

Participation in Athletic Activities May Be Associated with Later Development of Hip and Knee Osteoarthritis

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DOI: 10.3810/psm.2011.11.1939

Abstract: Participation in physical activity and recreational sports is critical for maintaining overall health; athletic activities and reduction in the incidence of several “lifestyle” diseases seem to have a dose-dependent relationship. Also, quality of life is enhanced in people who are active and regularly participate in sports. However, sports-related joint loading and strenuous occupational loading have been shown to increase the risk of osteoarthritis (OA), which seems to have a multifactorial etiology. This article reviews the literature on known connections between participation in sports and athletic activities and development of secondary OA in the joints of the major upper and lower limbs (ie, knee, hip, elbow, and shoulder) in athletes without injury. Most studies examining the connection between participation in sports and later development of OA usually provide low-level evidence and have many methodological weaknesses. Based on the literature reviewed in this article, it may be concluded that the connection between participation in athletic activities and development of OA has not been proven; however, the condition is highly likely to occur in the hip and knee joints. Definite conclusions regarding the connection between development of glenohumeral and/or elbow OA and participation in athletic activities cannot be drawn.

Keywords: osteoarthritis; athlete; sports; upper limb joints; lower limb joints

Introduction

Participation in physical activity and recreational sports is critical for maintaining overall health; athletic activities and reduction of the incidence of several “lifestyle” diseases¹ (eg, cardiovascular disease,²⁻⁴ diabetes mellitus⁵⁻⁸) seem to have a dose-dependent relationship. Also, individuals who are active and regularly participate in sports have a better quality of life.⁹⁻¹⁴ However, sports-related joint loading and strenuous occupational loading have been shown to increase the risk of osteoarthritis (OA).¹⁵ The normal and moderate loading of any joint is considered necessary for the well-being of its articular cartilage because it maintains the latter’s health and function, although its histomorphology, structural properties, and composition change throughout a patient’s lifetime.¹⁶ During skeletal development, the mechanical environment present at each joint continually transforms the tissue biology and growth in order to establish the physiological geometry of the surface contours and its topologic variation in thickness.^{17,18} In the elderly, cartilage gradually loses its mechanical and physical integrity; however, the maintenance of the normal structure of the cartilage and its characteristics still depend on the effects caused by the mechanical loading.¹⁶ This is probably why

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a methodic evaluation of several OA-prone joints through a wide range of ages clearly demonstrated that the best-preserved cartilage is found in areas of high load bearing and contact.^{16,18} In contrast, articular sites that have little or sporadic joint contact and pressure, often with indicating signs of fibrillation as early as in adolescence and middle age, are almost universally degenerated.^{19–22}

Changes in the loading stress exerted on any joint through altered physical activity levels may elicit either an anabolic or catabolic response. This response depends on the intensity, duration, and age of exercise onset.²³ Moderate exercise, particularly as shown in models of younger animals, generates anabolic changes in cartilage, such as decreased proteoglycan extractability, increased proteoglycan content, and increased cartilage thickness.²⁴ However, the implication of high-intensity exercise or a sudden increase in exercise in an individual at an older age is associated with the initiation of catabolic changes in cartilage, and eventually leads to OA.^{23,24} These degenerative changes may include, but are not limited to, a site-specific proteoglycan loss, a decreased collagen network structure, and reduced cartilage stiffness. However, severe inactivity (eg, immobilization) also results in catabolic changes, such as reduced proteoglycan content and cartilage thickness.²⁴ Results from several magnetic resonance image studies show similar clinical findings.^{24–28} However, Eckstein et al²⁹ could not establish whether cartilage is modulated with changes in mechanical stimulation, and Cicuttini et al³⁰ reported that the volume of the tibial cartilage was inversely associated with the amount of physical activity performed.

Despite the recent advances in research and development of some promising new therapies, no treatment can efficiently and safely prevent or cure OA.³¹ Furthermore, the etiology, at least in most cases, is not fully clear.³² This article reviews the currently available literature on known connections between participation in sports and athletic activities and development of secondary OA in the joints of the major upper and lower limbs (ie, knee, hip, elbow, and shoulder).

