Journal of Athletic Training 2017;52(6):497–506
doi: 10.4085/1062-6050-50.2.08

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systematic review

Is Participation in Certain Sports Associated With Knee Osteoarthritis? A Systematic Review

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Objective: Information regarding the relative risks of developing knee osteoarthritis (OA) as a result of sport participation is critical for shaping public health messages and for informing knee-OA prevention strategies. The purpose of this systematic review was to investigate the association between participation in specific sports and knee OA.

Data Sources: We completed a systematic literature search in September 2012 using 6 bibliographic databases (PubMed; Ovid MEDLINE; Journals@Ovid; American College of Physicians Journal Club; Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Review, Database of Abstracts of Reviews of Effects; and Ovid HealthStar), manual searches (4 journals), and reference lists (56 articles).

Study Selection: Studies were included if they met the following 4 criteria: (1) an aim was to investigate an association between sport participation and knee OA; (2) the outcome measure was radiographic knee OA, clinical knee OA, total knee replacement, self-reported diagnosis of knee OA, or placement on a waiting list for a total knee replacement; (3) the study design was case control or cohort; and (4) the study was written in English. Articles were excluded if the study population had an underlying condition other than knee OA.

Data Extraction: One investigator extracted data (eg, group descriptions, knee OA prevalence, source of nonexposed controls).

Data Synthesis: The overall knee-OA prevalence in sport participants (n = 3759) was 7.7%, compared with 7.3% among nonexposed controls (referent group n = 4730, odds ratio [OR] = 1.1). Specific sports with a significantly higher prevalence of knee OA were soccer (OR = 3.5), elite-level long-distance running (OR = 3.3), competitive weight lifting (OR = 6.9), and wrestling (OR = 3.8). Elite-sport (soccer or orienteering) and nonelite-sport (soccer or American football) participants without a history of knee injury had a greater prevalence of knee OA than nonexposed participants.

Conclusions: Participants in soccer (elite and nonelite), elite-level long-distance running, competitive weight lifting, and wrestling had an increased prevalence of knee OA and should be targeted for risk-reduction strategies.

Key Words: injury, athletic injuries, injury prevention, epidemiology

Key Points

- Sport participation may increase the risk of osteoarthritis, but it is unclear whether this is due to the specific sport, a sport-related injury, or some other unknown factor.
- Participation in certain sports (eg, soccer, elite-level long-distance running, competitive weight lifting, wrestling) may be associated with knee osteoarthritis later in life.
- Because the current literature primarily focuses on elite-level male athletes, future researchers need to study female athletes, nonelite athletes (eg, high school level), and recreational athletes.
- Athletes who choose to participate in contact and collision sports such as soccer and football at elite levels for many years should know they may have an increased likelihood of developing osteoarthritis. They should implement strategies to mitigate other factors (eg, preventing obesity and severe joint injuries) associated with the development of osteoarthritis.

Osteoarthritis is a common chronic disease that affects 27 million US adults[1] and accounts for 55% of arthritis-related hospitalizations[2] and 20% of ambulatory medical care visits.[3] Known risk factors for osteoarthritis (OA) include older age, female sex, obesity, prior joint injury, occupation, and genetics.[4–8] The lifetime risk of symptomatic knee OA is reported to be 44.7% overall, 56.8% among those with a history of knee injury, and 60.5% among obese persons.[9] Some authors[4,10–13] have stated that sport participation may increase the risk of OA, but it is unclear whether this is due to the specific sport, a sport-related injury, or some other unknown factor. Independent of the risk of knee OA after joint trauma,[14] some sports that involve twisting, turning, and jumping (eg, soccer) impart high biomechanical forces to the knee joint. When accumulated over the years, these forces may play a role in the joint degeneration that leads to OA. Clarifying these mechanisms is important for developing primary prevention interventions for OA.

The health benefits of physical activity and exercise summarized by the "Physical Activity Guidelines Advisory Committee report"[15] in 2008 provide overwhelming evidence to support the national promotion of a physically active lifestyle. This report also supplied the most up-to-date evidence on the potential hazards of physical activity and exercise, including musculoskeletal injuries, cardiac events, and the epidemiologic association between physical activity participation and the risk of OA. One finding from this expert panel was that participation in the types and amounts of physical activity recommended for health benefits has not been shown to increase the risk of OA. Formal sport participation, whether competitive or not, is not necessary to lead a physically active lifestyle. However, sport participation is a common way in which children and adolescents are physically active. The report qualitatively examined only the role of participation in specific sports and the development of OA but did not quantify the role of injury in this relationship. For public health purposes, information regarding the association between participation in specific sport activities and the development of OA is critical for shaping health-communication messages and developing and evaluating potential OA-prevention interventions.

The purpose of our study was to conduct a systematic review of the literature to investigate the quantitative association between participation in specific sports and the chance of developing knee OA. A secondary purpose was to attempt to distinguish the effects of joint injury from those of sport participation with respect to the chance of developing knee OA.

