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Epidemiology of Sports Injuries

Review

Epidemiology of knee osteoarthritis

S Muraki[1]*, S Tanaka[2], N Yoshimura[3]

Abstract

Introduction

The prevalence of knee osteoarthritis is much higher in Caucasians than in Asians or in black people. Few population-based studies regarding the incidence of knee osteoarthritis were found, with the incidence of knee osteoarthritis being higher in Japanese than in Caucasians. However, strict comparisons among these studies are limited, because the definition of the incidence of knee osteoarthritis is not the same for each study. A few risk factors for knee osteoarthrit is were established, such as female gender and obesity. Several cross-sectional studies have found that the presence of a previous knee injuryis significantly associated with the incidence of knee osteoarthritis, but longitudinal studies did not find this significant correlation. However, the same longitudinal studies found significant associations between previous knee injuries and incident knee pain. One of the limitations in previous studies is the definition of knee osteoarthritis. The most popular grading system for knee osteoarthritis is Kellgren–Lawrence classification. However, joint space narrowing and osteophytosis cannot be separately assessed in this grading system. Recent studies have suggested distinct causes for both joint space narrowing and osteophytosis. These studies have also found an independent association between joint space narrowing and osteophytosis with the quality of life of the person. This is a review of population-based studies for knee osteoarthritis.

Conclusion

To further assess new risk factors or markers, joint space narrowing and osteophytosis should be assessed separately using a fully automatic system that measures joint space width and osteophyte area.

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Introduction

Knee osteoarthritis (OA) is a major public health issue and causes chronic pain and disability among elderly in most of the developed countries. It is characterised by several pathological features, including joint space narrowing and osteophytosis. Despite the urgent need of strategies for the prevention and treatment of this condition, demographics on the overall disease prevalence and the affected subgroups are not adequately characterised yet. The reported prevalence of radiographic knee OA differs considerably among previous population-based epidemiologic studies.In addition, apart from age, sex, obesity and occupational activities, there are only a few other established risk factors for knee OA.

We aimed to review the literature on population-based studies investigating knee OA.

Prevalence of knee osteoarthritis

Twelve previously published studies on the prevalence of knee OA were identified after performing a search in the English literature[1–12] (Table 1). Epidemiologic studies on elderly Caucasians in the United States and Europe have shown that the prevalence of knee OA with Kellgren–Lawrence(KL) grade 2 or higher was 30–40%; where as studies in Asia have found a prevalence of 60% or higher. Thus, the prevalence of knee OA is higher in Asian populations than in Caucasian populations. Based on these studies, Caucasians show a lower prevalence of radiographic OA than that found in other races. Furthermore, the Johnston County study and the National Health and Nutrition Examination Survey (NHANES) studies reported that African-Americans have a higher prevalence of radiographic knee OA than did Caucasians. However, in the NHANES studies, the prevalence rates of knee OA were lower than those in other studies;this discrepancy was explained by differences in radiographic acquisition. In these studies, knee radiographs were obtained in a non-weight-bearing position, as opposed to other studies, where in knee radiographs were obtained in a weight-bearing position. The Chingford study presented lower prevalence of knee OA because subjects were much younger than those who participated in other studies.

In terms of KL grading, KL grade 2 indicates the presence of osteophyte formation; and grade 3 indicates joint space narrowing in addition to osteophyte formation; KL ≥ 2 is generally thought to be the standard for the diagnostic criterion of knee OA[13]. However, accumulating evidence has shown that osteophytosis and joint space narrowing have distinct aetiologic mechanisms, and their progression is neither constant nor proportional[14]. Hence, to assess these two pathological features separately, the

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Table 1 Comparison of radiographic knee OA prevalence among population-based epidemiologic studies

Author (Study name)	Kellgren	Felson (Framingham)	Hart (Chingford)	van Saase (Zoetermeer)	Jordan (Johnston County)	Anderson (NHANES I)	Dillon (NHANES III)	Hirsh (NHANES III)	Muraki (ROAD)	Yoshida (Hizen-Oshima)	Zhang (Beijing)	Du (Shanghai)
Reference	1	2	11	4	6	3	5	7	12	10	8	9
Ethnicity	UK	Whites in USA	UK	Netherlands	Black and Whites in USA	Black and Whites in USA	Black and Whites in USA	Black in USA	Japan	Japan	China	China
Age	55–64	≥63	45–64	≥60	≥65	65-74	≥60	≥60	≥60	≥63	≥60	60–69
Total number (men:women)	370 (171:199)	1420 (589:831)	985 (-:985)	1123 (457:666)	1175	1182 (575:607)	2415 (1,144:1,271)	457	2282 (817:1,465)	358 (-:358)	1781 (730:1,051)	700
Radiographic knee OA												
KL ≥ 2 (men:women)	34.7 (29.8:40.7)	33.0 (30.9:34.4)	– (-:12.0)	30.0 (21.9:35.6)	40.6	15.1 (9.0:20.3)	37.4 (31.2:42.1)	– (42.8:60.6)	61.9 (47.0:70.2)	– (-:46.8)	38.8 (27.6:46.6)	64.1
KL ≥ 3 (men:women)	12.9 (11.1:15.1)	15.7 (16.0:15.5)		10.2 (6.7:12.7)	13.6		10.2 (6.5:12.9)		20.6 (13.5:24.6)			

