

## RISK OF OSTEOARTHRITIS ASSOCIATED WITH LONG-TERM WEIGHT-BEARING SPORTS

### A Radiologic Survey of the Hips and Knees in Female Ex-Athletes and Population Controls

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**Objective.** To estimate the risk of osteoarthritis (OA) of the hip and knee due to long-term weight-bearing sports activity in ex-elite athletes and the general population.

**Methods.** A retrospective cohort study was conducted of 81 female ex-elite athletes (67 middle- and long-distance runners, and 14 tennis players), currently ages 40–65, recruited from original playing records, and 977 age-matched female controls, taken from the age-sex register of the offices of a group general practice in Chingford, Northeast London, England. The definition of OA included radiologic changes (joint space narrowing and osteophytosis) in the hip joints, patellofemoral (PF) joints, and tibiofemoral (TF) joints.

**Results.** Compared with controls of similar age, the ex-athletes had greater rates of radiologic OA at all sites. This association increased further after adjustment for height and weight differences, and was strongest for the presence of osteophytes at the TF joints (odds ratio [OR] 3.57, 95% confidence interval [95% CI] 1.89–6.71), at the PF joints (OR 3.50, 95% CI 1.80–6.81), narrowing at the PF joints (OR 2.97, 95% CI 1.15–7.67), femoral osteophytes (OR 2.52, 95% CI 1.01–6.26), and hip joint narrowing (OR 1.60, 95% CI 0.73–

3.48), and was weakest for narrowing at the TF joints (OR 1.17, 95% CI 0.71–1.94). No clear risk factors were seen within the ex-athlete groups, although the tennis players tended to have more osteophytes at the TF joints and hip, but the runners had more PF joint disease. Within the control group, a small subgroup of 22 women who reported long-term vigorous weight-bearing exercise had risks of OA similar to those of the ex-athletes. Ex-athletes had similar rates of symptom reporting but higher pain thresholds than controls, as measured by calibrated dolorimeter.

**Conclusion.** Weight-bearing sports activity in women is associated with a 2–3-fold increased risk of radiologic OA (particularly the presence of osteophytes) of the knees and hips. The risk was similar in ex-elite athletes and in a subgroup from the general population who reported long-term sports activity, suggesting that duration rather than frequency of training is important.

Osteoarthritis (OA) is one of the most common causes of disability in developed countries. An increase in the level of recreational physical activity is being widely encouraged as a major public health initiative to reduce cardiovascular disease and osteoporosis, yet the risks associated with excessive sports activity are unclear. To date, results of studies that have investigated the effects of weight-bearing exercise on the skeleton of athletes have been conflicting. Reports of negative effects have included studies of knee or hip OA in former cross country runners (1) and track athletes (2), a study of veteran Californian runners (3), and a study of knees and ankles of veteran military parachutists (4). Reports of positive effects have included a study from Finland of male ex-runners with OA (5), a recent record linkage study of male Finnish athletes showing a 2-fold risk of

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hospital admission for OA of the hip, knee, and ankle (6), a study of hip and knee OA in soccer players (7), and a study of hip, but not knee, OA in a group of female physical education teachers (8).

Part of the inconsistency in these previous studies may stem from methodologic problems, such as the lack of a control group, small numbers, potential selection bias by including only current runners, potential referral bias by defining cases referred for radiography or operation, and difficulty distinguishing between the effects of running and the presence of an injury. Based on our knowledge of these problems, we carried out a retrospective cohort study to examine radiologic differences in the knees and hips between a group of female ex-elite middle- and long-distance runners and tennis players, recruited from original playing records, and a large female age-matched sample from the general population.

## PATIENTS AND METHODS

**Ex-athletes.** One hundred fifty seven names were obtained of female ex-elite middle- and long-distance runners and tennis players, with the assistance of the International Athletics Club and Lawn Tennis Association of the UK. These ex-athletes, currently between the ages of 40 and 65, had competed at the national or international level between 1950 and 1979. The names and addresses of 117 ex-athletes (74.5%) were traced, and these women were invited to attend a clinical and radiologic examination, which included radiographs of the knees (anteroposterior [AP] and lateral views) and the hips. Detailed information was collected on the running and playing history of each ex-athlete, as well as the history of joint injuries. An estimate of pain threshold was obtained using dolorimeter scores with a calibrated pressure gauge over an area of 0.5 cm<sup>2</sup>. Measurements (expressed as kg/cm<sup>2</sup>) were taken separately at the forehead and index finger, using standard methods (9) whereby subjects were asked to indicate when the pressure changed to pain. Due to a learning curve, only a single assessment was used.