METHODS

Data Sources and Searches

We conducted a comprehensive literature search through September 2012 with the assistance of a reference librarian at Temple University who had 29 years of database search experience. The 6 primary databases searched were (1) PubMed, (2) Ovid MEDLINE, (3) Journals@Ovid, (4) American College of Physicians Journal Club, (5) Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, and (6) Ovid HealthStar. We performed a secondary search of EBSCO*host* databases (eg, SPORTDiscus), ProQuest CSA, FirstSearch, and PEDro but located no additional articles beyond those in PubMed and Ovid. Studies were identified using predetermined search criteria: (*osteoarthritis* OR *degenerative joint disease*) AND (*knee* OR *patellar* OR *tibiofemoral*) AND (*prevalence* OR *incidence* OR *epidemiology* OR *odds ratio*) AND (*sport* OR *sports* OR *sport participant* OR *athletic* OR *athletics* OR *football* OR *track* OR *rugby* OR *ballet* OR *weightlifter* OR *weightlifters* OR *military* OR *servicemen* OR *servicewomen* OR *soccer* OR *running* OR *dance* OR *exercise* OR *baseball* OR *hockey* OR *strength training* OR *soldier*) AND (*case control* OR *cross section** OR *cohort*). In addition to searching electronic databases, we manually searched tables of contents for 4 journals: *Arthritis and Rheumatism* and *Arthritis Care & Research*, January 1990 through April 2012; *Osteoarthritis and Cartilage*, 1993 through April 2012; and *Scandinavian Journal of Rheumatology*, January 1999 through April 2012. We also manually searched the reference lists of full-text articles to identify potential additional articles not indexed by the electronic databases. No additional articles were located with the manual search, confirming that we had found all of the relevant articles. Because all of the included articles were from journals listed in PubMed, we monitored only PubMed for updates through March 3, 2013. This systematic review had no external funding source.

Study Selection

Studies were included if they met the following 4 criteria: (1) an aim was to investigate an association between sport participation and knee OA; (2) the outcome measure was radiographic knee OA, clinical knee OA, total knee replacement, self-reported diagnosis of knee OA, or placement on a waiting list for a total knee replacement; (3) the study design was case control or cohort; and (4) the study was written in English. *Case-control design* was defined as a study that compared a history of sport participation between 2 groups of people: individuals with or without knee OA. In contrast, *cohort design* was defined as a study that compared the presence of knee OA among groups of people categorized by whether or not they had a history of sport participation. Articles were excluded if the study population had an underlying condition (eg, infection, rheumatoid arthritis, ankylosing spondylitis, tuberculosis, hemochromatosis, or sickle cell disease), patellofemoral OA alone or progression of knee OA alone was reported, and data were reported by knee rather than by individual. Studies were included regardless of how the original authors defined sport participation and knee OA. One study[16] was excluded because the participants were single-limb amputees who participated in elite-level volleyball. If the primary reviewer (J.B.D.) was unsure whether a study met the inclusion and exclusion criteria, 2 other authors (J.M.H., M.R.S.) reviewed them, and the group reached a consensus.

An overview of study selection is provided in Figure 1. Initially, we performed the electronic and manual searches of reference lists as well as tables of contents of selected journals. To ensure that all potential articles were selected for further review and none were missed, 2 authors (J.B.D., M.R.S.) screened the first 100 records to establish whether 1 person could accurately capture all appropriate studies. The interrater agreement ($\kappa = 0.96$) was high, and therefore, for the remaining records, the titles, key words, and full abstracts were screened by 1 author (J.B.D.). Records not meeting the inclusion and exclusion criteria were eliminated; if information in the abstract was insufficient to assess inclusion and exclusion criteria, we obtained the full-text article.[16] After the initial screening process, articles were retrieved and were subsequently rescreened and assessed for meeting the inclusion and exclusion criteria.

Data Extraction and Quality Assessment

Two raters (J.B.D., J.M.H.) assessed the quality of the included studies using the Newcastle-Ottawa Scale (NOS). We chose this scale due to its ease of use and because we could use it to assess both case-control and cohort study

