Sports Injury, Occupational Physical Activity, Joint Laxity, and Meniscal Damage

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ABSTRACT. ***Objective.*** To investigate the risk factors for meniscal damage, an important determinant of knee osteoarthritis.

Methods. We studied 243 men and women aged 20–59 years in whom the diagnosis of a meniscal tear was confirmed for the first time at arthroscopy, over a 25 month period, in 2 British hospitals. Each case was compared with one or 2 community controls, matched by age and sex, who were registered with the same general practitioner. Information on exposure to risk factors was obtained by a structured questionnaire and physical examination.

Results. Meniscal tear was strongly associated with participation in sports during the 12 months preceding the onset of symptoms; the risk was particularly high for soccer (OR 3.7; 95% CI 2.1–6.6). Higher body mass index and occupational kneeling (OR 3.8; 95% CI 1.3–11.0) and squatting (OR 2.9; 95% CI 1.0–8.0) were associated with an increased risk of degenerative meniscal lesions, after adjustment for social class, joint laxity, and sports participation. Joint laxity was associated with degenerative meniscal lesions independently of occupational physical activity, sports, and obesity.

Conclusion. Our results confirm the importance of sporting activities entailing knee torsion in acute meniscal tear. They also point to a role for occupational activity, adiposity, and joint laxity in the pathogenesis of degenerative meniscal lesions. Modifying these mechanical risk factors may serve to reduce the risk of meniscal injury and may also help to prevent later knee osteoarthritis. (J Rheumatol 2002;29:557–63)

Key Indexing Terms:
EPIDEMIOLOGY KNEE OSTEOARTHRITIS
MENISCAL TEAR MENISCECTOMY

Meniscal injuries are responsible for an estimated 25,000 hospital admissions per year in England and Wales[1] (personal communication, S. Joseph, Statistics Division, Department of Health, London). The incidence is highest in young and middle aged men, and it is an important cause of time lost from work[2-6]. Moreover, as well as causing immediate symptoms and disability[7], meniscal damage and its surgical treatment is associated with a 4-fold increase in the longterm risk of knee osteoarthritis (OA)[8-11].

Despite its importance, little is known about the epidemiology of meniscal injury. Analysis of case series has established that the highest incidence is in men aged 20–49 years[3,4,6], and indicates that some 70% of hospital cases are precipitated by obvious acute trauma, often while playing sport[5,6,12]. However, it is unclear what factors predispose individuals to meniscal damage when they are exposed to trauma, or why some people acquire injuries in the absence of appreciable trauma.

One possible risk factor may be prolonged or repeated bending of the knees, for example through kneeling or squatting at work. Studies in Germany have suggested that degeneration of knee cartilage is unusually common in miners (an occupation that entails frequent kneeling and squatting)[13,14], and an increased prevalence of meniscectomy has been described in British coal miners[15]. In Finland, a cross sectional survey of 168 carpet and floor layers who knelt for long periods at work showed a 10% prevalence of previous meniscal tear verified by a physician, as compared with a prevalence of 5% in a control group of 146 painters[16]. The difference was not statistically significant, however. These findings suggest an occupational hazard, but they require confirmation. We therefore carried out a case-control study of meniscal injuries treated in hospital.

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MATERIALS AND METHODS

Patients. The cases were residents of Southampton and Portsmouth Health Districts aged 20–59 years, who were admitted to Southampton General Hospital or Queen Alexandra Hospital, Portsmouth, during the 25 month period from March 1, 1996, to March 31, 1998, and in whom a diagnosis of meniscal tear was confirmed for the first time at arthroscopy. Meniscal lesions were classified as acute or degenerative using the system of Hardin, *et al*[17]. These patients were approached, either in person while they were still in hospital or by post after their discharge, and were invited to take part in the study. Those who agreed were visited at home by a research nurse and interviewed using a structured questionnaire. Among other things, this asked about history of knee symptoms, smoking habits, alcohol consumption, participation in sports since leaving school and specifically in the 12 months leading up to the onset of their knee symptoms, and about each job held for a year or longer since leaving school, including whether it involved a range of specified physical activities. In addition, their height and weight were measured with a portable stadiometer and electronic scales, and they were examined for signs of joint laxity, which were summarized by a Beighton score[18].