**Controls.** The control group comprised 1,003 women, ages 44–67, taken from a general population survey carried out in Chingford, a district of Northeast London. This population was drawn from the age–sex register of a large group general practice, which totaled 1,535 women on average, with an adjusted response rate of 79%, and has been described in detail elsewhere (10). This population is essentially similar to the UK averages in terms of height, weight, smoking habits, and socioeconomic status. Similar information on physical activity and other demographic variables was obtained by a nurse-administered questionnaire. Radiographs of the pelvis and AP weight-bearing views of the knee were obtained for 977 women.

Lateral views of the patellofemoral (PF) joint were not available in the Chingford survey; therefore, control values for this joint were obtained from a group of age-matched unrelated women participating in a study of twins drawn from

around the UK. This group was similar to the Chingford population in terms of height, weight, smoking habits, alcohol use, hormone replacement therapy use, hysterectomy status, and physical activity.

Neither the ex-athletes nor the controls were aware of the hypothesis being tested, although all had agreed to participate in a survey of “bones and joints” that involved radiographs.

**Assessment of physical activity.** Current weight-bearing sports activity was categorized by units of activity per week, as described in the Allied Dunbar Health Survey (11). These units were defined as 15 minutes of vigorous weight-bearing exercise or 30 minutes of moderate weight-bearing exercise. Vigorous categories included jogging, squash, tennis, hockey, badminton, and aerobics, and moderate exercise included table tennis, golf, stretching exercises, and social dancing. Walking and bowls were not considered sports for this analysis, and swimming and cycling were also excluded since they are primarily non-weight-bearing activities. Women who reported <1 activity unit per week were categorized as having a zero score.

Details of past sports activity were assessed in the population by a self-administered questionnaire that inquired about sports performed between the ages of 20 and 30, and each past sports activity was categorized in the same manner as for current sports. Details of current occupational activity and number of miles walked per week were also recorded for the control group only. The control group was categorized into overall lifetime sports groups of low (<1 unit/week), moderate (1–3 units/week), and active ( $\geq 4$  units/week) sports participation, both in the past and currently. Adequate and complete information on past and current sports activity was available for a total of 585 women in the control population.

**Radiologic methods.** Standard radiographic techniques were used for both groups: focal length of 100 cm, AP view of the pelvis in 15° of internal rotation, AP weight-bearing views of the knees in full extension, and lateral views of the PF joint in 30° of flexion. After a period of training and tests of intra- and interobserver reproducibility, ex-athlete and control films were read by 3 observers: 1 (DJH) for all films and a further 2 observers. In cases of disagreement, grading was resolved by open consensus. Tibiofemoral (TF) and PF joints were graded for 2 principal individual features: presence of osteophytes, graded 0–3 (grade 1 on this scale is equivalent to grade 2 on the Kellgren-Lawrence scale [12]) and joint space narrowing, graded 0–3. All grades were assessed using an atlas of radiographic features (13). A case of CA was defined as grade  $\geq 1$  for individual features in either knee. Minimum interbone distance was also recorded with a transparent ruler at the TF joints. AP radiographs of the hips were scored for the presence of femoral osteophytes using an atlas (11), and minimum joint space narrowing (<2.5 mm) was scored using a transparent ruler, according to the method of Croft et al (14). Acetabular osteophytes were ignored for the analysis, being of doubtful clinical relevance.