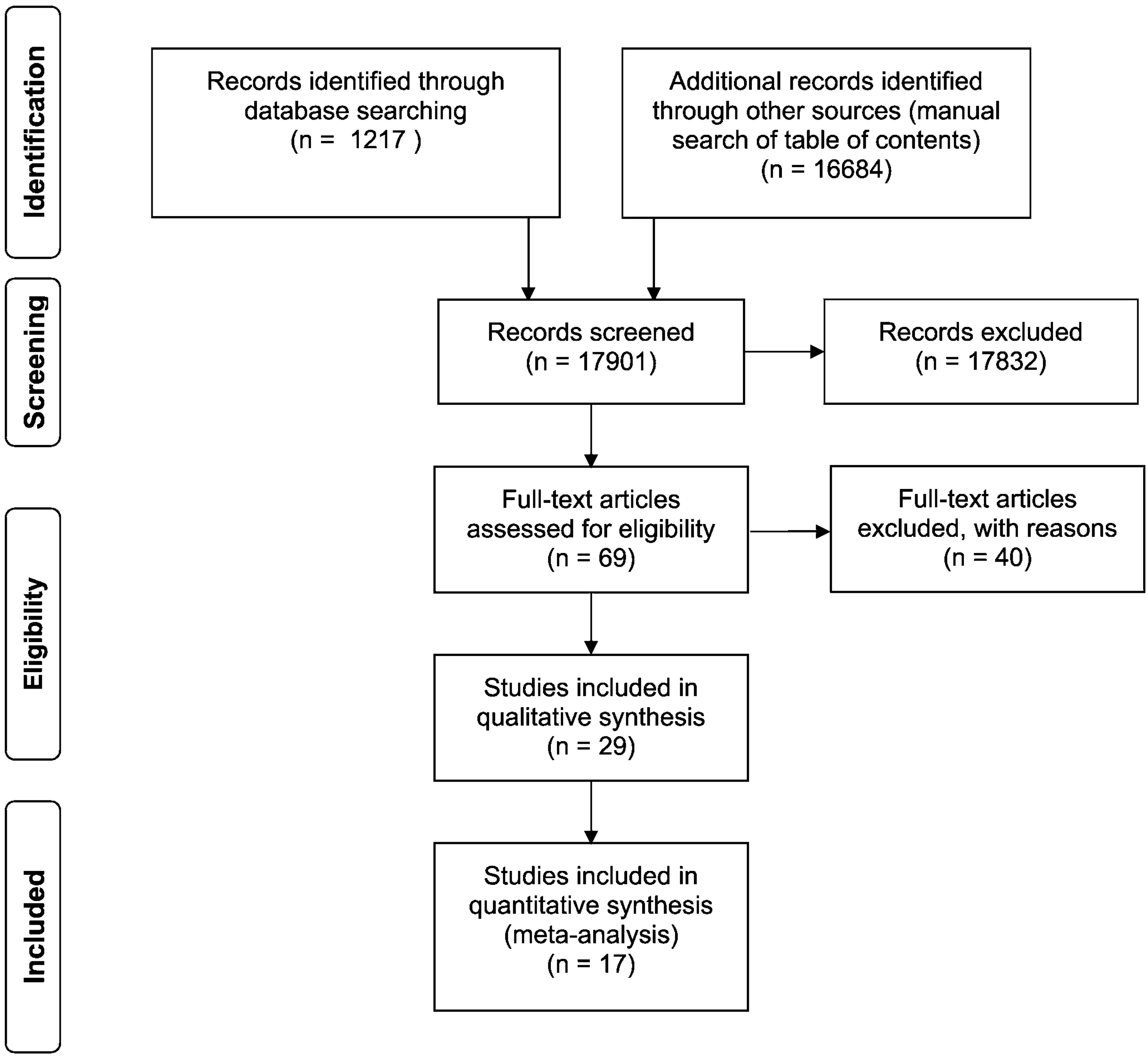

Figure 1. Study selection. An electronic search with automatic elimination of duplicates and manual search of table of contents identified 17 901 records. Among the 69 full-text articles screened, most articles (n = 40) were eliminated due to the study design or a definition of *osteoarthritis* that did not meet the inclusion criteria. We evaluated 29 articles with a qualitative analysis and 17 articles with quantitative methods.

designs.[17] The NOS has separate checklists for case-control and cohort studies and assesses studies in 3 areas: selection (4 items), comparability (1 item), and exposure for case-control studies or outcome for cohort studies (3 items). Each checklist totals 9 possible points, with a higher score indicating better quality. Coding rules and procedures were clarified as necessary (see Supplemental File for a full description, available online at http://dx.doi.org/10.4085/1062-6050-50.2.08.S1). Two authors (J.B.D., J.M.H.) independently rated each study in random order using the appropriate NOS instrument (case-control or cohort form), and a third rater (K.P.H.) provided consensus as needed. Additional details about the quality assessment are included in the Supplemental File.

During this quality-assessment process, 40 additional articles were excluded due to inappropriate study designs (eg, cross sectional) or inadequate details regarding the assessment of outcome measures. This left 29 articles for the qualitative synthesis; 17 of these had sufficient information and the appropriate study design to be included (Figure 1).

