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Former Male Elite Athletes Have a Higher Prevalence of Osteoarthritis and Arthroplasty in the Hip and Knee than Expected

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Running title: Sports as Risk Factor for Osteoarthritis

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ABSTRACT

Background: Intense exercise has been reported as one risk factor for hip and knee osteoarthritis (OA).

Purpose: This study aimed to evaluate (1) whether this is true for both former impact and nonimpact sportsmen, (2) if the risk of a hip or knee arthroplasty due to OA is higher than expected, and (3) if joint deterioration is associated with knee injuries.

Study Design: Cohort study; Level of evidence, 3.

Methods: The prevalence of OA and arthroplasty in the hip and knee were registered in 709 former male elite athletes with a median age of 70 years (range 50–93), retired from sports for a median 35 years (range 1–63), and compared with 1368 matched controls. Odds ratios (ORs) are presented as means with 95% confidence interval (95% CIs).

Results: The risk of hip or knee OA was higher in former athletes (OR 1.9, 95% CI 1.5, 2.3), as was arthroplasty based on OA in either of these joints (OR 2.2, 95% CI 1.6, 3.1). The risk of hip OA was doubled (OR 2.0, 95% CI 1.5, 2.8) and hip arthroplasty 2.5 times higher (OR 2.5, 95% CI 1.6, 3.7) in former athletes than in controls, predominantly driven by a higher risk in former impact athletes. Also, the risk of knee OA was higher (OR 1.6, 95% CI 1.3, 2.1), as was knee arthroplasty (OR 1.6, 95% CI 0.9, 2.7), driven by a higher risk in both former impact and nonimpact athletes. Knee OA in impact athletes was associated with knee injury.

Conclusion: Hip and knee OA and hip and knee arthroplasty are more commonly found in former male elite athletes than expected. A previous knee injury is associated with knee OA in former impact athletes but not in nonimpact athletes.

Keywords: arthroplasty; football; former athletes; hip injury; joint replacement; osteoarthritis (OA); runners; soccer; soft tissue knee injury; sport

INTRODUCTION

Osteoarthritis (OA) renders a huge burden in terms of personal suffering and high costs for society. The cause is not fully understood, but the multifactorial background and defined risk factors such as age, family history, certain work, obesity, muscle weakness, trauma and mechanical load have been highlighted, where age often is regarded the dominant risk factor.¹ “Wear and tear” has been the most longstanding biomechanical theory in an attempt to explain the pathogenesis of OA, where aging is simply the accumulation of joint loading cycles over a lifetime.²⁴ Systemic factors are often described as predisposing degenerative joint changes, while local mechanical factors determine the distribution and the severity of the disease.^{1, 14, 24} Dye⁵ introduced “the tissue homeostasis theory,” a hypothesis implying that the joint acts as a biological transmission, and redirects mechanical loads. When intense biomechanical long-term stress and microinjuries are added to the joint, the redirection of loads may be insufficient. If the process continues, it will lead to joint failure.^{5, 7, 11, 24} Epidemiological studies support this view, reporting an association both between hip OA and heavy occupations such as shipyard work, mining and farming and also between knee OA and occupations that include squatting and kneeling such as carpeting and floor laying.^{31, 32} High mechanical stress and repeated traumatic joint injuries in elite athletes have also been shown deleterious for the joint.^{2, 4, 13, 16, 17, 25, 26, 33, 34} Football, rugby, soccer, handball (also known as team handball or European handball), and ice hockey are all sports with high impact and torsion of the lower limb, and athletes in these sports are therefore suggested to be at high risk of developing OA.^{2, 11} Whether nonimpact athletes are also at higher risk is controversial. A recent report found a linear correlation between the extent of long-distance skiing and severe OA,¹⁷ whereas intense running has been inferred to increase the risk,^{16, 25, 33} not alter the risk,^{9, 10, 12, 22} or even reduce the risk of hip OA.²⁹ In contrast, the risk of OA is not increased in individuals with moderate physical activity,^{25, 27, 30} and low mobility may even be associated with an increased risk of knee OA.²⁸ A refined biomechanical hypothesis, “the muscle dysfunction theory,” has been put forward, in which the author suggests

that muscles may be the main force absorbers of the joint.⁷ The hypothesis may partly explain the differences in the reported data and the beneficial effect of moderate exercise on lower limb joints. In this model any type of muscle dysfunction seen, for example with ageing, fatigue, or loss of proprioception caused by ligament tears and other types of soft tissue joint injuries, would be the main local mediating factor for developing OA.⁷ In analogy, vigorous exercise that has been reportedly associated with clinical or subclinical soft tissue injuries around the hip^{4, 15, 26} or knee^{14, 18, 19} may lead to either direct joint damage or prolonged joint deterioration.^{7, 24}

With these hypotheses in mind, we designed a study with the aim to evaluate whether former male elite athletes in both impact and nonimpact sports have a higher prevalence of hip and knee OA, and hip and knee joint replacement surgery than controls, and what influence a significant soft tissue knee injury has in the development of hip and knee OA.