**Reproducibility.** After a series of combined training sessions in radiography, 50 knee and hip radiographs with a range of disease severity were read twice by 2 trained observers, 1 month apart, using the standardized atlas. Reproducibility was good at all joint sites, with an average kappa statistic of >0.78 for both intra- and interobserver agreement. In the TF

**Table 1.** Characteristics of the ex-athlete and control populations\*

Characteristic	Ex-athletes (n = 81)	Controls (n = 977)
Age, years	52.3 (6.1)	54.2 (6.0)‡
Height, cm	166 (6.0)	162 (6.0)‡
Weight, kg	61.0 (8.8)	66.9 (11.8)‡
Body mass index, kg/m <sup>2</sup>	22.1 (2.8)	25.6 (4.3)‡
Current or ex-smokers, no.	11 (13.6)	463 (46.2)‡
Knee pain, no.†	27 (33.3)	248 (24.9)
Knee injury, no.†	3 (3.7)	120 (13.7)‡
Hip pain, no.	15 (18.5)	165 (18.5)

\* Values are the mean (SD) or frequency (%).

† n = 994 for knee pain; n = 874 for knee injury.

‡ P < 0.05 between groups, using unpaired t-test or chi-square analysis for proportions.

joint, intra- and interobserver agreement kappas ranged from 0.64 to 1.00 for osteophytes, and from 0.48 to 0.74 for joint space narrowing. For the PF joint, agreement ranged from 0.58 to 0.85. For the hip, agreement was excellent, ranging from 0.84 to 1.00. The reproducibility of dolorimeter scores was tested on 20 subjects using 2 observers. Intraobserver correlations were  $r = 0.65$  at the index finger and  $r = 0.88$  at the forehead, and interobserver correlations were  $r = 0.38$  at the index finger and  $r = 0.75$  at the forehead.

**Statistical analysis.** An estimate of the relative risk of sports activity for the development of OA was obtained from the odds ratios (OR), simultaneously adjusted for age, height, and weight, using logistic regression with the Egret statistical package (SERC, Seattle, WA). Additional adjustments for other potential confounders were also made. Comparisons were made 1) between the ex-athlete group and the whole control population, and 2) within the control population, comparing active and moderate sport groups with the low-activity controls.

## RESULTS

Thirty-four (29.1%) of the 117 traced ex-athletes were nonresponders: 21 (17.9%) did not reply to the invitation and 13 declined to participate. Of the non-responders who gave a reason, 1 had a total hip replacement, 1 had lymphoma, 2 were hospitalized, and 2 considered themselves too elderly to travel. Two tennis players (2.4%) consented to a clinical examination but declined radiographs. Thus, 81 ex-athletes participated in the study (70.9% of those traced). The ex-athletes were of a formerly high, or elite, level and included at least 2 Olympic gold medalists and 2 Wimbledon singles champions. Radiographic information was available on 81 ex-athletes (67 runners and 14 tennis players), 977 female Chingford population controls, and an additional 215 population controls for the PF joint. Table 1 shows

the demographic characteristics of the ex-athletes and Chingford population controls.

The mean age of the ex-athletes was similar to that of the controls, although the ex-athletes were, on average, taller by 4 cm, lighter by 5.9 kg, and less likely to smoke. The additional controls (for whom there were lateral knee views) were similar in terms of height and weight to those from Chingford, although, on average, were 2 years older than the Chingford controls. As expected, the proportion of women in the 2 groups currently participating in different levels of weight-bearing sports activities showed many more ex-athletes (51.9%) in the top activity category ( $\geq 4$  units per week) compared with controls (5.8%). Eight hundred eleven control subjects (81.3%) responded that they currently participated in little or no sports (<1 unit), compared with 22 (27.2%) of the ex-athletes. The ex-runners had a mean duration of competition of 15.3 years and the ex-tennis players had a mean of 19.3 years. The ex-athletes reported that they currently averaged 3.1 hours of vigorous weight-bearing sports per week (ex-runners 2.6 hours, and ex-tennis players 5.7 hours). Those ex-athletes still running completed a mean of 14.6 miles per week (range 0–50), and ex-tennis players played a mean of 5.2 hours per week (range 0–18). Reported knee pain in the past, lasting more than 2 weeks in a month, was similar between the groups, but reported knee injury (immobility >1 month) was uncommon in the ex-athletes compared with the controls (Table 1). Reported hip pain was similar in the ex-athletes and controls.

Table 2 compares the crude prevalence rates of the radiologic features in ex-athletes at the different joint sites. Increases were seen in the ex-athlete group more clearly for osteophyte formation at the hips, but also at the TF joints for osteophytes and the PF joints for both osteophytes and narrowing. It should be noted that in this young population, the majority of radiologic features indicated early disease, i.e., grade 1 changes (mild but definite disease). For example, of the 18 ex-athletes with TF joint osteophytes, 12 (66.7%) were grade 1, 4 (22.2%) grade 2, and only 2 (11.1%) grade 3. A similar distribution of severity was seen for other sites.

