, or the conscript is transferred to a physically less-demanding duty. A service class change due to a knee injury diagnosis is a reliable indicator of longer term disability to cope with normal military service.

Follow-up

The follow-up time for each conscript was calculated from entry into military service to the first hospitalization due to a knee injury or to the discharge from the service if no hospitalizations occurred. The total exposure time for the population at risk was calculated from a register containing the total number of realized service days during the study period. The total exposure time for the population at risk during the study period was 97 503 person-years.

Aerobic fitness and anthropometric measurements

For the purposes of data analysis, height and weight were divided into quartiles. Age was divided into three groups matched by size. Body mass index (BMI) was computed as the weight in kilograms divided by the square of the height in meters (kg/m^2). The International Classification of adult underweight, overweight, and obesity according to BMI by the World Health Organization was used to divide the conscripts into different categories as follows: BMI <18.5 was classified as a underweight, 18.5–24.99 as normal, 25–29.99 as overweight, and ≥30 as obese. Aerobic condition was measured by determining the distance covered in a 12-min Cooper running test. Results were divided in four categories as follows: <2200 m (poor), 2200–2599 m (fair), 2600–2999 m (good), and ≥3000 m (very good). The Finnish Defence Force muscular strength test includes distance of horizontal jump without speed and number of sit-ups, push-ups, pull-ups, and back lifts performed in 1 min, with values ranging from 0 to 3 points per movement. A total of 0–4 points was considered poor, 5–8 points as fair, 9–12 points as good, and 13–15 points as very good.

Person-time incidence rates for knee injuries leading to hospitalization were calculated by dividing the number of persons with a knee diagnosis by the total exposure time, and 95% confidence intervals (CI) were reported. Subjects might have been hospitalized multiple times for the same diagnosis, and for this reason, only first admissions were taken into account when calculating the incidence. The number of possible readmissions, surgical operations, and service class changes by diagnoses are also reported.

Risk factor analyses for knee injuries were calculated by logistic regression. The main outcome variables were (1) hospitalization due to knee injuries in general and (2) hospitalization due to knee injuries as categorized into the specific ICD-10 diagnoses [ACL and PCL tears (S83.5), fresh and old meniscal tears (S83.2, M23.2), MCL and LCL tears (S83.4), traumatic chondral lesions (S83.3), and patellar dislocations (S83.0)]. Risk factors analyzed were the conscript's age, length of military service, weight, height, BMI, and physical performance as measured with Cooper's 12-min running test and muscle strength. First, we constructed a logistic regression model including age, the length of military service, and risk factors one by one. Only those risk factors significantly associated ($P < 0.05$) with outcome were included into the final logistic regression model. Because BMI and weight had a strong interaction, only BMI was included into the final logistic regression model. Odds ratios (OR) were calculated with a 95% CI. Statistical analyses were performed using SPSS 17.0 (IBM Corporation, NY, USA) for Windows software.

The Medical Ethics Committee of the institution provided approval for this study.

Results

The total number of 18–30-year-old male conscripts who started their military service during the study period of January 1, 1998, to December 31, 2002, was 128 584. The total exposure time for the population at risk during the study period was 97 503 person-years. The mean duration of military service was 9 months.

Table 1. Incidence (per 1000 person-years) of hospitalization due to knee injuries among 128 584 conscripts in 1998–2002 in Finland

	Cases	Incidence*	95% CI
Men			
Old meniscal tear	298	3.1	2.7–3.4
Patellar dislocation	236	2.4	2.1–2.7
Fresh meniscal tear	214	2.2	1.9–2.5
ACL/PCL tear	208	2.1	1.9–2.4
MCL/LCL tear	99	1.0	0.8–1.2
Fresh chondral lesion	18	0.2	0.1–0.3
Total	1073	11.0	10.4–11.7

*Cases per 1000 person-years.
ACL, anterior cruciate ligament; CI, confidence interval; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

The total number of subjects with a knee injury leading to at least one hospitalization was 1073 (0.8% of all conscripts), and the person-time hospitalization incidence rate was 11 cases per 1000 person-years (95% CI: 10.4–11.7). Two hundred ninety-eight subjects (27.8% of the hospitalizations) were hospitalized for old meniscal tear followed by acute patellar dislocation (236 cases/22.0%), fresh meniscal tear (214 cases/19.9%), ACL/PCL tear (208 cases/19.4%), MCL/LCL tear (99 cases/9.2%), and fresh chondral lesion (18 cases/1.7%). Detailed results for person-time hospitalization incidence rates are presented in Table 1.