A data-extraction spreadsheet was generated and reviewed by all of the authors and 1 external reviewer. One author (J.B.D.) collected key information from each article: (1) publication data: first author, publication year, journal, country, study design, and quality-assessment score; (2) OA (outcome) details: definition of *OA* and time of follow-up; (3) group descriptions: sources of controls and nonexposed cohort, sources of cases and exposed cohort, matching variables, sport, level of sport participation, years of experience playing sports, sex, percentage lost to follow-up, sample size, and participant age, height, weight, and

Table 1. Prevalence and Odds Ratios of Osteoarthritis (OA) Among 11 Retrospective Cohort Studies by Sport

Association With OA	Sport	Sport Participants n OA	No OA	Total	OA Prevalence, %	Nonexposed Participants n OA	No OA	Total	OA Prevalence, %	Crude Odds Ratio[a]	95% Confidence Interval
Significant											
	Elite and nonelite soccer[21,24,26,27,30,31]	79	960	1039	7.6	81	3417	3498	2.3	3.47	2.53, 4.77
	Elite long-distance running[26,27]	8	183	191	4.2	19	1413	1432	1.3	3.25	1.40, 7.53
	Elite weight lifting[26,27]	12	130	142	8.5	19	1413	1432	1.3	6.87	3.26, 14.46
	Elite wrestling[26]	12	244	256	4.7	18	1385	1403	1.3	3.78	1.80, 7.96
Unclear but possible[b]											
	High school American football[29]	11	12	23	47.8	1	10	11	9.1	9.17	1.00, 83.77
	Elite throwing[26]	5	162	167	3.0	18	1385	1403	1.3	2.38	0.87, 6.48
	Elite handball[31]	7	134	141	5.0	30	1215	1245	2.4	2.12	0.91, 4.91
	Elite cross-country skiing[26]	3	115	118	2.5	18	1385	1403	1.3	2.01	0.58, 6.92
	Elite ice hockey[26,31]	7	219	226	3.1	48	2600	2648	1.8	1.73	0.77, 3.87
	Elite orienteering[25,28]	54	237	291	18.6	26	180	206	12.6	1.58	0.95, 2.62
Unclear but unlikely[c]											
	Elite basketball[26]	1	84	85	1.2	18	1385	1403	1.3	0.92	0.12, 6.94
	Elite boxing[26]	4	230	234	1.7	18	1385	1403	1.3	1.34	0.45, 3.99
	Elite shooting[22]	11	41	52	21.2	120	388	508	23.6	0.87	0.43, 1.74
	Elite track and field[22,23,26]	76	718	794	9.6	257	2161	2418	10.6	0.89	0.68, 1.17

[a] Odds ratio calculated as No. of sport participants with OA × No. of nonexposed participants without OA / No. of sport participants without OA × No. of nonexposed participants without OA.
[b] Odds ratio <0.70 or >1.50.
[c] Odds ratio = 0.70–1.50.

body mass index; and (4) outcome measures: prevalence of OA, frequency of OA, crude odds ratio (OR), adjusted OR, confounding variables, and associated *P* values. A second author (J.M.H.) then randomly selected 4 articles to assess the accuracy of the extracted data. The 2 authors had fewer than 5 contradictory findings in the extracted data (1013 data cells).

Before data analysis, we classified specific sports based on intensity, knee-injury rate, impact, and torsional loading: low, medium, or high.[18] Two independent orthopaedic and sports medicine researchers reviewed our sport risk-level classification, including an author of the initial classification system. Sport classification by risk level for the reviewed articles is provided in Supplemental Table 1.

Data Synthesis and Analysis

We calculated OA prevalence rates, ORs, and 95% confidence intervals (CIs) for specific sports (Table 1) and for 6 a priori sensitivity analyses designed to assess the heterogeneity of results depending on potential confounding factors (Tables 2 and 3). These factors represent 2 unique domains: study-related and sport-related factors. The 3 study-related factors addressed potential concerns about study design: (1) source of the nonexposed cohort, (2) quality score, and (3) year of publication. The sport-related factors reflected items associated with joint loading (eg, repetitive overloading or high-force loading injuries): (1) loading classification of sport, (2) level of competition, and (3) injury status. Because a secondary goal of this systematic review was to separate the effect of joint injury versus sport participation, we further explored injury status in 2 sets of cohort studies: those in which authors excluded individuals with injuries or noted that their sample had no history of injury and those in which authors stratified their data based on the presence or absence of a history of knee injury (Table 3). We did not include case-control studies in these analyses because respondents could report participation in multiple sports, making it impossible to identify the independent effect of a specific sport on OA prevalence. Prevalence rates among retrospective cohort studies were calculated by summing the total number of OA cases among sport participants (across studies in a single sport) and dividing by the total number of participants in a specific sport (across studies). The same calculations were performed for the nonexposed cohorts (numerator = number of OA cases, denominator = total number of unexposed persons). The 95% CIs for ORs were based upon methods described by Armitage and Berry.[19] All calculations were performed in Excel (version 2010; Microsoft Corporation, Redmond, WA). *Significant odds ratios* were defined as 95% CIs that did not encompass 1.00. To assess the association between a history of participation in certain sports and knee OA, we classified sports into 3 categories: (1) significant association with OA, (2) unclear but possible association with OA, and (3) unclear but unlikely association with OA. *Unclear but possible association with OA* was defined as an OR <0.70 or >1.50. *Unclear but unlikely association with OA* was defined as an OR between 0.70 and 1.50. These cut points were based on ORs that correspond to a small standardized effect size (d = 0.20).[20]