However, since the ex-athletes were taller, leaner, and younger on average, and age and obesity are major risk factors for OA, the crude rates are likely to be confounded by these differences and not further comparable. After adjustment for age alone, the OR increased further, and adjustment for height and weight differences increased the association at most sites. This in-

**Table 2.** Frequency and risk of radiologic osteoarthritis in ex-athletes versus population controls, comparing crude results with results adjusted for age alone (A), and for age, height, and weight (AHW)

Area, feature	Controls (n = 977)		Ex-athletes (n = 81)		Crude odds ratio (95% confidence interval)	Odds ratio, A (95% confidence interval)	Odds ratio, AHW (95% confidence interval)
	no.	%	no.	%			
Knee at tibiofemoral joint							
Osteophytes	145	14.8	18	22.2	1.69 (0.96–2.90)	2.08 (1.17–3.70)	3.57 (1.89–6.71)
Narrowing	359	36.7	28	34.6	0.91 (0.57–1.46)	0.93 (0.58–1.50)	1.17 (0.71–1.94)
Knee at patellofemoral joint							
Osteophytes	60	28*	34	42	1.86 (1.09–3.16)	2.7 (1.51–5.09)	3.50 (1.80–6.81)
Narrowing	27	12.6*	11	13.6	1.09 (0.51–2.31)	2.27 (0.97–5.34)	2.97 (1.15–7.67)
Hip							
Osteophytes	37	4.0	7	9.0	2.37 (1.02–5.51)	2.49 (1.06–5.82)	2.52 (1.01–6.26)
Narrowing	73	7.9	9	11.5	1.53 (0.73–3.18)	1.67 (0.78–3.42)	1.60 (0.73–3.48)

\* n = 215

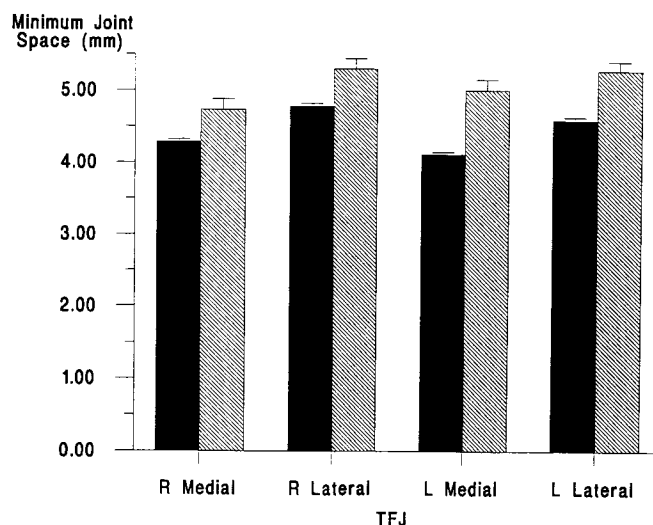
crease was clearest for the presence of osteophytes at the TF joint (OR 3.57, 95% CI 1.89–6.71), the PF joint (OR 3.50, 95% CI 1.8–6.81), and the femoral neck (OR 2.52, 95% CI 1.01–6.26). An increased risk of narrowing was seen at the PF joint (OR 2.97, 95% CI 1.15–7.67) and the hip (OR 1.60, 95% CI 0.73–3.48), but not at the TF joint (OR 1.17, 95% CI 0.71–1.94).