Materials and Methods

The PubMed database was searched from registry inception to July 2011 to identify all articles that assessed the potential connection between participation in sports and development of secondary OA. Several key search terms were used to narrow our search. The term “osteoarthritis” revealed 44 204 articles, and the term “secondary osteoarthritis” retrieved 2169 articles. Adding the term “athlete” to “secondary osteoarthritis” led to only 3 articles; hence, it was decided to perform independent literature searches for each joint under

investigation. When the terms “osteoarthritis,” “knee,” and “athlete” were combined, 102 articles were identified. The terms “osteoarthritis,” “hip,” and “athlete” led to 44 articles; the terms “osteoarthritis,” “elbow,” and “athlete” retrieved 13 articles; and the terms “osteoarthritis,” “shoulder,” and “athlete” retrieved 16 articles. The total number of abstracts under investigation was 175. After excluding irrelevant articles, reviews, studies addressing the management of athletes who currently practiced sports, studies evaluating the mid- or long-term postoperative results, case reports, and articles not in English, this number was narrowed to 24. These articles were evaluated in this review. The reader should be aware that some of the articles reviewed were found within the references section of other articles.

Because of the existing limitations regarding the total number of search terms for each review article, as well as the number of references, it was decided that evaluating the possible connection between the development of OA in the lumbar, thoracic, and cervical spine and participation in athletic activities ought to be addressed in another review article.

Results

Evaluation of the Development of OA in Large Lower Limb Joints

The results from 5 articles, which are reviewed in this section, are summarized in Table 1. Lower limb weightbearing joints, especially the knee and hip, are usually at high risk of developing OA, either primary (due to repetitive stress and/or malalignment and/or anatomy³³) or secondary to trauma. In a case-control study, Klünder et al³⁴ evaluated 57 retired football players both clinically and radiographically. Hip OA was found to occur statistically significantly more often in the study group than in the control group. However, such a relationship could not be established regarding the knee joint. Kujala et al³⁵ reported similar results in a retrospective study, in which they examined the hospital admissions attributed to OA of the hip and knee in 2049 former male athletes who had practiced endurance, mixed, and power sports. Results were compared with those of a control group of 1403 patients. Participation in mixed and power sports led to increased rates of hospital admissions. Endurance sports also led to an increased admission rate in the study group, but at an older age. Spector et al³⁶ performed a retrospective cohort study, in which they radiographically examined 81 female former elite athletes, and compared the results with those of a large number of age-matched controls. The incidence of radiographically apparent OA in the hips and knees of those in the study group was found to be increased 2 to 3 times, even

Table I. Studies Evaluating Potential Relationship Between Development of OA in Joints of the Major Lower Limbs and Participation in Athletic Activities

Study	Sport	Patients, N	Control Group	Level of Evidence	Evaluation	Reported Prevalence	Comments
Klünder et al ³⁴ (1980) Case-control	Football	57 retired players	Yes	III-B	Clinical and radiologic	OA of the hip joint was found to occur significantly more often in the football players than in the controls. No such relationship could be found regarding the knee joint.	–
Sohn and Micheli ³⁷ (1985) Prospective longitudinal	Varsity cross-country running	504 former runners	Yes	III-B	Questionnaire	No association between moderate long-distance running and development of OA of the hip or knee	The study had a large sample size, a long average follow-up time, and good measures for incidence of OA
Panush et al ³⁸ (1986) Case-control	Marathon running, running	17 male runners (9 marathon runners)	Yes	III-B	Clinical and radiologic	No difference in radiographic OA at the hip, knee, ankle, or foot	–
Kujala et al ³⁵ (1994) Retrospective Case-control	Endurance, mixed, power sports	2049 former male athletes	Yes	III-B	Hospital admissions for OA	Athletes had higher incidences of hospital admissions for OA of the knee, hip, and ankle than controls	Mixed and power sports led to increased admission rates for premature OA; in endurance athletes, the admission rates were at an older age
Spector et al ³⁶ (1996) Retrospective cohort	Middle- and long-distance running, tennis	81 female former elite athletes	Yes	III-B	Radiologic	A 2- to 3-fold increase in the incidence of radiographic OA of the hip and knee in the study group even when controlled for age	Similar rates of reported knee pain between the former athletes and control subjects; low number of participants

when subjects were controlled for age. However, the reported rates of knee pain did not differ between either group.