MATERIALS AND METHODS

Through a mailed questionnaire, we collected information about hip and knee OA and hip and knee arthroplasty in 709 former internationally or nationally ranked male athletes all found in an archived review book of former Swedish elite athletes, the archives of the Swedish Olympic Committee, or from an previously published study of male elite athletes.²⁰ The former athletes were a median 70 years old (range 50–93) and had retired from competitive sports a median 35 years (range 1–63) ago (Table 1). There were 397 former soccer players, 147 handball players, 69 ice hockey players, all classified as having participated in impact sports, and 43 canoeists, 20 long-distance runners, 9 weight lifters, 8 gymnasts, 8 swimmers, 6 biathletes and 2 racing cyclists, all classified as having participated in non-impact sports. Among the 96 nonimpact athletes, 64 were former Olympic competitors. From the Swedish national computerized population records, two male controls were matched to each athlete, by sex and date of birth, with their names standing closest to the former athletes in the register. The primary response rate was 74% for the former athletes and 64% for the controls. As our aim was to include 2 controls for every athlete, we invited the second closest individual in the register in those athletes missing 1 control and the controls from the cited study.²⁰ This rendered 1368 controls aged median 70 years (range 51–93), of whom 619 had participated in recreational exercise. The mailed questionnaire, previously used in similar studies,^{8, 21} included evaluation of anthropometrics, medical history, fractures, soft tissue knee injuries, surgical interventions and lifestyle characteristics such as nutrition, alcohol, smoking, physical activity, weekly hours of athletic training, and occupational load. Information on joint illness was considered valid only if diagnosed by a physician and included soft tissue knee injury such as meniscal and/or ligament tears, fractures, hip or knee OA, and joint replacement surgery in these joints because of OA. The expression “hip or knee” denotes patients with either hip deterioration, knee deterioration, or both, as appose to deterioration estimates of a specific joint, and the expression “hip and knee” denotes the total burden of society when discussed in general. Eight athletes and 21 controls had

sustained a hip fracture and 4 athletes and 7 controls a knee fracture. The number of individuals with valid answers for each question is reported in Tables 2 to 4.

The study was reviewed and approved by a human research ethics committee and performed in accordance with the Declaration of Helsinki. Statistical calculations were performed using Statistica[®], version 7.1 (StatSoft, Tulsa, Oklahoma). Data are presented as means with 95% confidence intervals (95% CIs) or as numbers with proportions (%). Group differences between athletes and controls were tested with Student *t*-test between means and χ^2 test. Before prevalence calculations were done, all individuals with a prior fracture in that specific joint were excluded. Age-adjusted odds ratio (ORs) with 95% CIs were estimated by logistic regression in different models adjusted for combinations of age, body mass index (BMI; kg/m²), occupational load, and previous physician-diagnosed soft tissue knee injury. P<0.05 was considered a statistically significant difference.

RESULTS

Few differences were found in anthropometrics and lifestyle between the former athletes and the control group (Table 1). Hip OA was found in 94 (14.2%) former athletes and 98 (7.9%) controls ($P<0.0001$), hip arthroplasties in 55 (8.3%) former athletes and 47 (3.8%) controls ($P<0.0001$), previous significant soft tissue knee injury in 245 (36.1%) former athletes and 332 (25.2%) controls ($P<0.0001$), knee OA in 129 (19.4%) former athletes and 163 (13.0%) controls ($P<0.001$), and knee arthroplasties in 24 (3.6%) former athletes and 30 (2.4%) controls ($P=0.12$) (Tables 3 and 4).

When estimating the combined burden of OA and arthroplasty in the hip and knee, we found that the age-adjusted risk of having hip or knee OA was 85% (OR, 1.85; 95% CI, 1.48, 2.30) higher, and the age-adjusted risk of having a hip or knee arthroplasty was more than doubled in the former athletes than in the controls (Table 2). The higher risk of OA seemed to be driven by a higher risk in former impact athletes, with a 75% higher risk in former soccer players, 2 times higher in handball players and 2.5 times higher in ice hockey players, while the 59% higher risk of hip or knee OA in nonimpact athletes did not reach statistical significance ($P=0.08$); neither did hip or knee arthroplasty in this subcohort ($P=0.47$) (Table 2).

After adjustment for age, the risk of having hip OA was doubled and that of having a hip arthroplasty 2.5 times higher in former athletes than in the controls (Table 3). The higher risk of hip OA seemed predominantly driven by a higher risk in former impact athletes, with a doubled risk in soccer and handball players and a tripled risk in ice hockey players, while the 35% higher risk in nonimpact athletes did not reach statistical significance ($P=0.43$) (Table 3). The result remained after adjustment for differences in age, BMI, occupational load, and soft tissue knee injury (Table 3, Figure 1).