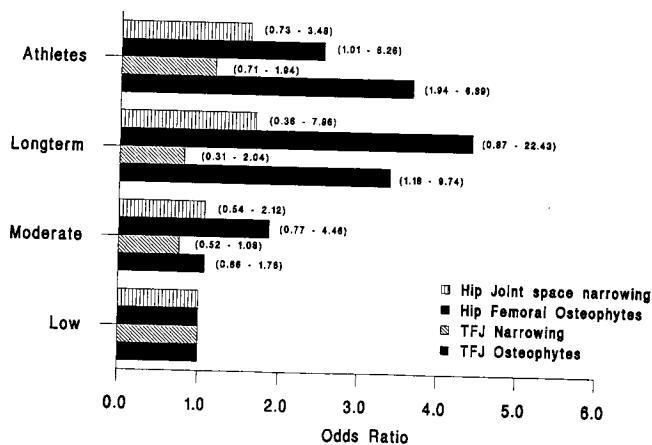
The mean joint spaces of those ex-athletes without any features of OA were greater than those of the normal controls at the TF joints by 0.41 mm (9.5%;  $P < 0.002$ ) and at the hip joints by 0.13 mm (3.6%;  $P = 0.17$ ). This difference remained significant after adjusting for age, height, and weight (Figure 1).

For the knee, adjustment for the presence of symptoms or history of knee injury did not affect the results, nor did adjustment for other potential confounders such as smoking, menopause status, or hysterectomy, or the use of body mass index rather than height and weight, or adjustments for age or weight alone. The results were of similar magnitude when only symptomatic individuals with radiologic features were defined as having OA (OR 3.75, 95% CI 1.71–8.26 at the TF joints, and OR 1.87, 95% CI 0.94–3.71 for TF joint space narrowing). No increase in the OR was seen when only symptomatic individuals with PF joint disease were included, and symptomatic hip joint narrowing was too rare for analysis.

Although the numbers were small, there was a suggestion of some radiologic differences (albeit nonsignificant) between ex-runners and ex-tennis players. Ex-tennis players had almost double the rate of osteophytes at the TF joints ( $n = 5$ ; 35.7%) and at the hip joints ( $n = 2$ ; 14.3%), compared with ex-runners ( $n = 13$ , 19.4% at

the TF joints, and  $n = 5$ , 7.8% at the hip). In contrast, ex-runners were found to have almost double the rate of osteophytes and narrowing at the PF joints ( $n = 30$ , 44.8% at the PF joints, and  $n = 10$ , 14.9% at the hip) compared with ex-tennis players ( $n = 4$ , 28.6% at the PF joints, and  $n = 1$ , 7.1% at the hip). No difference in duration of competition or mileage in training was noted between ex-athletes with and without OA of the knee or hip. There were no clear differences between ex-athletes who had stopped or continued sports. Of the 22 (27.1%)

**Figure 1.** Mean  $\pm$  SD minimum joint space (in mm) at the tibiofemoral joint (TFJ) in osteophyte-free individuals. Values for ex-athletes (■) are compared with controls (▨).



**Figure 2.** Risks and 95% confidence intervals of different levels of sports activity for features of osteoarthritis at the hip and knee in the control population and in the ex-athletes (adjusted for age, height, and weight), in relation to the inactive control population. TFJ = tibio-femoral joint.

ex-athletes who were no longer competing, only 1 (4.5%) reported knee injury.

Figure 2 shows comparisons of the frequency of radiologic OA within the control population for the different sports categories. The only clear increase in OA risk between the sports categories in the control population was seen in those women ( $n = 22$ ) reporting long-term sports activity  $\geq 4$  units per week. They had increased OR similar to that of ex-athletes for all features. This increased still further after adjustment for age, height, weight, walking, and occupation. The associated risk in individuals ( $n = 216$ ) who participated in moderate amounts of sports (1–3 units) was not clearly seen. Individuals ( $n = 59$ ) currently participating in  $\geq 8$  units of sports activity per week, but  $< 4$  units in the past, were found to have no clear increased risks of OA at the TF joints or PF joints, although a weak association was seen for the presence of femoral osteophytes (OR 2.04, 95% CI 0.68–6.09).