OA, osteoarthritis; NHANES, National Health and Nutrition Examination Survey.
The knee radiographs obtained were the anterior–posterior view in a standing position for all studies except the three NHANES studies, in which radiographs were obtained in non-weight-bearing views.

present study examined not only the prevalence of knee OA with KL ≥ 2, but also the prevalence of knee OA with KL ≥ 3. Six previously published studies on the prevalence of knee OA in elderly were identified in a search of the English literature[1,2,4–6,12] (Table 1). In contrast to KL ≥ 2 OA, the prevalence of KL ≥ 3 OA was not significantly different between Japanese men and Caucasians, although it was higher in Japanese women. This indicates that the prevalence of KL = 2 knee OA is particularly high in Japan, especially in men. Considering the definition of the KL grade, this may mean that osteophytosis is more prevalent in elderly Japanese men, whereas joint space narrowing is similar between the two ethnic groups. There is accumulating evidence that osteophytosis and joint space narrowing have distinct aetiologic mechanisms. Several studies on experimental mouse models for OA have identified a cartilage-specific molecule, carminerin, that regulates osteophytosis without affecting joint cartilage destruction during OA progression[14]. Hence, some risk factors may be specific to osteophytosis in elderly Japanese.

Incidence of knee osteoarthritis

Five population-based studies on the incidence of knee OA were identified in a search of the English literature[15-19]. The Framingham Osteoarthritis Study in the United States[15] had an approximately 8.1-year follow-up, and the incidence rate of KL ≥ 2 knee OA was found to be 11.1% (1.4% per year) in Caucasian men and 18.1% (2.2% per year) in Caucasian women. A population-based study in the United Kingdom[16] demonstrated that in an approximately 5.1-year follow-up, the incidence rate of KL ≥ 2 knee OA was 18.5% (2.3% per year). However, this analysis did not separate sexes. In the Research on Osteoarthritis/osteoporosis Against Disability (ROAD) study in Japan[19], the incidence of KL ≥ 2 OA was 2.0% per year for men and

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3.7% per year for women. These values were slightly higher than those obtained in previous epidemiologic studies in the United States and Europe[15,17], implying that the incidence of knee OA is higher among Japanese than among Caucasians.

To the best of our knowledge, no population-based studies on Caucasians have investigated the incidence of KL ≥ 3 knee OA. In the Chingford study[16], knee OA was not defined according to KL grade, but rather according to osteophytosis and joint space narrowing. The Chingford study showed that in an approximately 4-year follow-up, the incidence of joint space narrowing was 12.6% (3.2% per year) in women. Considering the KL grade definition, these findings may be comparable to our results for the incidence of KL ≥ 3 knee OA. However, a closer comparison of the results from both the studies provides limited accuracy. In the ROAD study in Japan[19], the incidence rate of KL ≥ 3 knee OA was 4.1% per year for Japanese women, which was also higher than that in Caucasian women. However, this higher incidence rate may be partly explained by the definition of the inclusion criteria for KL ≥ 3 knee OA: cases that started as KL < 3 were eligible for this outcome and were combined with incident (e.g. knees starting at KL 0–1) and progressive disease (knees starting at KL = 2) cases. In the present study, we have also examined the progression of knee OA and found that the progression rate of knee OA was 5.2% and 6.3% per year in Japanese men and women, respectively. These results were also higher than those of other studies in the United States and United Kingdom (2.2–3.9%)[15,17]. The higher incidence of radiographic knee OA in Japanese could also be attributed to lifestyle factors, because the traditional Japanese lifestyle includes sitting on the heels of the feet for prolonged periods and use of Japanese-style lavatories, requiring squatting and kneeling, which are associated with knee OA. These positions may cause mechanical stress to the knee joint and possibly accelerate disease progression.