After adjustment for age, the risk of having knee OA was 64% higher in former athletes than in the controls ($P=0.0001$) (Table 4). The 58% higher risk of having a knee arthroplasty did not reach statistical significance ($P=0.10$) (Table 4). The higher risk of knee OA

seemed to be driven by a higher risk both in former impact athletes, with a 52% higher risk in former soccer players, 82% in handball players, 88% in ice hockey players, and in nonimpact athletes, with an 81% higher risk (Table 4). However, when adjusting for differences in age, BMI, occupational load, and soft tissue knee injury, the higher relative risk remained only in nonimpact athletes, now 3 times higher than expected (Table 4, Figure 1). When the risk of knee arthroplasty in the different subgroups was evaluated, the small number of individuals in each group made the data unrobust and difficult to interpret, and therefore, only raw data are presented (Table 4, Figure 1).

DISCUSSION

This report suggests that elderly male former elite athletes impose a burden on society regarding hip and knee OA, as well as hip and knee replacement surgery, that is around twice as much as would be expected according to age. There seems, however, to be different pathophysiological pathways in the development of hip and knee OA. Before this report, few studies had made any direct comparison between athletes in impact and nonimpact sports regarding OA in the hip or knee joint.^{9, 11} The higher prevalence of hip OA in athletes was predominantly driven by a higher risk in impact athletes, irrespective of the type of impact sport, and not associated with previous soft tissue knee injury. In contrast, the higher prevalence of knee OA in athletes was driven by higher risks in both impact and nonimpact athletes. Knee OA in impact athletes was associated with previous soft tissue knee injuries, whereas no such association was found in nonimpact athletes.

The increased prevalence of hip and knee OA in former athletes is supported by data in the literature,^{2, 11} although some studies suggest an even higher risk of OA than in our study.^{4, 13, 25, 26} However, there are also studies suggesting that the risk of hip or knee OA is unaffected by intense exercise.^{9, 10, 12, 22, 29} The discrepancies in conclusions may be explained by variations in the examined cohorts,³ in that some studies only include a small sample size imposing a type II error, while others include middle-aged individuals with a low absolute risk of OA; different studies include different types, intensities, and duration of sporting career, and finally, confounders such as BMI, work load, and soft tissue knee injuries are not always adjusted for.

There may be several explanations why athletes in impact sports are at higher risk of developing hip OA^{4, 11, 13, 25, 26} than participants in nonimpact sports.^{9, 10, 12, 22, 29} As the definition implies, repeated impacts, often sudden, without adequate proprioception and muscle absorption, may lead to minor injuries in the hip, resulting in groin pain and muscle fatigue, which will eventually lead to stiffening and OA.⁷ Serious soft tissue hip injuries are rarely

reported, compared with soft tissue knee injuries,⁴ but minor muscle sprains, ligament damage, or labral damage are likely to accompany elite sporting activities, and underreporting may be the reason why a physician-diagnosed hip injury does not seem to be a necessary precursor of hip OA.^{4, 26} Manning and Hudson,¹⁵ for example, showed less range of joint motion already in professional soccer players aged 16 to 18, even without being exposed to a prior clinically relevant hip injury, suggesting these findings to be early signs of joint degeneration.

There are data in the literature suggesting soft tissue knee injuries also play a role in the development of hip OA.²⁷ Hypothetically, a knee injury may lead to muscle dysfunction in the thigh and, according to the muscle dysfunction hypothesis proposed by Hurley et. al.,⁷ would then also affect the development of hip OA. Our data do not support this hypothesis, as we found no significant influence of a previous soft tissue knee injury on the prevalence of hip OA in the athletes. We did, however, find an association between athletes in impact sports, soft tissue knee injury, and the prevalence of knee OA, a well-described association in the literature.^{14, 19}

It is now considered general knowledge that the risk of sustaining an anterior cruciate ligament (ACL) injury and/or meniscal tear is higher in impact athletes than in nonsporting individuals¹⁴ and that a knee injury is a risk factor for future knee OA,^{6, 14, 18, 19, 25, 30} which also was verified in the current study. In impact sports, these types of injuries seemed to be associated with an increased risk of knee OA. More interesting, with no soft tissue knee injury, impact athletes were no longer at higher risk of knee OA, while nonimpact athletes now showed a 3 times higher risk. This indicates that the pathophysiological pathway for increased risk of knee OA in nonimpact sports is different from that in impact sports. We can only speculate in regard to causality, but soft tissue knee injuries could be involved in impact-loaded sports,¹⁴ and long-term repeated biomechanical stress could be involved in nonimpact sports.^{17, 32}