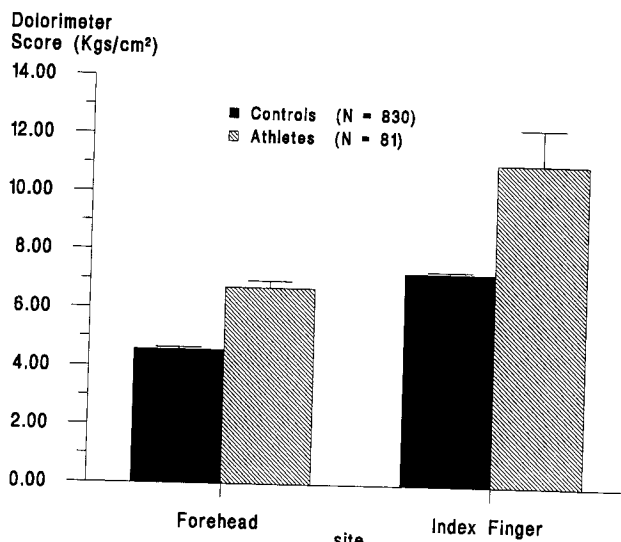
Mean dolorimeter scores for pain threshold of the forehead and index fingers in the ex-athletes were almost twice those of the population controls (Figure 3). At the forehead, the mean measurement for ex-athletes was  $4.6 \text{ kg/cm}^2$  (SEM 0.06) and for the controls was  $6.7 \text{ kg/cm}^2$  (SEM 0.24), and at the index finger, the mean for ex-athletes was  $7.3 \text{ kg/cm}^2$  (SEM 0.08) and for the controls was  $11 \text{ kg/cm}^2$  (SEM 1.24). These results were significantly different for both sites, and were not altered by adjustment for differences in age, height, and weight.

No differences were seen within the ex-athlete groups; in particular, the ex-athletes who no longer participated in sports maintained high scores. No differences in pain thresholds were seen within the different categories of the population control group.

## DISCUSSION

We have found that ex-elite athletes have a 1.6–3.6-fold increased risk of OA at the hip and knee, compared with controls, after adjusting for age, weight, and height differences. Weight is the most important known modifiable risk factor for OA of the knee (10), and the finding that the elevated risk increased further after adjustment suggests that running has both a protective effect by keeping weight down and a detrimental effect by its association with radiologic changes. Rates of hip OA in ex-athletes were higher, compared with controls, irrespective of body weight. The small proportion of women in the general population who were currently active in sports and were in their twenties had rates of OA similar to those of the ex-athletes. Pain thresholds were markedly higher in the ex-athletes and may explain the lack of increase in knee pain.

The radiologic presence of osteophytes in the knee, even in the absence of symptoms, has been found to be related to subsequent (10 years later) disability and physical functioning in the NHANES I epidemiologic followup survey of the normal US population (15).



**Figure 3.** A comparison of the mean  $\pm$  SEM dolorimeter scores in  $\text{kg/cm}^2$  for the forehead and index finger (pain threshold) of ex-athletes versus controls.

## RISK OF OA ASSOCIATED WITH SPORTS

Whether osteophyte formation in the ex-athletes of the present study has the same relationship with OA and any resulting disability is unclear. The presence of a definite osteophyte has been shown in our control population to be more strongly associated with knee pain and more reproducible than joint space narrowing, although both are likely to independently contribute to the disease process. A question remains, however, about whether the osteophytes that result from intense physical activity are different from those normally seen in a sedentary population. The sites of the osteophytes that were recorded were all classic sites of OA, and osteophytes at sites of muscle insertion or "traction" such as the greater trochanter, which are common in athletes, were not included. Moreover, these traction spurs were not associated with an increased osteophyte tendency in the knees or hips.

The increased radiologic changes seen with only a minor increase in symptoms could be due simply to the modest correlations between the two, or alternatively, to the markedly higher pain thresholds in the ex-athletes, or to the effect of stronger supporting tissues and muscles in the ex-athletes. This would imply that disability might be delayed in these patients. It is unclear whether our inability to detect obvious joint space narrowing at the TF joint was a true negative or reflects its poorer reproducibility and performance as an epidemiologic marker of early OA (16). Another possible explanation is the 10% increase in joint space width in normal athletes. If running at a young age increases cartilage thickness, as seen in some animal models (17,18), it would take longer to visualize changes, since proportionally more cartilage would have to be lost. Croft et al have shown that, at the hip, minimum joint space is the best predictor of pain in a population (14), but it is likely that femoral osteophytes are also independently important (19).

The increased rates of OA in the long-term sports group in the control population suggested that duration of sports activity, rather than eliteness per se, is the important factor. The possible site differences between ex-athlete groups raises interesting questions about different mechanical stresses in different activities; for example, running has a greater detrimental effect on the PF joints, and twisting and sudden changes in acceleration and deceleration can affect the TF joints. However, to clearly separate sports would require a considerably greater sample size of a number of different athlete groups.