Sohn and Micheli,³⁷ who published one of the few available prospective longitudinal studies, published different results. With the use of a questionnaire in cross-country runners, the researchers evaluated the development of pain and compared these results with those of former college swimmers (controls). The authors concluded that moderate long-distance running and future development of hip and knee OA had no association. In a case-control study, Panush et al³⁸ reported that there was no difference in clinically and radiographically evaluated OA of the hip, knee, ankle, and foot between the study group (17 male runners) and control group (18 male nonrunners).

Evaluation of the Development of Hip OA

Table 2 summarizes the results from the 10 most relevant articles. In 3 studies, there were no control groups.³⁹⁻⁴¹ In the only available prospective, multicenter, case-series study, Nogier et al⁴¹ reported an increased incidence of hip OA

(62% of the clinically and radiographically evaluated hips) in a group of 292 patients, of whom 70% practiced sports either professionally or leisurely. The association between participation in sports and later development of OA was also confirmed in several other studies,⁴¹⁻⁴⁷ which evaluated both clinically and radiographically participating patients. Philippon et al⁴⁰ arthroscopically evaluated 45 elite athletes and reported findings of diffuse OA in 4 of them at the time of arthroscopy. Femoroacetabular impingement, which seems to be one of the main causes, may lead to development of hip OA in athletes.⁴⁸

However, Puranen et al,⁴⁹ in one of the earliest published relevant studies, reported that rates of radiographically assessed hip OA in 60 former marathon runners were similar to those of 115 controls. It is important to note that the time of the assessment differed between the 2 groups.

Evaluation of the Development of Knee OA

The results from the 10 most relevant articles, which are reviewed in this section, are summarized in Table 3. Five studies had no control groups.⁵⁰⁻⁵⁴ In the only available

Table 2. Studies Evaluating the Potential Relationship Between Development of Hip OA and Participation in Athletic Activities

Study	Sport	Patients, N	Control Group	Level of Evidence	Evaluation	Reported Prevalence	Comments
Puranen et al ⁴⁹ (1975) Case-control	Running	60 former marathon runners	Yes	III-B	Radiologic	No higher rates of radiographic OA were seen in 60 former marathon runners compared with controls	The timing of radiographs differed for the 2 groups
Marti et al ⁴² (1989) Retrospective cohort	Long-distance running, bobsled	36 former athletes	Yes	III-B	Radiologic	High-intensity running was associated with a significantly higher incidence of radiographic evidence of OA of the hip	Limitations of the study: atypically high intensity of running, small sample size, lack of correlation with history of injury to the hip joint, and use of radiographic evidence as the sole measure of OA
Lindberg et al ⁴³ (1993) Case control	Soccer	286 male former players	Yes	III-B	Radiologic	Coxarthrosis occurred in 5.6% of the former soccer players and in 2.8% of the control group ($P = 0.04$)	The prevalence of coxarthrosis among the 71 elite soccer players was 14% compared with 4.2% in age-matched controls and nonelite players
Vingård et al ⁴⁴ (1998) Case control	Previous various sports activities of patients who had undergone THA	230 case subjects	Yes	III-B	Clinical and radiologic	The relative risks of developing OA of the hip leading to THA was 2.3 for those with high sports exposure and 1.5 for those with medium sports exposure compared with those with low sports exposure	Participation in sports was low, and therefore, individual risk estimates for different sports activities were not possible to obtain
Lane et al ³⁹ (1999) Cross-sectional	Past recreational and sports-related physical activities	5818 elderly women	No	IV	Clinical and radiologic	The risk of symptomatic hip OA was modestly increased in women who were in the highest quartile for all physical activities as a teenager, at age 50 years, and weightbearing activities at age 30, years compared with women in the lowest quartile of activity	Recreational physical activities performed by women before menopause may increase the risk of radiographic and symptomatic hip OA
Shepard et al ⁴⁵ (2003) Cross-sectional case-control	Professional football	92 athletes	Yes	III-B	Clinical and radiologic	Nine of the 68 ex-professional football players who replied had OA of the hip, and 6 of them had undergone a total of 8 THAs. Two patients from the control group had hip OA.	The 2 groups differed significantly ($P < 0.001$). The odds ratio for OA of the hip was 10.2
Schmitt et al ⁴⁶ (2004) Cross-sectional case-control	Javelin throwing, high jumping	41 former elite athletes	Yes	III-B	Clinical and radiologic	Hip OA was more common in both groups of athletes than in controls	10 years after retirement, the reduction of function in activities of daily living was slight, as compared with a corresponding average population