This study is currently the largest retrospective, matched cohort study that evaluated not only the risk of having hip and knee OA in older age but also hip and knee arthroplasty. Two smaller studies, one in 535 men³³ and one in 503 women,³⁴ have found that

compared to nonactive individuals, moderate physical activity is associated with 2.6 times higher risk in men and 1.5 times higher risk in women of hip replacement surgery, while intense activity is associated with 4.5 times higher risk in men and 2.3 times higher risk in women. Another study that evaluated participants in an annual Swedish ski race of 90 km (Vasaloppet) found among 50,000 individuals a 3 times higher rate of individuals with hip arthroplasties and 2 times higher rate of individuals with knee arthroplasties in those with 5 or more ski races and a fast finish time compared to those who only had participated once and with a slow finish time.¹⁷ Another article that evaluated 19 former Olympic competitors with an untreated ACL injury found 42% with a knee arthroplasty 35 years after their career ended.¹⁸ The inclusion of arthroplasty, and not only OA, as end-point variables is of most importance because the roughly doubled prevalence of hip or knee arthroplasty compared with what would be expected by age improves the ability to inform elite athletes about the long-term adverse effects of exercise. Finally, we must emphasize that our estimations only deal with the increased burden of OA and joint replacement surgery in elite athletes and do not discuss the exercise-induced beneficial effects, such as a reduction of cardiovascular disease, osteoporosis, and diabetes mellitus,²³ or the outcome after moderate intensive training that has been reported harmless^{25, 27, 30} or beneficial²⁸ for the cartilage. In addition to direct medical benefits of sporting activity, other positive outcomes such as building teamwork skills and self-confidence must not be forgotten.

Advantages of this study include the large sample size, the inclusion of both impact and nonimpact sportsmen, the evaluation of different joints, the use of both OA and joint arthroplasty as end-point variables, and the adjustments for relevant confounders including the influence of an earlier knee soft tissue injury. Limitations include the risk of selection bias with the study design, so that individuals with high risk of OA may also be good in and voluntarily choose sports. In other words, this study design cannot state a causal relationship between intense exercise and OA. However, since we found only minor differences in anthropometrics and lifestyle when comparing former athletes and controls, selection bias seems less probable. It

would also have been advantageous to have a larger cohort of individuals in order to reduce the risk of making a type II error, a risk that is high in the smallest cohorts such as athletes with a knee arthroplasty, nonimpact athletes with any hip event, and athletes within a specified sport.

In summary, this report shows that the risk of having hip and knee OA and hip and knee arthroplasty is around doubled in older retired male elite athletes compared with matched controls. Data also indicate that the pathophysiological pathways in elite athletes for developing hip and knee OA are different depending on type of sport and evaluated joint. A previous soft tissue knee injury does not influence the risk of developing hip OA in either former impact or nonimpact athletes. Furthermore, a similar injury does not influence the risk of developing knee OA in nonimpact athletes, while it is of major importance for the development of knee OA in impact athletes.

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Table 1. Anthropometry and lifestyle factors in 709 former male elite athletes with a median age of 70 years (range 50–93), retired from competitive sports median 35 years (range 1–63), and in 1368 controls with a median age of 70 years (range 51–93). Data are presented as means with 95% confidence interval (95% CIs) in brackets or as proportions (%). The p-values represent comparison of each athletic group (all; impact sport; nonimpact sport) with the 1368 controls. Statistically significant differences are highlighted in bold text.