Table 2. **Sensitivity Analysis of Prevalence and Odds Ratios of Osteoarthritis (OA) Among 11 Retrospective Cohort Studies**

	Sport Participants				Nonexposed Participants					
	n				n					
Characteristic	OA[a]	No OA[b]	Total	OA Prevalence, %	OA[c]	No OA	Total	OA Prevalence, %	Crude Odds Ratio[a]	95% Confidence Interval
Loading classification of sport										
Low[22]	11	41	52	21.2	120	388	508	23.6	0.87	0.43, 1.74
Medium[26]	3	115	118	2.5	18	1385	1403	1.3	2.01	0.58, 6.92
High[21–31]	387	3776	4163	9.3	347	4383	4730	7.3	1.30	1.11, 1.51
Source of nonexposed participants										
Community based[30,31]	43	810	853	5.0	43	1916	1959	2.2	2.37	1.54, 3.64
Hospital or medical practice[21,24,25]	42	92	134	31.3	26	108	134	19.4	1.90	1.08, 3.33
National military service[22,23,26,28]	172	2489	2661	6.5	276	2321	2597	10.6	0.58	0.48, 0.71
Sport (shooting)[27]	22	66	88	25.0	1	28	29	3.4	9.33	1.20, 72.66
Level of competition										
Elite (including county teams)[21–28,30,31]	270	3251	3521	7.7	337	3810	4147	8.1	0.94	0.80, 1.11
Nonelite (including high school)[29,30]	20	218	238	8.4	10	573	583	1.7	5.26	2.42, 11.41
Injury status										
No history of knee injury[21,25,29,30]	53	277	330	16.1	29	617	646	4.5	4.07	2.53, 6.54
History of knee injury[b] [29,30]	15	41	56	26.8	2	12	14	14.3	2.20	0.44, 10.98
History not sufficiently reported[c] [22–24,26–28,31]	222	3151	3373	6.6	312	3616	3928	7.9	0.82	0.68, 0.98
Quality assessment: Newcastle-Ottawa score										
<4[22,24]	65	256	321	20.2	125	440	565	22.1	0.89	0.64, 1.25
>4[21,23,25–31]	225	3213	3438	7.0	222	3943	4165	5.3	1.24	1.03, 1.51
Year of publication										
Before 2000[24–30]	162	2632	2794	5.8	64	2356	2420	2.6	2.27	1.69, 3.04
After 2000[21–23,31]	128	837	965	13.3	283	2027	2310	12.3	1.10	0.88, 1.37

[a] Odds ratio calculated as No. of sport participants with OA × No. of nonexposed participants without OA / No. of sport participants without OA × No. of nonexposed participants without OA.
[b] Roos et al (1994) injury data[30] for controls were based on the control group for the entire study and not the elite-matched controls.
[c] Includes Kujala et al (1995) and Kujala et al (1999), who statistically controlled for injuries or did not provide sufficient details about the injuries.[27,28]

Table 3. Characteristics of 4 Studies That Controlled for Injuries, by History of Knee Injury

Study	Source of Nonexposed Participants	Source of Exposed Participants	Osteoarthritis Definition	Injury Definition	Follow-up, y	Prevalence, % (No.)		Crude Odds Ratio (95% Confidence Interval)
						Exposed Participants	Nonexposed Participants	
Excluded knee injuries or no history of knee injuries reported								
Elleuch et al[21]	Hospital or medical practice	Professional or elite soccer	Kellgren-Lawrence Scale ≥3	Excluded fractures, meniscal or ligament injury, surgery	>20	56.0 (28/50)	28.0 (14/50)	
Konradsen et al[25]	Hospital or medical practice	County orienteering teams	Ahlbäck Scale ≥1	No injuries reported	0	35.0 (9/27)[a]	27.0 (7/27)[a]	
								2.47 (1.26, 4.83)
Stratified by injury: no history of knee injury								
Roos et al[30]	Community based	Professional or elite soccer	Loss of joint-space width	No meniscal or ACL injury	ND	10.7 (6/56)	1.3 (7/559)	
Roos et al[30]	Community based	Nonelite soccer	Loss of joint-space width	No meniscal or ACL injury	ND	2.7 (5/183)	1.3 (7/559)	
Moretz et al[29]	ND	High school football (US)	Kellgren-Lawrence Scale	No time-loss injury	20	35.7 (5/14)	10.0 (1/10)	
								4.73 (2.00, 11.21)
Stratified by injury: history of knee injury								
Roos et al[30]	Community based	Professional or elite soccer	Loss of joint-space width	Injured meniscus or ACL	ND	33.3 (5/15)	15.4 (2/13)	
Roos et al[30]	Community based	Nonelite soccer	Loss of joint-space width	Injured meniscus or ACL	ND	12.5 (4/32)	15.4 (2/13)	
Moretz et al[29]	ND	High school football (US)	Kellgren-Lawrence Scale	Trauma requiring missed day	20	66.7 (6/9)	0.0 (0/1)	
								2.20 (0.44, 10.98)

Abbreviations: ACL, anterior cruciate ligament; ND, no data reported.