(Continued)

Table 2. (Continued)

Study	Sport	Patients, N	Control Group	Level of Evidence	Evaluation	Reported Prevalence	Comments
L'Hermette et al ⁴⁷ (2006) Case control	Handball	20 former elite handball players	Yes	III-B	Clinical and radiologic	60% of the handball players were diagnosed with OA in ≥ 1 of the hip joints compared with 13% of the control subjects	The risk of developing premature hip OA seems high for retired handball players and significantly greater than for the general population
Philipon et al ⁴⁰ (2007) Retrospective case series	Various sports (mainly hockey)	45 professional athletes	No	IV	Clinical and arthroscopic	4 patients (1 baseball player, 1 football player, 1 hockey player, and 1 golfer) had extensive diffuse OA at time of arthroscopy	The purpose of this study was to define associated pathologies and determine if an arthroscopic approach to treating femoroacetabular impingement can allow professional athletes to return to high-level sports
Nogier et al ⁴¹ (2010) Prospective case series	Regional or national level competitive sports (30%), leisure or amateur sports (40%), no sport activity (30%)	292	No	IV	Clinical and radiologic	62% of hips showed OA, with 25% at the evolved stage	There was a 35% rate of dysplasia, 63% rate of impingement, and 5% rate of normal radiograph results

Abbreviations: OA, osteoarthritis; THA, total hip arthroplasty.

prospective comparative study, Lane et al⁵⁵ reported no difference in the incidence of OA of the knee (and hand and spine) between a group of 35 runners (study group) and 33 matched controls after a 5-year follow-up. Similar results were found after an additional follow-up of 4 years (total of 9 years from the first study's initiation).⁵⁶ Non-statistically significant differences between athletes and controls were found in another 2 studies.^{57,58} Of the remaining 6 studies, Deacon et al,⁵⁹ in the only study with a control group, reported that the study group (50 former elite football players) had a significantly greater prevalence and severity of functional and radiographically confirmed knee OA than the control group. The 5 remaining studies reported varying rates of knee OA (26%–63%).^{51–54,60}

Evaluation of the Development of OA in Large Upper Limb Joints

Despite our efforts, we were unable to identify an adequate number of studies evaluating the late development of glenohumeral and elbow OA in former athletes. The few available studies were reviews discussing the management of athletes who currently practice sports, case reports, or small case series, which mainly evaluated functional outcomes following the operative treatment of either instability or osteochondral lesions. In the only available large cohort study,

Vingård et al⁶¹ had examined the influence of elite track and field activities on the musculoskeletal system in 114 Swedish men aged 50 to 80 years and compared the results with those of 355 randomly selected referents in the same age group. The authors concluded that the prevalence of glenohumeral OA tended to decrease in the group of athletes.

Discussion

Osteoarthritis is the most common form of degenerative arthritis.⁶² Although the precise etiology is still unclear, OA is multifactorial, involving both genetic and environmental factors.³² Genetic factors (ie, mutations or variations) result in the development of defects or variability in cartilage matrix properties and chondrocyte metabolism.⁵ In the case of matrix defects caused by mutations of the matrix genes, the age-dependent degeneration of the cartilage may occur as a result of even normal mechanical stresses on a joint.³² Some variations of the inherited sequence of genes may lead to an increased risk for OA.⁶³

Environmental factors include overloading on joints and repetitive injury involving ligaments and menisci (as in individuals practicing competitive or recreational sports), as well as joint malalignment. Obesity seems to be an independent risk factor for OA development. Flugsrud et al⁶⁴ reported a dose-response association between body mass index and risk

Table 3. Studies Evaluating the Potential Relationship Between Development of Knee OA and Participation in Athletic Activities