Table 2 presents the readmission status and number of surgical operations of any kind for each hospitalized subject. Approximately 30% of all cases had consecutive hospitalizations after the first admission. Surgery was required in 59% of the cases, and knee injuries led to a service class change (notable disability) in 32% of the cases.

Subjects hospitalized for ACL/PCL tears had readmission in 45% of the cases, and more than half of the primary cases led to a service class change. Hospitalizations for patellar dislocation also led to many readmissions but led to a service class change in only 23% of the cases. Meniscal tears and fresh chondral lesions led to a service class change in approximately one third of the cases. MCL/LCL tears led to a service class change in only 11% of the cases. Subjects hospitalized for old meniscal tears had surgery in 83% of the cases. Corresponding numbers were 62% for fresh meniscal tears, 67% for ACL/PCL tears, 44% for fresh chondral lesions, 31% for patellar dislocations, and 28% for MCL/LCL tears.

Mean time from the beginning of the service to the first hospitalization was 126 days. Twenty-five percent of the injuries occurred during the basic training period (first 8 weeks, days 1–56), 49% during the special and team training period (days 57 to 180) and 26% during the leadership period (days 180 to 365). Corresponding numbers for old meniscal tears were 13%, 57%, and 31%, for patellar dislocations were 43%, 34%, and 23%, for fresh meniscal tears were 22%, 54%, and 24%, for cruciate ligament tears were 18%, 51%, and 31%, for

Table 2. Readmission status, service class changes, and need for surgical operations among Finnish conscripts with knee injury in 1998–2002

	Primary admission (N of subjects)	Cases requiring readmission (%)	Service class change (%)	Cases requiring surgery (%)
Old meniscal tear	298	70 (23)	91 (31)	248 (83)
Patellar dislocation	236	84 (36)	55 (23)	73 (31)
Fresh meniscal tear	214	60 (28)	66 (31)	133 (62)
ACL/PCL tear	208	94 (45)	110 (53)	140 (67)
MCL/LCL tear	99	10 (10)	11 (11)	28 (28)
Fresh chondral lesion	18	3 (17)	6 (33)	8 (44)
total	1073	321 (30)	339 (32)	630 (59)

ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

Table 3. Logistic regression predicting hospitalization due to knee injuries among 128 584 Finnish conscripts in 1998–2002

Predictor	Odds ratio	95% CI for odds ratio	
		Lower	Upper
Age			
18–19	1		
20	1.0	0.9	1.3
21–30	1.7	1.3	2.2
Length of military service			
180 days	1		
270 days	1.5	0.9	2.4
360 days	1.3	1.03	1.5
Underweight			
No	1		
Yes	0.7	0.4	1.1
Overweight and obesity			
No	1		
Overweight	1.0	0.8	1.3
Obesity	1.6	1.03	2.5
Muscle strength			
Lowest quartile	1		
Second quartile	1.0	0.7	1.3
Third quartile	1.1	0.8	1.5
Highest quartile	1.6	1.2	2.4

CI, confidence interval.

Table 4. Multivariate logistic regression model of specific knee diagnoses among 128 584 Finnish conscripts in 1998–2002. Only significant variables are shown

Predictor	Odds ratio	95% CI for odds ratio	
		Lower	Upper
Patellar dislocation			
Overweight and obesity			
No	1		
Overweight	1.1	0.8	1.7
Obesity	2.0	1.1	3.5
Age			
18–19	1		
20	1.4	1.01	2.0
21–30	1.1	0.6	1.9
MCL/LCL tear			
Overweight and obesity			
No	1		
Overweight	0.9	0.4	2.0
Obesity	3.1	1.4	7.0
Fresh meniscal tear			
Weight			
Lightest quartile	1		
Second quartile	1.8	0.97	3.4
Third quartile	1.9	0.99	3.5
Heaviest quartile	2.6	1.4	5.0
Muscle strength			
Lowest quartile	1		
Second quartile	1.0	0.4	2.5
Third quartile	2.2	0.8	6.0
Highest quartile	3.5	1.04	12.2
Old meniscal tear			
Age			
18 to 19	1		
20	1.2	0.8	1.7
21–30	2.4	1.5	3.6
Weight			
Lightest quartile	1		
Second quartile	1.2	0.8	1.9
Third quartile	1.9	1.2	2.9
Heaviest quartile	1.8	1.1	2.8
ACL/PCL tear			
Muscle strength			
Lowest quartile	1		
Second quartile	1.2	0.5	2.9
Third quartile	1.7	0.7	3.8
Highest quartile	2.6	1.04	6.5

ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

collateral ligament tears were 32%, 53%, and 15%, and for fresh chondral lesions approximately were 10%, 60%, and 30%. The three most common injuries during the first 8 weeks were patellar dislocation (47% of the cases), fresh meniscal tear (16%), and old meniscal tear (14%). Corresponding numbers for days 57–180 were 32% for old meniscal tears, 21% for fresh meniscal tears, and 20% for patellar dislocations. During the days 180–365, 33% of the injuries were for old meniscal tears, 24% patellar for dislocations, and 19% for cruciate ligament tears.

Higher age was significantly associated with knee injury leading to hospitalization (OR 1.7; 95% CI: 1.3–2.2; Table 3). Obesity was also significantly associated with hospitalization for knee injury, and the risk increased with an increase in the BMI. Subjects with BMI ≥ 30 had an OR of 1.6 (95% CI: 1.03–2.5) for knee injuries as compared with the subjects with BMI < 25. Subjects with the greatest muscular strength had 1.6 (95% CI: 1.2–2.4) times the risk of knee injury hospitalization compared with subjects in the lowest quartile. The results of the 12-min running test, underweight, and height were not associated with hospitalization for knee injury.

Final logistic regression models (Table 4) were used to determine risk factors for hospitalizations due to specific ICD-10 knee diagnoses. Obesity was a statistically significant risk factor for hospitalizations due to patellar dislocation and MCL/LCL tears. Obesity had an OR of 2.0 (95% CI: 1.1–3.5) for hospitalization due to patellar

dislocation and an OR of 3.1 (95% CI: 1.4–7.0) for hospitalization due to MCL/LCL tear. Weight was an independent risk factor for meniscal tears. The heaviest weight quartile had an OR of 2.6 (95% CI: 1.4–5.0) for hospitalization due to a fresh meniscal tear and an OR of 1.8 (95% CI: 1.1–2.8) for hospitalization due to an old meniscal tear. The oldest age-group had a 2.4 times (95% CI: 1.7–4.5) greater risk for old meniscal tears compared with the youngest age-group. Subjects in the highest muscle strength quartile had an increased risk for fresh meniscal tears and ACL/PCL tears.

Discussion

This study is the largest published investigation of the incidence and risk factors of knee injuries that can be generalized to the young adult male population. The incidence rate was 11 cases per 1000 person-years, indicating that each year, more than 1 of 100 young adult males will be hospitalized because of knee injury during their conscription. As many as one third of all young adult males hospitalized with knee injuries will undergo a service class change, indicating long-term notable disability. Older age and obesity were the most important risk factors for knee injuries.

This study has several strengths. First, it involved a population of 128 584 conscripts with a total exposure time of nearly 100 000 person-years. Second, due to the compulsory nature of military service, the male conscripts of the present study well represented Finnish young adults who had passed their medical examination performed by a physician as healthy when entering into military service. The findings can thus be generalized to the young adult male population. Compulsory military service is an interesting indicator of how general population reacts to the challenges of progressive physical exercise. Minor disorders are often provoked under these circumstances, due to the physically demanding nature of the military service. Third, all conscripts were required to use only the services of the primary military health-care units and Central Military Hospital when in need of medical treatment. The NHDR database from which the data were obtained is complete and highly accurate (Salmela & Koistinen, 1987; Keskimaki & Aro, 1991; Mattila et al., 2008). This database allowed us to include each and every hospitalized knee injury that occurred during the follow-up time. Mattila et al. (2008) examined the coverage and accuracy of diagnosis in the Finnish NHDR between the years 1997 and 2002. Coverage was examined by comparing patients with a confirmed cruciate ligament injury in the arthroscopy register of the Finnish Central Military Hospital to their register data in the NHDR. Accuracy was assessed by reviewing original medical reports, MRI, and arthroscopy files. NHDR register coverage for cruciate ligament injuries was 92%, and register accuracy was 89%.