For each case who took part in the study, we sought 2 community controls of the same sex and matched as closely as possible for age, who were registered with the same general practitioner. Potential controls were identified from the practice age-sex register, and with permission from their general practitioner, were sent a letter asking them to participate. A single reminder was sent to those who did not reply. Those who agreed and who did not have a history of meniscal injury were visited at home and interviewed and examined in a similar manner to the cases. Participation in sports was ascertained since leaving school and in the 12 months up to the onset of symptoms in the matched case. Where possible, controls who could not be contacted or who declined to participate were replaced.

Statistical analysis. Associations with risk factors were examined by conditional logistic regression, and were summarized by odds ratios (OR) with 95% confidence intervals (CI). Within each matched set all occupational and sporting histories were censored at the time of onset of the case's symptoms. Similarly, smoking was classified according to habits at the time the case's symptoms began.

RESULTS

Interviews were completed by 254 (72%) of 353 eligible cases who were identified over the study period, and by 461 (28%) of 1639 controls whom we attempted to recruit. Among the nonresponding cases, 26 declined to participate, 6 could not be interviewed for other reasons, and 67 did not reply when mailed. The loss of controls occurred because of refusal (255), failure to reply when mailed (914), and refusal of the general practitioner to permit an approach to the subject[9]. The analysis is based on 218 cases with 2 matched controls and 25 with one matched control. The remaining 11 cases were excluded because no controls had been obtained for them.

Of the 243 cases included in the analysis, 196 were men and 47 were women. Their ages at the time of arthroscopy ranged from 20 to 59 years, with mean 40.1 and median 40 years. Most controls (94%) had ages within one year of that of their matched case, and all were matched to within 8 years of age. The time since the onset of the cases' symptoms ranged from less than a month to 47 years, with a median of just over 12 months. In most cases (77%), the symptoms had started suddenly, including 78 (32%) with sudden onset while playing sport (most commonly soccer) and 52 (21%) with sudden onset while at work. One hundred twenty-six cases (52%) had arthroscopic appearances suggesting a definite acute meniscal tear using the classification system of Hardin, *et al*[17], while 71 (29%) were classified as having definite degenerative meniscal lesions only. The 2 features occurred together in one case (0.4%); the remaining 45 (19%) could not be classified by the orthopedic surgeons as definitely showing features of acute or degenerative lesions.

Table 1 summarizes the association of knee cartilage injury with various physiological indices. For this analysis, height and weight were each classified into thirds of their distribution by sex in cases and controls combined. The cut-points for height were 1.75 and 1.80 m in men and 1.60 and 1.66 m in women. For weight the cut-points were 75.0 and 86.0 kg in men and 59.0 and 70.0 kg in women. No relation was found with stature, but risk was significantly elevated in heavier subjects and in those with a higher body mass index (BMI). The association with higher BMI was confined to those subjects with degenerative meniscal lesions (OR 4.7; 95% CI 1.9–11.2, highest versus lowest thirds of distribution of BMI), and was not apparent among those with acute meniscal injuries (OR 1.0; 95% CI 0.6–1.7). Risk was also elevated for Beighton scores greater than zero (OR 1.9; 95% CI 1.2–3.0), but did not rise progressively as scores increased to 2 and higher. The main indices of joint laxity giving rise to a positive Beighton score were the ability to touch the wrist on passive flexion of the thumb and to place the palms of the hands flat on the floor when flexing the trunk with the knees straight. When subjects with acute and degenerative meniscal lesions were analyzed separately, similar associations were found with Beighton score.

Table 2 shows associations of knee cartilage injury with

Table 1. Associations of knee cartilage injury with height, weight, body mass index, and Beighton score. Each risk factor was examined in a separate regression model.