Study	Sport	Patients, N	Control Group	Level of Evidence	Evaluation	Reported Prevalence	Comments
McDermott and Freyne ⁶⁰ (1983) Observational	Middle and long distance running	20 middle and long distance runners complaining of knee pain	No	IV	Clinical and radiologic	OA of varying degrees was found in 6 runners	A torn meniscus requiring surgery was found in 1 athlete, and 1 had considerable ligamentous laxity. Both conditions predispose to the development of degenerative changes
Moretz et al ⁵⁷ (1984) Case-control	Football	23 football players studied for 20 years after high school competition	Yes	III-B	Clinical and radiologic	No statistically significant increase in OA	A significant increase in knee OA was found in the subgroup of football players who had sustained knee injuries
Lane et al ⁵⁸ (1986) Cross-sectional comparative	Running	41 long-distance runners	Yes	III-B	Clinical and radiologic	No difference in the incidence of OA between runners and nonrunners	–
Lane et al (1993) ⁵⁵ (1998) ⁵⁶ Prospective comparative	Running	35 runners	Yes	III-B	Clinical and radiologic	No difference in the incidence of OA of the knee, hand, and spine in runners and nonrunners	Small sample size and limited follow-up time (5 years)
Kujala et al ⁵¹ (1995) Observational	Long-distance running, soccer, weightlifting, shooting	117 male former top-level athletes	No	IV	Clinical and radiologic	Soccer players (26%) had the highest prevalence of tibiofemoral OA; weightlifters (28%) had the highest prevalence of patellofemoral OA	The risk for knee OA was increased in subjects with previous knee injuries, high body mass index at age 20 years, previous participation in heavy work, and kneeling or squatting work, and in subjects participating in soccer.
Deacon et al ⁵⁹ (1997) Retrospective cohort	Football	50 elite former players	Yes	III-B	Radiologic	Players had significantly greater prevalence and severity of functional and radiologic knee OA than controls	Football players with a history of intra-articular ligamentous and/or meniscal injury had greater risk of functional OA and radiologic OA than those with a history of collateral ligament injury or no injury
Larsen et al ⁵² (1999) Retrospective cohort	Football	69 former national team elite players	No	III	Clinical and radiologic	Signs of OA were present in 63% of the injured knees and 33% of the injured ankles. The incidence of arthritis in the group of 17 uninjured players was 26% in the knee and 18% in the ankle.	In elite football players, knee and ankle injuries seemed to have serious long-term outcomes; however, noninjured players also had a higher risk of developing arthritis than the normal population
Turner et al ⁵³ (2000) Cross-sectional	Football	284 former professional players	No	IV	Clinical	49% rate of lower limb OA; knee was the most common site	–
Drawer and Fuller ⁵⁴ (2001) Cross-sectional	Professional soccer	500 former players	No	IV	Clinical	The rate of lower limb OA was 32%	More respondents were diagnosed with knee OA than either ankle or hip OA

Abbreviation: OA, osteoarthritis.

for later hip arthroplasty. Obese men were found to have > 8 times the risk compared with underweight men for undergoing total hip arthroplasty, whereas obese women had 5 times the risk compared with underweight women. Loss of muscle strength (as in former elite athletes or amateur athletes who modified their training activities or completely abandoned training habits) is another important environmental factor, although recent studies fail to detect an association between muscle strength and later development of OA. Øiestad et al⁶⁵ reported no association between the weakness of quadriceps after anterior cruciate ligament reconstruction and development of knee OA, as measured 10 to 15 years later. Thorlund et al⁶⁶ performed a study in 31 patients who had received operative treatment (and 31 population-based controls) and concluded that factors other than loss of muscle strength are responsible for the perceived functional limitations, and suggested that training to improve strength alone may not be sufficient to improve self-reported function in patients at high risk of knee OA. All of the aforementioned conditions (genetic and environmental) can result in abnormal mechanical stresses on the joint, leading to cartilage degeneration. Because OA seems to occur as a result of 1 or a combination of these factors, investigation of the detailed pathogenic mechanisms in all of these conditions remains a formidable challenge.³²