This study had also some weaknesses. First, the predictor variables were measured during the first weeks of military service, and it is possible that weight or physical performance changed during the subsequent service time. Second, although all hospitalized injuries were taken into account, we had no data on less-severe injuries. It has been estimated that only 1 of every 20 military injuries results in hospitalization (Jones et al., 2000). Third, approximately 700–800 males a year are relieved from the service before. Chronic diseases such as diabetes, asthma, and mental health problems are the main reasons for exemption from military service. Reg-

ister data used in this study did not include information whether the knee injury occurred during sports, military exercises, or vacations. Taanila et al. (2009) examined this issue in Finnish conscripts. They included musculoskeletal disorders, and knee joint was the second most common injury location (18%). As many as 91% of the injuries occurred during actual military service, 9% occurred during vacations, and 0.5% occurred on the way to vacation or back to the garrison. Most common etiological circumstance was combat training in combat gear followed by marching and other physical exercises. It is also worth noticing that military service is usually performed between 19 and 20 years old, and after that, the number of conscripts rapidly decreases by each age year. For this reason, age categories matched by the number of study subjects are unevenly distributed (groups: 18–19 years old, 20 years old, and 21–30 years old). Unevenly distributed age categories can be considered as a limitation. However, distributing subjects to a larger number of age categories would have led to a relatively small number of knee injuries in older age categories. This would have violated logistic regression assumptions of adequate sample size and increased the effects of chance (random error), which might produce spurious results.

The overall person-time incidence rate for knee injuries in present study was 11 per 1000 person-years. This result confirms findings from an earlier study showing similar incidence rates of knee injuries in the Finnish general population (Kannus & Jarvinen, 1989). The overall incidence rate of all injury hospitalizations among Finnish conscripts is 94 per 1000 person-years (Mattila et al., 2006). Because the sample population was congruent with the present study, our results suggest that more than one tenth of all injuries leading to hospitalizations are knee injuries. This would be consistent with the report by de Loes et al. (2000) that knee injuries comprise 10% of all sports injuries in males. Majewski et al. (2006) reported that almost 40% of all sports-related injuries were knee injuries. These studies, however, included samples of selected athletes rather than the general male population and included only sports injuries, and are thus not directly comparable with our results.

The most common ICD-10 diagnosis in hospitalized subjects was old meniscal tear (28%), followed by acute patellar dislocation (22%), fresh meniscal tear (20%), ACL/PCL tear (19%), MCL/LCL tear (9%), and fresh chondral lesions (2%). In the study by Majewski et al. (2006), minor knee distortions without damage to any particular structure occurred in 34% of the cases. The most common specific knee diagnosis was an ACL tear (20%), followed by MM tear (11%), chondral lesion (11%), MCL tear (8%), contusion injury due to direct trauma (6%), LM tear (4%), and patellar dislocation (3%). In our study, only specific ICD-10 diagnoses were included in the analysis. The percentage of hospitaliza-

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tions for meniscal tears and patellar dislocations was clearly higher in our study, whereas the proportion of ACL tears and chondral lesions was lower. Participation in organized sports significantly increases the risk for ACL tears (Parkkari et al., 2008), which would explain the higher percentage in Majewski's study in which only sports injuries were taken into account. We also included all of the hospitalized injuries that occurred during leisure time and were not associated with military or sports training. Majewski's study also included older patients than those in our study. The number of chondral lesions increases with age (Curl et al., 1997).

Two thirds of all hospitalized subjects required surgery. Almost all subjects hospitalized due to old meniscal tears required surgery. Surgical treatment was also often needed for the subjects with fresh meniscal tears and ACL/PCL tears. The subjects with fresh chondral lesions, patellar dislocations, and MCL/LCL tears rarely required surgery. In the study of Majewski et al. (2006), the percentage of clinically diagnosed ACL tears requiring surgery was 87%, and the percentages were, respectively, 5% for LM, 84% for MM, 78% for PCL, 59% for MCL, and 49% for LCL. The proportion of injuries needing surgery was generally higher in their study than in the present study. It is noteworthy that in Majewski's study, which focused on athletes, surgery was required for ACL/PCL tears more often than in our study focusing on ordinary young adult males.