| | Athletes | | | | Controls | | | |
|--------------------------------------|-----------------------|---------------------|--------------------------------|---------------------|----------------------------------|---------------------|------------------------|--|
| | <i>All</i> (n=709) | <i>P value</i> | <i>Impact sport</i> (n=613) | <i>P value</i> | <i>Nonimpact sport</i> (n=96) | <i>P value</i> | <i>All</i> (n=1368) | |
| Anthropometrics | | | | | | | | |
| Height (cm) | 178.0 (177.5, 178.5) | p < 0.001 | 177.9 (177.4, 178.4) | p < 0.001 | 178.7 (177.1, 180.3) | p = 0.008 | 176.8 (176.5, 177.2) | |
| Weight (kg) | 83.2 (82.3, 84.0) | p < 0.001 | 82.9 (82.1, 83.8) | p = 0.006 | 84.9 (81.7, 88.2) | p = 0.005 | 81.4 (80.8, 82.0) | |
| Body mass index (kg/m ²) | 26.2 (26.0, 26.5) | p = 0.18 | 26.2 (25.9, 26.4) | p = 0.34 | 26.6 (25.6, 27.5) | p = 0.12 | 26.0 (25.9, 26.2) | |
| Lifestyle factors | | | | | | | | |
| Age when starting to train (y) | 13.5 (13.3, 13.7) | — | 13.4 (13.2, 13.6) | — | 14.1 (13.4, 14.8) | — | — | |
| Age when starting to compete (y) | 14.8 (14.6, 15.0) | — | 14.7 (14.5, 14.9) | — | 15.7 (15.0, 16.5) | — | — | |
| Age when ceasing to compete (y) | 35.3 (34.7, 35.9) | — | 35.6 (35.0, 36.2) | — | 33.1 (31.4, 34.9) | — | — | |
| Duration of competitive career (y) | 20.5 (19.9, 21.1) | — | 20.9 (20.3, 21.6) | — | 17.3 (15.6, 19.1) | — | — | |
| Duration of retirement period (y) | 33.6 (32.9, 34.4) | — | 33.7 (32.9, 34.5) | — | 33.1 (30.9, 35.3) | — | — | |
| Current activity level (hrs/week) | 3.7 (3.4, 4.0) | p = 0.22 | 3.7 (3.3, 4.0) | p = 0.27 | 3.8 (2.9, 4.6) | p = 0.47 | 3.4 (3.1, 3.7) | |
| Age at retirement from work (y) | 62.8 (62.5, 63.1) | p = 0.66 | 62.8 (62.5, 63.1) | p = 0.76 | 63.1 (62.2, 64.1) | p = 0.39 | 62.7 (62.5, 62.9) | |
| Current cups of coffee per day (n) | 3.6 (3.4, 3.8) | p = 0.29 | 3.7 (3.5, 3.8) | p = 0.67 | 3.2 (2.7, 3.6) | p = 0.03 | 3.7 (3.6, 3.9) | |
| Early work retirement (%) | 48.7 | p = 0.43 | 50.4 | p = 0.17 | 34.5 | p = 0.07 | 46.7 | |
| History as a blue-collar worker (%) | 18.8 | p = 0.04 | 19.1 | p = 0.06 | 17.0 | p = 0.19 | 23.2 | |
| Any exclusion of food (%) | 3.4 | p = 0.97 | 3.3 | p = 0.91 | 4.3 | p = 0.65 | 3.4 | |
| Any exclusion of dairy products (%) | 7.2 | p = 0.90 | 7.0 | p = 0.78 | 8.5 | p = 0.69 | 7.4 | |
| Current smoker (%) | 11.9 | p = 0.13 | 13.6 | p = 0.68 | 1.1 | p < 0.001 | 14.3 | |
| Teetotaler (%) | 15.0 | p < 0.001 | 14.1 | p < 0.001 | 21.3 | p = 0.58 | 23.8 | |
| Any current disease (%) | 48.8 | p < 0.001 | 50.4 | p = 0.001 | 38.5 | p < 0.001 | 58.3 | |
| Any current medication (%) | 55.7 | p < 0.001 | 57.0 | p = 0.005 | 47.3 | p = 0.002 | 63.6 | |

Table 2. Prevalence of hip or knee osteoarthritis (OA) and hip or knee arthroplasty in 709 former male elite athletes with a median age of 70 years (range 50–93), retired from competitive sports median 35 years (range 1–63), and in 1368 controls with a median age of 70 years (range 51–93). Data are presented as number of individuals with proportions (%) in brackets and as odds ratios (ORs) with 95% confidence intervals (95% CIs) in different models adjusted for combinations of age, body mass index (BMI), occupational load, and soft tissue knee injury. Statistically significant differences are highlighted in bold text.

| | N* | Participants with OA/arthroplasty, unadjusted | | Adjusted for age | Adjusted for age, BMI and occupational load | Adjusted for age, BMI, occupational load and soft tissue knee injury |
|--|------|---|----------------------|--------------------------|---|--|
| | | n (%) | P-value | OR (95% CI) | OR (95% CI) | OR (95% CI) |
| Osteoarthritis to either of the hip or knee | | | | | | |
| All athletes | 668 | 194 (29.0) | p < 0.0001 | 1.85 (1.48, 2.30) | 1.86 (1.45, 2.39) | 1.71 (1.29, 2.26) |
| Controls | 1265 | 235 (18.6) | — | 1.00 | 1.00 | 1.00 |
| Nonimpact sport | 90 | 22 (24.4) | p = 0.17 | 1.59 (0.95, 2.64) | 1.33 (0.74, 2.38) | 1.67 (0.87, 3.23) |
| Impact sport | 578 | 172 (29.8) | p < 0.0001 | 1.89 (1.50, 2.38) | 1.94 (1.50, 2.51) | 1.72 (1.29, 2.30) |
| Soccer | 371 | 104 (28.0) | p < 0.0001 | 1.75 (1.34, 2.29) | 1.80 (1.34, 2.42) | 1.62 (1.15, 2.26) |
| Handball | 141 | 44 (31.2) | p < 0.001 | 2.00 (1.36, 2.94) | 2.21 (1.45, 3.36) | 2.05 (1.27, 3.30) |
| Ice hockey | 66 | 24 (36.4) | p < 0.001 | 2.59 (1.53, 4.37) | 2.37 (1.34, 4.17) | 1.78 (0.95, 3.31) |
| Hip or knee arthroplasty | | | | | | |
| All athletes | 664 | 76 (11.4) | p < 0.0001 | 2.22 (1.58, 3.12) | 2.21 (1.50, 3.27) | 2.61 (1.66, 4.10) |
| Controls | 1251 | 72 (5.8) | — | 1.00 | 1.00 | 1.00 |
| Nonimpact sport | 90 | 6 (6.7) | p = 0.72 | 1.38 (0.57, 3.29) | 1.21 (0.45, 3.24) | 1.56 (0.52, 4.73) |
| Impact sport | 574 | 70 (12.2) | p < 0.0001 | 2.34 (1.66, 3.32) | 2.35 (1.58, 3.49) | 2.72 (1.72, 4.32) |
| Soccer | 368 | 42 (11.7) | p < 0.001 | 2.17 (1.45, 3.24) | 2.20 (1.41, 3.45) | 2.61 (1.56, 4.36) |
| Handball | 141 | 19 (13.5) | p < 0.001 | 2.61 (1.52, 4.48) | 2.73 (1.49, 5.02) | 3.00 (1.48, 6.06) |
| Ice hockey | 65 | 9 (13.8) | p = 0.008 | 2.80 (1.32, 5.92) | 2.76 (1.26, 6.05) | 3.35 (1.42, 7.94) |