Given that the genetic predisposition to development of OA is considered, at least currently, as equal among athletes practicing sports, this article attempted to assess the influence of the “mechanical factor” (ie, joint loading due to athletic activities) in the later development of OA. After reviewing the available literature, we believe that participation in athletic activities (at least in professional athletes, but not limited to them) and later development of OA might be connected. Regardless of the sport, the repetitive stress and microtrauma exerted on joints that are involved in athletic training seems to increase the possibility for most athletes to develop OA. However, this point is debatable because mechanical stimulation may act both positively and negatively on articular cartilage.²⁴ Also, major trauma seems to be positively connected to development of OA,⁶⁷ despite strong arguments to the contrary.⁶⁸ Nonetheless, this topic was not discussed in this review. It is possible that when a patient who has a genetic predisposition for development of OA practices sports, he or she may have a higher risk for developing OA. However, no data support this argument.

The majority of relevant studies examined the association between athletic activities and development of OA in the major weightbearing joints of the lower limb (ie, hip and

knee). Lower limbs are affected not only due to the practice of sports, but also due to several daily activities (eg, standing, walking, stair climbing), which may also predispose them to later development of OA due to purely mechanical reasons. This is probably why the prevalence of hip and knee OA in the general population is considerably much higher than the prevalence of shoulder or elbow OA.⁹

The connection between development of hip OA and participation in sports seems possible. Thirteen of the 15 available studies (Tables 1, 2) reported an increased prevalence of hip OA among former athletes. Football players,^{34,43,45} athletes practicing endurance and power sports,⁵² runners,^{36,42} javelin throwers,⁴⁶ high jumpers,⁴⁶ handball players,⁴⁷ and hockey players⁴¹ were at high risk of developing OA. However, there are still many factors not controlled; therefore, the reader should read and interpret these data cautiously.

Regarding the association between participation in athletic activities and development of knee OA, the results were somewhat different. Nine of the 15 available studies positively confirmed the increased prevalence of knee OA in athletes (Tables 1, 3). In the remaining 6, no such connection could be established. Endurance and power sports athletes,⁵¹ runners,^{36,50,51} soccer players,^{51,54} weightlifters,⁵¹ and football players^{52,53,59} were evaluated to be at higher risk of developing OA. Due to the very limited available literature, conclusions regarding the development of secondary glenohumeral and shoulder OA in athletes cannot accurately be drawn.

The reader should note that most studies examining the connection between participation in sports and later development of OA are usually of low-level evidence and have many methodological weaknesses. Most are retrospective, cohort, or case-control studies. We located and examined only 3 prospective studies.^{37,55,56} However, the level of evidence even for these 3 studies was III-B. It is true that performing a prospective, especially a level I study examining the association between participation in athletic activities and development of OA, is probably impossible because a proper randomization of patients is not feasible. Furthermore, OA develops after several years or decades following participation in athletic activities. As a result, obtaining adequate follow-up is extremely difficult. Identification of patients who have OA and who had been practicing sports is another important issue, as well as the proper diagnosis of OA by means of radiographic examinations, clinical evaluations, personal interviews, questionnaires, or functional and quality-of-life assessment tools.

After these limitations, it seems to be clearly understood that one cannot, or at least it is very difficult to, compare results between studies regarding development of OA in the large joints of the upper and lower limbs in patients who used to or continue to practice sports. Further investigation with the help of large, multicenter, prospective, case-control studies is mandatory, because it will allow us to draw final conclusions by eliminating as many limitations and as much bias as possible.

Summary

Most studies examining the connection between participation in sports and later development of OA provide low level of evidence and have many methodological weaknesses. The fact that there is no strong correlation between symptoms and radiographic findings in patients with OA complicates the issue. The connection between development of hip OA and participation in athletic activities is highly possible, as well as a connection between development of knee OA and participation in athletic activities; hence, the prevalence of knee OA in athletes is higher than in nonathletes.⁶⁹ Based on the currently available literature reviewed in this article, definite conclusions regarding the connection between development of glenohumeral and/or elbow OA and participation in athletic activities cannot be drawn.

Conflicts of Interest Statement

Kyriakos A. Papavasiliou, MD; Eustathios I. Kenanidis, MD; Michael E. Potoupnis, MD; Artemis Kapetanou, MD; and Fares E. Sayegh, MD disclose no conflicts of interest.

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