[a] Calculations were based on the authors' reporting of percentages and reflect rounding error.

RESULTS

Study Characteristics

We identified a total of 1217 articles with the electronic search and screened an additional 16 684 manually for a total of 17 901 articles. After extensive screening (see Figure 1 for the study-selection process), we extracted data from 17 articles (see Supplemental Table 2): 11 retrospective cohort studies[21–31] and 6 case-control studies.[32–37] Quality-assessment (NOS) scores ranged from 3 to 7 (Supplemental Tables 3 and 4). Most studies originated in European countries (13 of 17); 2 were based in the United States. The majority of articles used the national military service (4 of 11) or hospital or medical practices (3 of 11) as the primary source for nonexposed participants. Four articles described individuals who had participated in sports for more than 20 years before inclusion,[21,22,27,29] 5 articles included individuals with fewer than 20 years since retiring from competitive sports,[23,25,26,28,31] and 2 studies did not report the time between sport participation and long-term follow-up.[24,30] Most retrospective cohort studies evaluated male elite or professional sport participants (10 of 11), compared with only 2 studies that included nonelite male sport participants. No retrospective cohort studies included female sports participants. Prevalence data for each individual study and sport are reported in Supplemental Tables 5 through 7.

Prevalence and Odds Ratios of OA by Sport

The overall knee-OA prevalence in sport participants (n = 3759) was 7.7% and among nonexposed controls was 7.3% (referent group n = 4730, OR = 1.1). Prevalences and ORs are reported for each sport in Table 1. Compared with unexposed persons, participants in soccer, elite-level long-distance running, competitive weight lifting, and wrestling had a higher prevalence of knee OA. The magnitudes of association were relatively large: those in elite long-distance running, soccer, weight lifting, and wrestling had a prevalence 3 to 7 times that for unexposed persons. Participation in nonelite (high school) American football was also associated with a higher prevalence of knee OA: approximately 9 times higher, but the range was large. Additionally, elite-level throwing, handball, cross-country skiing, ice hockey, and orienteering were classified as possibly associated with an increased prevalence of knee OA, but the sample sizes were too small to provide conclusive results. The remaining sports (elite basketball, boxing, shooting, and track and field) were classified as sports unlikely to be associated with knee OA.

Sensitivity Analyses

Sensitivity analyses for combined (not specific) sports participation in the 11 cohort studies are reported in Table 2. Higher-quality studies (NOS > 4) indicated a positive association between sport participation and knee OA, but this trend was not detected among the 2 studies with lower quality. Sports characterized as high loading were associated with an increased prevalence of knee OA, whereas medium-loading and low-loading sports were not. Summary estimates varied substantially by the source of the unexposed participants. Studies with other low-impact sport participants (eg, shooters) as the comparison group had the highest magnitude of association (7–9 times higher) with knee OA. Studies with general community members or hospital or medical practice sources of unexposed participants had a moderate magnitude of association with knee-OA prevalence, whereas sport participants in studies with national military service participants as the nonexposed cohort had an approximately 40% lower prevalence of knee OA. Among studies published before 2000, specific sport participation was associated with a higher prevalence of knee OA compared with unexposed persons; however, this association was not seen in research published after 2000.

Among all nonelite-level sports combined, sport participation was associated with about a 5 times higher prevalence of knee OA, but when studies of all elite-level sports were analyzed together, sport participation was not associated with knee OA. Most authors did not report sufficient information about individual histories of knee injuries, and in these studies, sport participation was associated with a 30% to 35% lower prevalence of knee OA. However, when authors did stratify by injury history, sport participants with no history of knee injury had an approximately 4 times higher prevalence of knee OA than unexposed persons. Sport participants with a history of knee injury had an increased prevalence of knee OA compared with unexposed persons (27% versus 14%, respectively), but this association was not statistically significant.

Characteristics of Studies That Controlled for History of Knee Injury

The characteristics of the 4 studies that excluded or stratified by history of injury are reported in Table 3. All of the studies included high-load and high–injury-risk sports, but each used different injury definitions. When injury status was controlled, uninjured elite-level sport participants had a higher prevalence of knee OA (OR = 9.46, 95% CI = 3.06, 29.24). Uninjured nonelite-sport participants (soccer or American football) also had a higher prevalence of knee OA than nonexposed participants (OR = 3.75, 95% CI = 1.46, 9.64). The ORs were not different among injured elite or nonelite sport participants; however, the sample sizes were small (injured elite = 15, injured nonelite = 41, nonexposed = 14). In studies that controlled for injury status by excluding participants with previous injuries, elite-sport participants (soccer or orienteering) still had a higher prevalence of knee OA than nonexposed participants.