In an observational study such as this, the prin-

cipal discussion should be of possible bias and confounding. Selection bias, in which the ex-athletes with injury would be less likely to be included, was reduced by obtaining the original names of the ex-athletes rather than selecting only those who were currently active. We therefore included athletes who were no longer participating in sports. Although only 52% of the original group were followed up, most of the losses were due to name changes or address errors rather than altered disease patterns. Some degree of selection bias is invariably present because all the ex-athletes who competed at the national or international level will have been "selected" to some degree, and those with serious joint injuries will not have achieved elite status. It is unlikely that the responders in the ex-athlete group differed markedly in terms of injury or OA compared with nonresponders, and there were certainly no more symptoms in the ex-athletes than expected. The similar results obtained in the small control population sports group suggest that selection bias was not a major factor.

Confounding by factors related to sports activity and OA are accounted for in the analysis. Age and weight are known and important risk factors and altered the estimates; other possible confounders, including smoking, menopause status, hysterectomy, and previous injury, did not affect the estimates of risk. Within the control group, walking and occupational activity were also accounted for. Using a different control group for the PF joint was necessary because the Chingford group did not have this radiographic view in their records. Demographics of the 2 control groups were very similar and any differences are unlikely to have affected the results. Furthermore, we could justifiably look in detail at the 585 controls with full past and current physical activity data, rather than at the whole group, due to the higher quality physical activity data for this group and the fact that this group's demographics were similar to those of the remaining women in the control population.

A number of previous studies have addressed this question. Most of the early studies were uncontrolled surveys of small numbers of current athletes, which produced discrepant results (1,2,5,8,20). Other studies of soccer players have included only those players who were symptomatic and for whom radiographs were requested (7). A study of 41 veteran runners over the age of 50 in California has shown no major differences in osteophytes or joint space of the knee compared with 57 controls at baseline or after 5 years of followup, although there was a suggestion of an increase in osteophytosis in the runners (3). More recent studies have included a

case-control study of 233 Swedish men with a recent hip prosthesis and 302 hospital controls, which showed a 2-4-fold increased risk associated with long-term sports activity (21). A large-scale record linkage study from Finland identified 2,049 male athletes and found an ~2-fold increase in hospital admissions with an ICD code for OA (6). Although this was a powerful study in terms of sample size, it had disadvantages, in that it could not exclude referral bias or diagnostic bias as an explanation for the results. Many of the admissions could have been for diagnostic arthroscopies. Nevertheless, these results, using very different methodology, are broadly in agreement with our own findings. Another recent study compared OA in 4 athlete groups: soccer players, weight lifters, runners, and shooters (22). They found that the first 2 groups had the highest rates of OA, partly due to increased rates of injury and body size.

There is considerable indirect evidence to support a relationship between long-duration, high-frequency weight-bearing exercise and OA of the hip and knee. Controlled experiments involving sheep walking on hard surfaces have shown a detrimental effect on joints (17). Moreover, observational epidemiologic studies of excessive bending of the hips in farmers (23) and occupational repetitive knee bending in men have been shown to increase the risk of OA (24).

If performing weight-bearing sports for a long duration confers an increased risk of OA, is there a safe level at which running does no harm? Our population sample of 977 was not large enough to clearly answer this question, as most women surveyed were sedentary and not at risk, although it suggests that the main risk is in the top 5% of women undergoing more than 1 hour of vigorous exercise per week who also participated in sports in their twenties. While it is possible that modern aids such as the cushioned training shoe or synthetic running surfaces may reduce this risk, this has to be balanced by the more punishing current training schedules. During the time period in which our runners competed, they were not allowed to run distances of more than 5,000 meters, and marathons were considered too dangerous for women. Therefore, an important future public health endeavor would be to determine which types and duration of weight-bearing exercise are beneficial for the heart and bones without damaging the joints.

In summary, we have found that long-term weight-bearing sports are related to the radiologic presence of OA at the hip and knee in middle-aged women. Prospective studies are needed to determine if these

changes will result in the same disability as would occur in the sedentary population in later life when OA becomes a major cause of pain and loss of function.

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