An important new finding in the present study was that as many as one third of all hospitalized subjects had service class change, indicating a severe decline in physical performance. Subjects with ACL/PCL tears had a service class change in more than half the cases. A decision for a service class change is never made easily and can be considered a reliable indicator of more severe injury causing longer term disability. There are no studies in the literature reporting disability rates of different knee injuries. The present study provides valuable information for clinicians regarding the prognosis of different knee diagnoses.

Most important risk factors for hospitalization for knee injury were older age and obesity. Obesity was a significant independent risk factor for patellar dislocation and MCL/LCL tears. Higher weight, but not BMI, was an independent risk factor for meniscal tears. Older age increased the overall risk for all hospitalizations and especially the risk for old meniscal tears.

The association of aerobic fitness and anthropometric properties to knee injuries has not been well studied. Heir and Eide (1996) suggested that the risk factors for musculoskeletal injuries in Norwegian conscripts are higher BMI, age over 23 years, and poor running condition. Disabling knee injuries leading to discharge from the U.S. army increase up to age 26, and obesity is a risk factor for disabling knee pain (Sulsky et al., 2000; Webb et al., 2004). Mattila et al. (2007a) reaffirmed that

obesity is also an important risk factor for musculoskeletal and lower limb injuries in Finnish conscripts. In their study, however, excellent aerobic performance increased the risk for lower limb injuries. Better muscle strength increased the risk for musculoskeletal injuries overall. Knee or shin injuries accounted for 27% of all injuries and 53% of lower limb injuries. In the present study, running test results were not associated with knee injuries. Better muscle strength instead was a statistically significant risk factor for knee injuries. Those with better muscle strength are likely to participate in sports more actively, which increases the risk for knee injuries (Kannus & Jarvinen, 1989). In addition, conscripts with better muscle strength may be required to perform more physically challenging tasks for which the risk of knee injury may be higher.

Risk factors have been studied by specific knee injury diagnosis. The risk factors for ACL tears are well studied (Bodor, 2001; Uhorchak et al., 2003; Lombardo et al., 2005; Majewski et al., 2006; Parkkari et al., 2008), whereas there are no comprehensive studies of the risk factors for MCL tears in the literature. A new important finding of the present study was that obesity (BMI > 30) was associated with a threefold greater risk of hospitalization due to MCL/LCL tear. Those in highest muscle strength quartile had an increased risk for ACL/PCL tears. Known risk factors for meniscal tears are sports participation, weak quadriceps muscle, and older age (Baker et al., 2002, 2003; Canale ebST, 2003). In the present study, increasing weight was associated with the increase in the risk for meniscal tears. Older age was a significant risk factor for old meniscal tears, and greater muscle strength was a significant risk factor for fresh meniscal tears. Risk factors for acute patellar dislocation are higher height and weight (Sillanpaa et al., 2008). In the present study, risk for knee injury increased with an increase in BMI. Obesity increased the risk for patellar dislocation twofold.

Further research is required. A long-term follow-up study is needed to determine whether knee injuries leading to a service class change cause permanent disability or persistent symptoms. The association between knee injuries and muscle strength also requires further studies.

Perspectives

The present study is the largest ever published study of incidence and risk factors for knee injuries that can be generalized to the young adult male population. Compulsory military service is an interesting indicator of how the general population reacts to the challenges of progressive physical exercise. The study included males between the ages of 18 and 30 years, that is, the group in which most knee injuries occur (Kannus & Jarvinen, 1989; Majewski et al., 2006; Gianotti et al., 2009), and participation in sports is common. As many as half of all

knee injuries are sports injuries (Kannus & Jarvinen, 1989). The present findings indicate that knee injuries cause a significant burden of hospitalization, often leading to surgery and longer term disability. Obesity increases the risk for hospitalization due to knee injury. Because higher age is associated with knee injuries, entering military service at the younger age of 18–20 may be beneficial. The prevention of knee injuries warrants further research.

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