Risk Factor	Cases (n)	Controls (n)*	OR (95% CI)
Height			
Low	88	170	1
Medium	77	134	1.1 (0.8–1.6)
High	78	156	1.0 (0.7–1.4)
Weight			
Low	64	171	1
Medium	91	160	1.5 (1.0–2.2)
High	88	130	1.8 (1.2–2.7)
BMI			
< 24.0	64	185	1
24.1–27.0	91	126	2.3 (1.5–3.4)
≥ 27.0	88	149	1.7 (1.2–2.6)
Beighton score			
0	121	293	1
1	47	63	1.9 (1.2–3.0)
≥ 2	75	105	1.9 (1.3–2.9)

* Information on height and BMI was missing for one control.

Table 2. Associations of knee cartilage injury with smoking, alcohol consumption, and social class. All risk factors were examined in a single regression model with adjustment for BMI and Beighton score, each classified as in Table 1. Analysis was restricted to 202 cases and 333 controls with complete information on all of the variables included in the regression model.

Risk Factor	Cases (n)	Controls (n)	OR (95% CI)
Smoking			
Never	86	168	1
Ex-smoker	51	79	1.1 (0.7–1.8)
Current smoker	65	86	1.3 (0.8–2.0)
Alcohol consumpton (units per week)			
0	38	48	1
1–14	97	184	0.7 (0.4–1.3)
15+	67	101	0.9 (0.5–1.6)
Social class			
Non-manual	77	197	1
Manual	125	136	2.5 (1.6–3.9)

smoking, alcohol consumption, and social class. Risk did not relate significantly to smoking or alcohol, but after adjustment for BMI and Beighton score, it was markedly elevated in manual as compared with non-manual classes (OR 2.5; 95% CI 1.6–3.9).

Knee cartilage injury was strongly associated with participation in sports during the 12 months preceding the onset of the case's symptoms (Table 3). The elevation of risk persisted after adjustment for social class, and was particularly high for soccer (OR 3.7; 95% CI 2.1–6.6). This association with soccer was limited to cases whose symptoms began acutely while playing the sport. There was no significantly increased risk for meniscal injuries that developed in other circumstances (OR 1.2; 95% CI 0.6–2.5), nor was there any increased risk of degenerative meniscal disease associated with playing soccer. We also estimated risks for participation in sports for a total of 5 years or longer before the onset of the case's symptoms. These too were significantly elevated, but were lower than those shown in Table 3.

In looking at associations with occupational activities, we adjusted risk estimates for BMI, Beighton score, and participation in sports. Table 4 shows the findings in relation to the work that was done at the time the case's symptoms began. Significant increases in risk were apparent for several activities including kneeling, squatting, driving, and lifting, even after adjustment for social class. On the other hand, there was no association with sitting or standing. The highest risk was for climbing 30 or more flights of stairs in an average working day (OR 2.4; 95% CI 1.6–3.8). The association with kneeling and squatting was apparent even for those cases whose symptoms did not begin suddenly while at work (OR 2.1; 95% CI 1.1–3.8 for kneeling, OR 1.9; 95% CI 1.0–3.5 for squatting), and was most pronounced for cases who had degenerative meniscal lesions. Thus, occupational kneeling was associated with an almost 4-fold increase in the risk of degenerative lesions (OR 3.8; 95% CI 1.3–11.0), but only a doubling in the risk of acute lesions (OR 2.3; 95% CI 1.1–4.8). Occupational squatting showed a similar tendency (degenerative lesions OR 2.9; 95% CI 1.0–8.0, acute lesions OR 1.8; 95% CI 0.9–3.9).

Table 5 shows the occupations that were said to involve kneeling or squatting by more than half the subjects (cases or controls) who reported them. Risk was significantly elevated for subjects who were employed in one of these jobs at the time the case's symptoms began (OR 2.7; 95% CI 1.7–4.3 with adjustment for BMI, Beighton score, participation in sports).

When the analysis presented in Table 4 was repeated with subjects classified according to whether they had been exposed to the occupational activities for at least 5 years in total by the time the case's symptoms began, risk estimates were little different. Nor were they altered importantly when social class was reclassified in 6 strata rather than 2.

The interaction between joint laxity and occupational kneeling or squatting as risk factors for meniscal injury is explored in Table 6. Risk was highest in subjects who were exposed to both risk factors.