Risk factors for knee osteoarthritis

Body mass index and gender

Obesity is a strong risk factor for incident knee OA[16,17,19], possibly because of the accumulation of mechanical stress on the knee joint. Previous studies have found that female genderis also a strong risk factor for incident KL ≥ 2 knee OA[15,17,19], possibly implicating the involvement of muscle strength to compensate for mechanical stress. As men generally have more muscle strength than women, muscle strength involvement may compensate for the mechanical stresson the joint, which reduces the risk of occurrence of the disease in men. However, the ROAD study has reported that female genderis not a significant risk factor for incident KL ≥ 3 knee OA or progressive knee OA. Furthermore, age and body mass index at baseline were risk factors for progressive knee OA, but their odds ratio for progressive knee OA was lower than the odds ratio for incident KL ≥ 2 knee OA. This discordance between the determinants for the incidence of KL ≥ 2 and KL ≥ 3 knee OA and determinants for the progression of knee OA using KL grade suggests that different mechanisms influence the initiation of osteophytosis (the principal abnormality in KL grade 2 disease) and joint space narrowing (the principal abnormality in KL grade 3 disease). However, as KL grade was defined by a categorical method, which is comparably insensitive to change, this discordance might simply be a function of the scoring system.

Previous injury

Cross-sectional studies on knee OA prevalence have observed a strong association with previous knee injury[20]. Although the incidence rate data from the Zoetermeer study, Framingham study, and Chingford study[15,16,19] reported a slight increase in the risk of knee OA with interim knee injury, all these studies were based on small sample pools. No significant association with past knee injury was seen in those groups. In contrast, the ROAD study[19] found that previous knee injury is a risk factor for incident knee pain, despite it not being significantly associated with incident radiographic knee OA. The correlation of knee pain with radiographic severity of knee OA is not as strong as expected[12], as knee pain may arise from various structures other than joint cartilage. These other structures, such as menisci, synovium, ligaments, bursae, bone and the bone marrow, may be damaged by a previous knee injury, thus leading to the incident knee pain.

Occupational activities

Comparison of odds ratios for knee OA associated with occupational activity among epidemiologic studies is shown in Table 2. As each study has defined knee OA differently, these results are not directly comparable. Even so, studies on Caucasians have suggested that jobs and occupational activities that require kneeling and squatting are associated with knee OA[21-26], whereas these same activities were not associated with KL ≥ 2 OA in Japan[27,28]. The discrepancies between Caucasian and Japanese subjects may be explained partly by the Japanese traditional lifestyle, which includes sitting on the heels of the feet and using the Japanese-style lavatory where subjects have to take a deep squatting position. These positions may cause mechanical stress on the knee joint and possibly accelerate progression of knee OA. Among elderly Japanese subjects, kneeling and squatting are common postures in daily life; this lifestyle factor could obscure the association between knee OA and the occupational activities of kneeling and squatting. The ROAD study also

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Table2 Occupational activities and knee OA among epidemiologic studies

Author	Felson		Cooper	Coggon	Sandmark	Man-ninen	Anderson	Muraki		Yoshimura	Lau
Reference	22		23	24	25	26	21	27		28	29
Ethnicity	Whites in USA		England	England	Sweden	Finland	Blacks and Whites in USA	Japan		Japan	Chinese
Age	≥63		≥55	≥47	≥55	≥55	55–64	≥50		≥45	
Total number (men:women)	1376 (569:807)		327 (90:237)	1036 (410:626)	1173 (589:584)	805 (195:610)	1250 (606:644)	1471 (531:940)		202 (-:202)	1,316 (332:984)
Definition of OA	KL ≥2	KL ≥3	KL ≥3 with knee pain	Listed for knee sur-gery	TKA	TKA	KL ≥2	KL ≥2	KL ≥3	KL ≥3 with knee pain	KL ≥3
Occupational activities											
Sitting on a chair (men:women)			1.2 (-:-)		– (0.7:0.9)			0.7* (0.6*:0.8)	0.8 (0.8:0.8)	– (-:0.4*)	
Standing (men:women)			0.8 (-:-)		– (1.7*:1.6*)	0.6* (0.4*:0.7)		2.0* (2.3*:1.8*)	1.4 (1.1:1.5)	– (-:1.2)	
Kneeling (men:women)			3.4* (-:-)	1.8* (1.7*:2.0*)	– (2.1*:1.5)	1.7*† (1.7:1.8*)		1.1 (0.8:1.4)	1.4* (0.9:1.7*)	– (-:1.0)	– (1.4:0.9)
Squatting (men:women)	– (2.2*:0.4)	– (2.0:0.7)	6.9* (-:-)	2.3* (2.2*:2.8*)	– (2.9*:1.1)	1.7*† (1.7:1.8*)	– (2.5*:3.5*)	1.2 (0.9:1.5*)	1.3* (1.0:1.5*)	– (-:1.1)	– (1.2:1.1)
Walking (men:women)			0.9 (-:-)	1.9* (1.7:2.1*)		1.1 (1.5:1.1)		1.8* (2.2*:1.6*)	1.1 (0.9:1.1)	– (-:0.9)	– (2.2*:1.4*)
Climbing (men:women)			2.7* (-:-)	1.5* (2.3*:0.7)	– (1.2:1.4)	1.6 (2.8:1.5)		2.2* (2.4*:1.9*)	1.3 (1.0:1.5)	– (-:0.9)	– (4.1*:6.1*)
Lifting weights (men:women)			1.4 (-:-)	1.7* (1.9*:1.5*)	– (3.0*:1.7*)	1.0 (0.9:1.1)		1.9* (2.3*:1.7*)	1.6* (1.3:1.7*)	– (-:1.0)	– (1.7:1.5*)