* Excluded in the analyses were 29 individuals with a history of hip fracture, 11 with a knee fracture, and, depending on the specific estimation, those who had not answered whether or not they had been diagnosed with a hip or knee osteoarthritis, and/or whether they had undergone a hip or knee replacement surgery.

Table 3. Prevalence of hip osteoarthritis (OA) and hip arthroplasty in 709 former male elite athletes with a median age of 70 years (range 50–93), retired from competitive sports median 35 years (range 1–63), and in 1368 controls with a median age of 70 years (range 51–93). Data are presented as number of individuals with proportions (%) in brackets and as odds ratios (ORs) with 95% confidence intervals (95% CIs) in different models adjusted for combinations of age, body mass index (BMI), occupational load, and soft tissue knee injury. Statistically significant differences are highlighted in bold text.

| | N* | Participants with OA/arthroplasty, unadjusted | | Adjusted for age | Adjusted for age, BMI and occupational load | Adjusted for age, BMI, occupational load and soft tissue knee injury |
|-------------------------|------|---|----------------------|--------------------------|---|--|
| | | n (%) | P-value | OR (95% CI) | OR (95% CI) | OR (95% CI) |
| Hip OA | | | | | | |
| All athletes | 662 | 94 (14.2) | p < 0.0001 | 2.03 (1.51, 2.76) | 2.18 (1.53, 3.10) | 2.18 (1.52, 3.13) |
| Controls | 1247 | 98 (7.9) | — | 1.00 | 1.00 | 1.00 |
| Nonimpact sport | 90 | 8 (8.9) | p = 0.73 | 1.35 (0.63, 2.92) | 0.90 (0.34, 2.39) | 0.94 (0.35, 2.52) |
| Impact sport | 572 | 86 (15.0) | p < 0.0001 | 2.14 (1.57, 2.92) | 2.37 (1.65, 3.38) | 2.35 (1.62, 3.40) |
| Soccer | 366 | 52 (14.2) | p < 0.001 | 2.01 (1.40, 2.89) | 2.19 (1.40, 3.29) | 2.14 (1.40, 3.25) |
| Handball | 141 | 21 (14.9) | p = 0.005 | 2.09 (1.25, 3.47) | 2.41 (1.38, 4.22) | 2.65 (1.50, 4.67) |
| Ice hockey | 65 | 13 (20.0) | p < 0.001 | 3.13 (1.64, 5.98) | 3.41 (1.72, 6.76) | 3.24 (1.58, 6.65) |
| Hip arthroplasty | | | | | | |
| All athletes | 663 | 55 (8.3) | p < 0.0001 | 2.47 (1.64, 3.70) | 2.71 (1.67, 4.38) | 2.94 (1.78, 4.85) |
| Controls | 1247 | 47 (3.8) | — | 1.00 | 1.00 | 1.00 |
| Nonimpact sport | 90 | 5 (5.6) | p = 0.40 | 1.87 (0.71, 4.90) | 1.75 (0.57, 5.35) | 1.90 (0.61, 5.91) |
| Impact sport | 573 | 50 (8.7) | p < 0.0001 | 2.56 (1.69, 3.87) | 2.83 (1.74, 4.61) | 3.05 (1.84, 5.07) |
| Soccer | 368 | 32 (8.7) | p < 0.001 | 2.54 (1.59, 4.06) | 2.83 (1.65, 4.85) | 3.02 (1.72, 5.28) |
| Handball | 141 | 12 (8.5) | p = 0.008 | 2.48 (1.27, 4.82) | 2.91 (1.37, 6.16) | 3.29 (1.53, 7.07) |
| Ice hockey | 64 | 6 (9.4) | p = 0.03 | 2.95 (1.20, 7.27) | 3.25 (1.26, 8.40) | 3.50 (1.32, 9.27) |