Table 3. Associations of knee cartilage injury with participation in sports in the 12 months preceding onset of the case's symptoms. Each sport was examined in separate regression models and all analyses were adjusted for BMI and Beighton score (classified as in Table 1.). Analysis was restricted to 202 cases and 333 controls with complete information on all of the variables included in the regression models.

Sport	Cases Exposed (n)	Controls Exposed (n)	Odds Ratio (95% CI)	
			Unadjusted for Social Class	Adjusted for Social Class*
Soccer	61	47	3.6 (2.0–6.2)	3.7 (2.1–6.6)
Rugby	7	5	1.9 (0.6–6.4)	2.2 (0.6–8.2)
Running	19	27	1.3 (0.7–2.5)	1.4 (0.7–2.8)
Swimming	58	70	1.7 (1.1–2.6)	1.6 (1.0–2.5)
Other	112	155	1.3 (0.9–1.9)	1.5 (1.0–2.2)

*Classified as non-manual or manual.

Table 4. Associations of knee cartilage injury with occupational activities in the job held at the time the case's symptoms began. Each activity was examined in separate regression models. All analyses were adjusted for BMI and Beighton score (classified as in Table 1) and for participation in sports (none, soccer, any other but not soccer) in the 12 months before onset of the case's symptoms. Analysis was restricted to 202 cases and 333 controls with complete information on all of the variables included in the regression models.

Occupational Activity	Cases Exposed (n)	Controls Exposed (n)	Odds Ratio (95% CI) Unadjusted for Social Class	Odds Ratio (95% CI) Adjusted for Social Class*
Sitting > 2 h in total per day	112	220	0.7 (0.5–1.1)	0.9 (0.6–1.4)
Standing or walking > 2 h in total per day	161	231	1.8 (1.1–2.8)	1.3 (0.8–2.2)
Kneeling > 1 h in total per day	68	67	2.6 (1.6–4.3)	2.2 (1.3–3.6)
Squatting > 1 h in total per day	61	62	2.2 (1.4–3.6)	1.8 (1.1–3.0)
Getting up from kneeling or squatting > 30 times per day	95	101	2.4 (1.6–3.7)	1.9 (1.2–3.1)
Driving > 4 hours in total per day	52	63	2.3 (1.4–3.8)	2.3 (1.4–4.0)
Walking > 2 miles in total per day	140	185	1.8 (1.2–2.7)	1.5 (0.9–2.3)
Climbing > 30 flights of stairs per day	102	94	2.7 (1.8–4.1)	2.4 (1.6–3.8)
Lifting or carrying 10+ kg > 10 times per week	125	146	2.4 (1.6–3.6)	1.9 (1.2–2.9)
Lifting or carrying 25+ kg > 10 times per week	78	88	2.1 (1.4–3.3)	1.7 (1.1–2.7)
Lifting or carrying 50+ kg > 10 times per week	50	36	3.0 (1.7–5.1)	2.4 (1.4–4.2)

* Classified as non-manual or manual.

DISCUSSION

This case-control study of meniscal injury suggests that sporting injuries are a major cause of acute meniscal tear. Degenerative meniscal lesions may be a consequence of occupational physical activity, particularly prolonged kneeling or squatting, and also of obesity. Joint laxity was associated with an increased risk of both acute and degenerative meniscal damage.

Interpretation of these findings must take into account several potential sources of bias. The first relates to the selection of cases for study. The orthopedic departments from which the cases were recruited provided the main service for the treatment of knee disorders in the health districts covered by the investigation. Some patients could have been missed because they were treated privately outside the National Health Service, and this may have contributed to the higher risk in manual compared to non-manual workers. However, the observed associations with sporting and occupational activities remained after adjustment for social class. A further loss of cases occurred because 28% of those who were eligible for study could not be contacted or declined to take part. If anything, however, we would expect the resultant attrition to have been greater for manual workers, and it seems unlikely that it would have led to over-representation of kneeling and squatting in the case group.