DISCUSSION

Physical activity is promoted for its health benefits, but the extent to which participation in specific sports may increase the risk of OA is unclear. Some researchers[4,10–13] have suggested that participation in select sports may increase the risk of knee OA, but these studies combined multiple sports, did not define the level of competition, included both sexes, or separated the influence of previous joint injuries. Our findings suggest that participants in soccer, elite-level long-distance running, weight lifting, or wrestling have a 3 to 7 times higher prevalence of knee OA, whereas participants in elite-level basketball, boxing, shooting, or track and field were unlikely to have knee

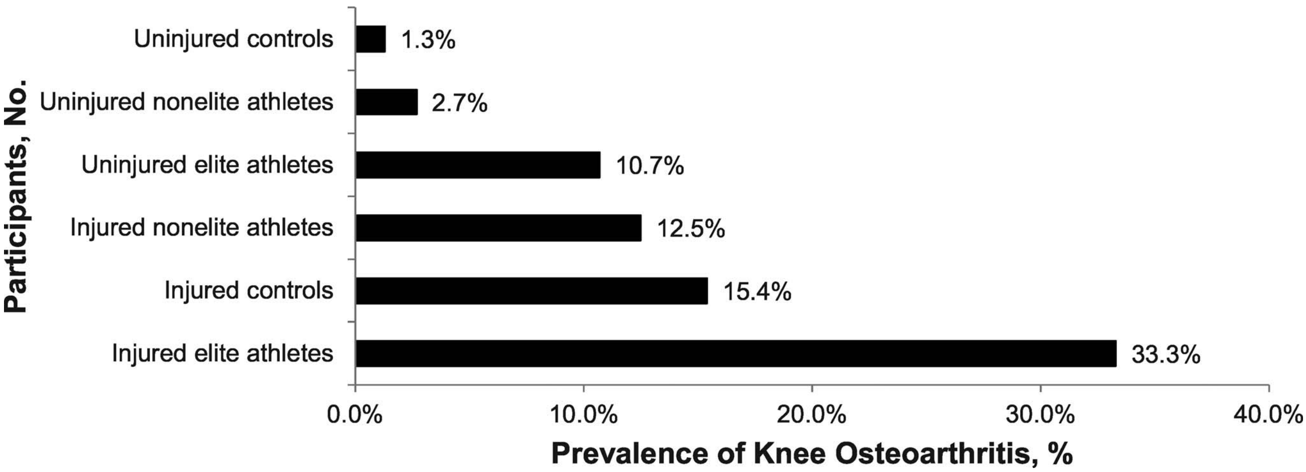

Figure 2. Prevalence (%) of knee osteoarthritis by injury status and level of play among soccer athletes and controls (no history of soccer participation). Prevalence was calculated using the raw data from Figure 1 of Roos et al (1994).[30]

OA. The prevalence of knee OA may be greater among participants in high school American football as well as elite-level throwing, handball, cross-country skiing, ice hockey, or orienteering, but the results were inconclusive. Furthermore, the lack of data regarding females was concerning because they represent a large percentage of athletes in the United States[38,39] and are at high risk for noncontact knee injuries[40,41] and OA.[42] Finally, it was difficult to assess the influence of age during sport participation, years of participation in competitive sports, and time between competition and follow-up, all of which may affect the risk of knee OA. These deficiencies in the literature are areas that warrant future investigation. Based on our systematic review, participation in certain sports is associated with a greater prevalence of knee OA. The increased odds of knee OA are likely confounded by the level of play and joint-injury history, but further research may be needed to confirm these hypotheses.

The sensitivity analyses reveal the complexity of the potential influence of level of play and previous injury on the risk of knee OA. Three of the 4 sports with increased prevalences of knee OA were studied exclusively among elite-level sport participants. Only 2 studies[29,30] in this systematic review included nonelite athletes. Roos et al[30] found that elite soccer participants were at greater risk for knee OA compared with nonelite participants and community-based controls (adjusted for age). Moretz et al[29] studied a small group of high school athletes playing American football; due to the small number and subsequent poor precision, the true association between nonelite football participation and knee OA risk is still unclear. When we combined these studies in the sensitivity analyses, nonelite participants had an approximately 5 times higher prevalence of knee OA than nonparticipants, although these estimates were not statistically significant. The paucity of information on nonelite sport participation severely hinders our ability to assess OA risk from participation in sports activities that are being promoted for health benefits.