OA, osteoarthritis; KL,Kellgren–Lawrence grading system; TKA, total knee arthroplasty.
*$P < 0.05$. †kneeling or squatting.

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demonstrated that the direction of association of kneeling and squatting with knee OA was also different between genders[27], although these differences were not significant except for squatting in women. Men generally have greater muscle strength than women, and muscle strength has a protective effect on knee OA; this may result in lower rates of OA in men.

Discussion

The authors have referenced some of their own studies in this review. These referenced studies have been conducted in accordance with the Declaration of Helsinki (1964) and the protocols of these studies have been approved by the relevant ethics committees related to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in these studies.

We reviewed the prevalence, incidence and risk factors for knee OA. The reported prevalence and incidence of radiographic knee OA differ considerably among races. However, because of the low inter-observer reliability of categorical classifications such as KL grading, these strict comparisons were limited. In addition, a few established risk factors for knee OA were found, other than age, sex and obesity. Further more, few established serum or urine markers were discovered, which may be partly due to the definition of knee OA. The most popular grading system for radiographic severity of knee OA is the KL grading system, which classifiesknee OA into five-grade (0–4) scales. KL grade 2 is defined as osteophyte formation and grade 3 as joint space narrowing in addition to osteophyte formation; KL ≥ 2 is generally thought to be the standard diagnostic criterion for knee OA. However, accumulating evidence has shown that osteophytosis and joint space narrowing have distinct aetiologic mechanisms and that their progression is neither constant nor proportional[14]. To assess these two pathological features separately, joint space narrowing and osteophytosis should be separately assessed. In addition, joint space narrowing and osteophyte formation were separately evaluated using a radiographic atlas of individual features published by the Osteoarthritis Research Society International (OARSI) in 2007. However, the grading is still limited in reproducibility and sensitivity because of the subjective judgement of individual observers and the use of categorical classification into four-grade (0–3) scales. To overcome this problem, joint space width or osteophyte area (OPA) should be evaluated using a fully automatic system. The ROAD study has shown that the association of joint space narrowing with osteophytosis was weak. When joint space narrowing and osteophytosis were assessed separately using a fully automatic system, quality of life (QOL), occupational activities and dietary intakes showed distinct associations with joint space narrowing and osteophytosis[28]. There is some controversy about the importance of radiographic osteophyte findings in populations, but the ROAD study showed that both joint space narrowing and osteophytosis independently reduce QOL, as estimated using the Western Ontario and Mc Master Universities Arthritis Index (WOMAC). Osteophytosis appears to start from the activation of periosteal layers, with initial generation of chondrophytes and subsequent calcification to real osteophytes. The process may be an adaptive reaction of the joint to cope with joint instability; thus, OPA may indicate the severity of joint instability, which may reduce QOL. In addition, when men and women were analysed separately, joint space narrowing was significantly associated with the WOMAC pain domain, but not with the physical function domain in men. In contrast, osteophytosis was associated with the physical function domain, but not with the pain domain.

Conclusion

According to the methodology of the WOMAC, pain domains estimate the severity of pain, indicating that joint space narrowing may be strongly associated with pain. In contrast, physical function domains assess difficulties in activity of daily living (ADL), indicating that osteophytosis may be mainly associated with ADL, particularly in men. In the future, to find new risk factors or markers for knee OA, joint space narrowing and osteophytosis should be assessed separately using a fully automatic system.

Abbreviations list

ADL, activity of daily living; KL, Kellgren–Lawrence; NHANES, National Health and Nutrition Examination Survey; OA, osteoarthritis; OARSI, Osteoarthritis Research Society International; OPA, osteophyte area; QOL, quality of life; WOMAC, Western Ontario and Mc Master Universities Arthritis Index.

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