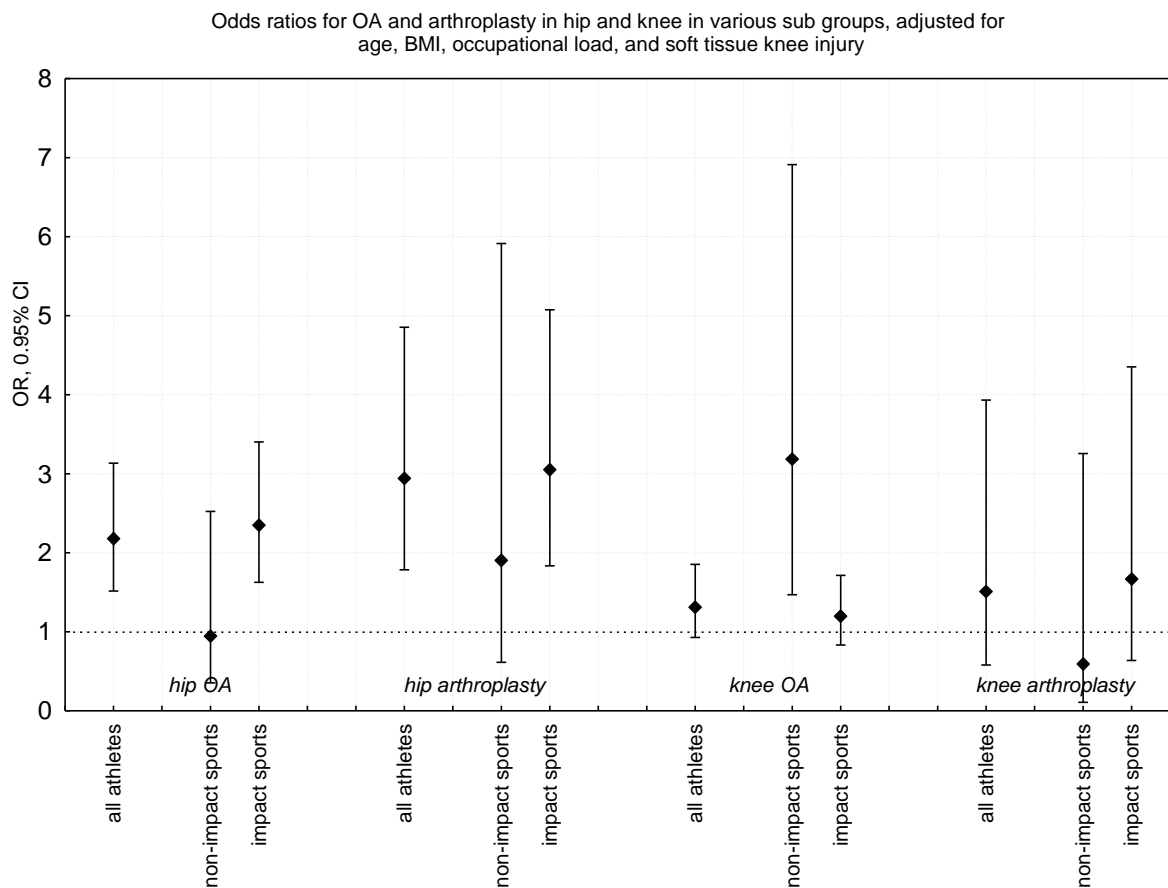
* Excluded in the analyses were 29 individuals with a history of hip fracture, and, depending on the specific estimation, those who had not answered whether or not they had been diagnosed with a hip osteoarthritis, and/or whether they had undergone a hip replacement surgery.

Table 4. History of soft tissue knee injury and prevalence of knee osteoarthritis (OA) and knee arthroplasty in 709 former male elite athletes with a median age of 70 years (range 50–93), retired from competitive sports median 35 years (range 1–63), and in 1368 controls with a median age of 70 years (range 51–93). Data are presented as number of individuals with proportions (%) in brackets and as odds ratios (ORs) with 95% confidence intervals (95% CIs) in different models adjusted for combinations of age, body mass index (BMI), occupational load, and soft tissue knee injury. Statistically significant differences are highlighted in bold text.