Roos et al[30] was the only group to evaluate elite and nonelite soccer participants with or without previous injuries. Their findings shed light on but still do not sufficiently clarify whether sport participation is associated with an increased risk of knee OA among those with no previous injury history. Using raw data from Roos et al,[30] stratified by level of play and injury status, we found that the prevalence of knee OA was lowest among uninjured controls (1.3%) and nonelite soccer players (2.7%) and highest among injured elite soccer players (33.3%), suggesting that injury status and level of play combine to produce a dose-effect relationship (Figure 2). However, these prevalence estimates should be interpreted cautiously because several are based on a small number of OA cases. Authors of 1 case-control study[36] noted that after adjusting for a history of knee injury, soccer and ice hockey participants no longer had an increased risk of knee OA, supporting the notion that joint injury may be a predominant factor in these sports. The authors captured information on "competitive versus noncompetitive" level of play, but this information was used only descriptively and not as an adjustment or stratification variable. In another case-control study of elite Australian-rules footballers, Deacon et al[43] found that previous joint injury was a strong predictor of knee OA. Level of play and previous injury are likely important confounders and possibly effect modifiers that influence the risk of knee OA and should be evaluated independently in future research.

Individually, the 4 sports whose participants were found to have a 3 to 7 times higher prevalence of knee OA were classified a priori as high risk based on sport intensity, knee-injury rate, joint impact, and torsional loading. However, when all of the high-risk sports were collapsed in the sensitivity analyses, the association with knee OA was reduced (30% greater odds). It is possible that combining seemingly similar sports (eg, racquet sports and team sports), as was common in previous research, masks the true relationship between specific sport participation and knee OA. Future investigators should pursue methods that provide sufficient power to analyze sports individually and allow for stratification by level of play and injury status.

The foundation of a cohort study is the comparison of outcomes between people who were exposed or unexposed.[44] There is no consensus on which comparison group may be the best (eg, has the least potential for selection bias), but the goal is for the comparison (unexposed) group to be identical in all ways to the exposed group of interest.[44,45] All studies in this review were focused on retrospective cohorts; the authors chose the exposed and unexposed groups based on membership in some historical group (members of a sports team, general community members, persons attending a specific hospital or medical practice, or adults entering mandatory military service). Most authors investigated persons entering mandatory national military service (totaling $>$5000) as the comparison group, which may be easy to identify accurately but may be prone to selection bias. National military service can involve similar joint loading and propensity for knee injuries compared with sports,[28] and therefore, one cannot truly say this comparison group is unexposed. In fact, in our sensitivity analyses, sport participants had a 39% to 42% lower prevalence of OA than military service controls. To develop data generalizable to the United States and other countries without mandatory military service, future researchers should consider other sources of unexposed participants (eg, community based) that can better inform public health messages about the risks related to nonelite and recreational sport participation.

We found significant gaps in the literature. Among the retrospective cohorts, no female sport participants were evaluated. This is a considerable deficiency in the literature because more than 40% of college and high school athletes in the United States are female[38,39] and women have higher rates of OA.[1] Furthermore, nonelite or recreational sport participants were underrepresented. In the United States, public health guidelines recommend 150 or more minutes per week of at least moderate-intensity aerobic exercise and 2 days of muscle-strengthening activity per week to reduce obesity and produce a multitude of health benefits for persons of all ages.[15] Participation in recreational sports can be 1 method of helping people reach these goals, but we still lack sufficient information to help people choose the sports that may reduce their risk of OA. However, authors of other systematic reviews have focused on general recreational physical activity (not necessarily specific sports). Urquhart et al[46] found strong evidence for no relationship between joint-space narrowing (a sign of OA and its severity) and physical activity (eg, sport participation, recreational running). Furthermore, they reported good evidence that physical activity protects against cartilage defects. Future prospective researchers should include more female and more nonelite sport participants; larger sample sizes; and low-, medium-, and high-risk sports. In addition, it will be beneficial to stratify by level of play and previous injury status, collect information about other key risk factors for knee OA (eg, body mass index, alignment), and use standardized definitions for knee OA and injuries.

CONCLUSIONS

We found that participants in certain sports (eg, soccer, elite long-distance running, weight lifting, and wrestling) may have an increased prevalence of knee OA. The increased odds of knee OA are likely confounded by the level of play and joint-injury history. Unfortunately, it is unclear whether these findings are applicable to females, due to a lack of data regarding female athletes. There were also insufficient data regarding participants at nonelite competition levels as well as the age during and duration of sport participation. Until we have more information to make clearer, data-based decisions regarding sport participation and OA risk, athletes who choose to participate in contact or collision sports, such as soccer and football, at elite levels for many years should know they have an increased likelihood of OA and should pay attention to mitigating factors (eg, preventing obesity and severe joint injuries) associated with the development of OA.

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SUPPLEMENTAL MATERIAL

Supplemental text and tables.

Found at: http://dx.doi.org/10.4085/1062-6050-50.2.08.S1

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