More important is the possibility that people whose jobs entail kneeling or squatting are more handicapped if they incur a knee cartilage injury, and as a consequence seek medical advice more readily and are selectively referred to hospital for investigation. This issue was addressed in a separate survey[19]. In brief, 2806 men aged 20–59 years completed a postal questionnaire on lifetime occupational activities and any history of knee symptoms. Symptomatic men whose work entailed kneeling or squatting were more likely to be referred to an orthopedic surgeon than the average (28 and 31 vs 24%). The findings of the survey suggest that selective referral does occur, and that it could explain part of the excess risk associated with kneeling and squatting at work, although it seems less likely that it would account for differential associations with degenerative as compared with acute lesions.

A second possible source of bias was the low response rate (28%) from controls. This may have led to under-representation of manual workers in the control group, but there is no reason to believe that manual workers whose jobs entailed kneeling or squatting would be less likely to participate than those who were not exposed to these activities. Thus, it is unlikely to have affected the risk estimates for kneeling and squatting that were adjusted for social class.

A third potential source of error was inaccuracy in the information obtained at interview. To reduce the possibility of differential recall of exposures, we did not ask cases directly about the work that they did when their injury occurred, but collected a lifetime occupational history and inferred the relevant job from a separate question about the

Table 5. Occupations most frequently reported to involve kneeling or squatting.

Occupation (SOC Code)*	Number of Subjects who Reported Occupation			Number of Subjects who Reported that the Occupation Involved Kneeling or Squatting		
	Cases	Controls	Total	Cases	Controls	Total
Garage managers (171)	1	1	2	1	1	2
Roofers, slaters, tilers (501)	8	3	11	7	3	10
Plasters (502)	4	2	6	4	2	6
Builders, building contractors (504)	5	2	7	3	2	5
Scaffolders (505)	0	3	3	0	2	2
Floorers, carpet fitters (506)	5	0	5	4	0	4
Painters and decorators (507)	8	9	17	8	8	16
Other construction trades (509)	11	3	14	7	3	10
Maintenance fitters (516)	12	32	44	8	18	26
Production fitters (electrical/electronic) (520)	2	3	5	2	2	4
Electricians, electrical maintenance fitters (521)	8	14	22	7	11	18
Electrical, television and computer engineers, telephone fitters (522-529)	12	22	34	9	11	20
Plumbers (532)	11	14	25	11	12	23
Metal plate workers, shipwrights, riveters (534)	2	3	5	2	3	5
Steel erectors (535)	0	1	1	0	1	1
Motor mechanics (540)	15	12	27	14	9	23
Vehicle body builders and repairers (541–542)	3	6	9	3	4	7
Carpenters and joiners (570)	16	17	33	14	15	29
Gardeners (594–595)	5	4	9	4	3	7
Other crafts (596–599)	14	9	23	9	5	14
Childcare and related (650–659)	5	14	19	5	9	14
Textiles and tannery process operatives (812–814)	0	1	1	0	1	1
Press stamping operatives (841)	1	0	1	1	0	1
Pipe layers (895)	1	0	1	1	0	1
Other construction occupations (920–929)	12	11	23	5	7	12
Cleaners (958)	12	18	30	9	8	17
Laborers (990)	21	21	42	11	14	25

* Standard Occupational Classification[21].

age at which symptoms began. Also, to obscure the main focus of the study, we asked about various occupational activities and not only about kneeling and squatting. Nevertheless, it is possible that cases remembered kneeling and squatting more completely than controls, perhaps because these activities were impaired by their injury. To address this possibility, we carried out a separate analysis based on job title. Occupations that were likely to involve kneeling or squatting were identified from the information provided by both cases and controls, and the resultant list of jobs (Table 5) appeared plausible. The fact that after adjustment for social class, work in these occupations was also significantly associated with meniscal injury (OR 1.9; 95% CI 1.2–3.2) indicates that the relationship with reported kneeling and squatting is unlikely to be explained by biased recall.

The strong association of knee cartilage injury with participation in soccer and rugby is not surprising given the high proportion of cases that result from injuries while playing these sports, usually through twisting of the knee. It is notable, however, that the association with soccer was confined to such cases, and there was no indication that participation in soccer increased the risk of meniscal injuries occurring in other circumstances. The higher rate of meniscal injury in swimmers is more surprising since swimming does not involve the same stresses on the knee. Although statistically significant, it could be a chance finding.