| | N* | Participants with soft tissue knee injury/OA/arthroplasty, unadjusted | | Adjusted for age | Adjusted for age, BMI and occupational load | Adjusted for age, BMI, occupational load and soft tissue knee injury |
|--------------------------------|------|---|----------------------|--------------------------|---|--|
| | | n (%) | P-value | OR (95% CI) | OR (95% CI) | OR (95% CI) |
| Soft tissue knee injury | | | | | | |
| All athletes | 678 | 245 (36.1) | p < 0.0001 | 1.66 (1.35, 2.02) | 1.53 (1.23, 1.92) | — |
| Controls | 1316 | 332 (25.2) | — | 1.00 | 1.00 | — |
| Nonimpact sport | 92 | 22 (23.9) | p = 0.79 | 0.89 (0.54, 1.46) | 0.80 (0.47, 1.37) | — |
| Impact sport | 586 | 223 (38.1) | p < 0.0001 | 1.81 (1.47, 2.23) | 1.67 (1.33, 2.10) | — |
| Soccer | 378 | 139 (36.8) | p < 0.0001 | 1.71 (1.34, 2.18) | 1.59 (1.22, 2.07) | — |
| Handball | 140 | 50 (35.7) | p = 0.007 | 1.65 (1.14, 2.38) | 1.47 (1.00, 2.17) | — |
| Ice hockey | 68 | 34 (50.0) | p < 0.0001 | 2.93 (1.79, 4.79) | 2.68 (1.60, 4.49) | — |
| Knee OA | | | | | | |
| All athletes | 664 | 129 (19.4) | p < 0.001 | 1.64 (1.27, 2.11) | 1.56 (1.17, 2.07) | 1.31 (0.93, 1.85) |
| Controls | 1258 | 163 (13.0) | — | 1.00 | 1.00 | 1.00 |
| Nonimpact sport | 90 | 18 (20.0) | p = 0.06 | 1.81 (1.04, 3.14) | 1.65 (0.90, 3.02) | 3.19 (1.47, 6.91) |
| Impact sport | 574 | 111 (19.3) | p < 0.001 | 1.62 (1.25, 2.12) | 1.55 (1.16, 2.08) | 1.19 (0.83, 1.71) |
| Soccer | 368 | 67 (18.2) | p = 0.01 | 1.52 (1.11, 2.07) | 1.46 (1.04, 2.05) | 1.13 (0.75, 1.72) |
| Handball | 141 | 30 (15.8) | p = 0.007 | 1.82 (1.18, 2.81) | 1.86 (1.16, 3.00) | 1.62 (0.89, 2.94) |
| Ice hockey | 65 | 14 (21.5) | p = 0.05 | 1.88 (1.01, 3.47) | 1.51 (0.77, 2.95) | 0.92 (0.42, 1.98) |
| Knee arthroplasty | | | | | | |
| All athletes | 658 | 24 (3.6) | p = 0.12 | 1.58 (0.91, 2.73) | 1.32 (0.73, 2.40) | 1.51 (0.58, 3.93) |
| Controls | 1245 | 30 (2.4) | — | 1.00 | 1.00 | 1.00 |
| Nonimpact sport | 91 | 1 (1.1) | p = 0.42 | 0.49 (0.07, 3.71) | 0.46 (0.06, 3.54) | 0.59 (0.11, 3.26) |
| Impact sport | 567 | 23 (4.1) | p = 0.05 | 1.74 (1.00, 3.02) | 1.45 (0.79, 2.64) | 1.67 (0.64, 4.35) |
| Soccer | 363 | 12 (3.3) | p = 0.35 | 1.40 (0.71, 2.77) | 1.15 (0.56, 2.39) | 1.21 (0.38, 3.84) |
| Handball | 141 | 7 (5.0) | p = 0.07 | 2.12 (0.91, 4.92) | 1.93 (0.75, 4.94) | 1.71 (0.33, 8.88) |
| Ice hockey | 63 | 4 (6.3) | p = 0.05 | 2.81 (0.96, 8.27) | 2.29 (0.75, 6.93) | 4.50 (1.02, 19.79) |

* Excluded in the analyses were 11 individuals with a history of knee fracture, and, depending on the specific estimation, those who had not answered whether or not they had been diagnosed with a soft tissue knee injury or knee osteoarthritis, and/or whether they had undergone a knee replacement surgery.

Figure 1. Odds ratios for hip and knee osteoarthritis (OA) and hip and knee arthroplasty in 709 former male elite athletes with a median age of 70 years (range 50–93), retired from competitive sports median 35 years (range 1–63), and in 1368 controls with a median age of 70 years (range 51–93). * Data are presented as odds ratios (ORs) with 95% confidence intervals (95% CIs) and adjusted for age, BMI, occupational load, and previous soft tissue knee injury.



* Excluded in the analyses were, depending on the specific estimation, 29 individuals with a history of hip fracture and 11 with a knee fracture, and, depending on the specific estimation, those who had not answered whether or not they had been diagnosed with a hip or knee osteoarthritis, and/or whether they had undergone a hip or knee replacement surgery.