In contrast to the association with soccer, the excess risk associated with occupational kneeling and squatting was not restricted to cases with sudden onset while at work, and although it may have been exaggerated by selective referral to hospital, it is consistent with earlier reports of a hazard from prolonged or repeated bending of the knees[13-15]. The associations that were found with occupational lifting and climbing of stairs and ladders are also plausible, in that these activities place increased mechanical stress on the knee. However, they have not been explored previously, and

Table 6. Associations of knee cartilage injury with occupational kneeling and squatting according to Beighton score. Risk estimates were derived from a single regression model with adjustment for BMI (classified as in Table 1), social class (manual or non-manual) and participation in sports (none, soccer, any other but not soccer). Analysis was restricted to 202 cases and 333 controls with complete information on all of the variables.

Type of Meniscal Injury	Beighton Score	Unexposed to Kneeling or Squatting* OR (95% CI)	Exposed to Kneeling or Squatting* OR (95% CI)
Acute	0	1.0	1.9 (0.8–4.8)
	1	1.3 (0.4–4.1)	3.4 (0.9–12.4)
	≥ 2	2.1 (0.9–5.0)	4.2 (1.3–14.4)
Degenerative	0	1.0	3.8 (1.1–13.7)
	1	1.3 (0.3–4.7)	5.9 (1.1–32.5)
	≥ 2	3.6 (1.1–12.1)	2.4 (0.4–16.0)
All	0	1.0	2.1 (1.2–3.9)
	1	1.7 (0.8–3.5)	4.0 (1.6–10.3)
	≥ 2	2.6 (1.4–4.8)	3.6 (1.5–8.7)

*Kneeling for > 1 h in total per day or squatting for > 1 h in total per day in the job held at the time the case's symptoms began.

require confirmation. The increased risk with occupational driving is more difficult to explain. Unlike kneeling and squatting, it does not appear to be associated with differential referral to hospital for knee symptoms[19], and the association cannot readily be attributed to bias. In a case-control analysis based on a cross sectional survey of knee pain among men from the same community as in the current study[19], no association was found with occupational driving. This suggests that the association in the current study may have occurred by chance.

In addition to the associations with sport and occupation, knee cartilage injury was also associated with obesity and with joint laxity as assessed by Beighton score. Obesity was more closely associated with degenerative meniscal lesions than with acute tears. No clear dose-response relation was found with BMI, but the elevation of risk in the higher two-thirds of its distribution was substantial and highly statistically significant. Obesity increases the mechanical load on the knee joint, and is an established risk factor for knee OA[20]. Further, obesity appears to increase the risk of knee OA independently of a history of knee injury[11]. Our data suggest that part of this association may be mediated through an effect of obesity on meniscal degeneration, which may then predispose to later cartilage loss.

The assessment of joint laxity could not be carried out blind to subjects' case-control status. However, the physical signs necessary for a positive Beighton score are clear and unlikely to be subject to major observation bias. The extent to which joint hypermobility predisposes to knee OA is uncertain, but our observation that a tendency towards joint laxity is associated with an increased risk of meniscal lesions would support a link with OA in later life. The biological explanation for the association of meniscal damage with joint laxity is unknown. Possibilities include increased mechanical loading of the meniscus in a knee with a lax joint capsule or ligaments, as well as shared structural defects in the collagen that makes up part of the joint capsule, supporting ligaments, and meniscal fibrocartilage.

Our results also suggest that people with joint laxity may be at particularly high risk of meniscal lesions if they undertake frequent or prolonged kneeling or squatting in their work. However, it is unlikely that the predictive value of a positive Beighton score would be sufficient to justify selective exclusion of workers from jobs that entail kneeling and squatting. A better preventive strategy is likely to lie in minimizing these activities.

Our case-control study of meniscal injury confirms the previously documented association of acute meniscal tear with sporting activities entailing torsion of the knee in partial flexion. It also points to a role of occupational activity, particularly prolonged kneeling or squatting, in the etiology of degenerative meniscal lesions; obesity and joint laxity appear to accentuate the effects of such workplace activities.

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