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Long Distance Running and Knee Osteoarthritis A Prospective Study

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Abstract

Background—Prior studies of the relationship of physical activity to osteoarthritis (OA) of the knee have shown mixed results. The objective of this study was to determine if differences in the progression of knee OA in middle- to older-aged runners exist when compared with healthy nonrunners over nearly 2 decades of serial radiographic observation.

Methods—Forty-five long-distance runners and 53 controls with a mean age of 58 (range 50–72) years in 1984 were studied through 2002 with serial knee radiographs. Radiographic scores were two-reader averages for Total Knee Score (TKS) by modified Kellgren & Lawrence methods. TKS progression and the number of knees with severe OA were compared between runners and controls. Multivariate regression analyses were performed to assess the relationship between runner versus control status and radiographic outcomes using age, gender, BMI, education, and initial radiographic and disability scores among covariates.

Results—Most subjects showed little initial radiographic OA (6.7% of runners and 0 controls); however, by the end of the study runners did not have more prevalent OA (20 vs 32%, p =0.25) nor more cases of severe OA (2.2% vs 9.4%, p=0.21) than did controls. Regression models found higher initial BMI, initial radiographic damage, and greater time from initial radiograph to be associated with worse radiographic OA at the final assessment; no significant associations were seen with gender, education, previous knee injury, or mean exercise time.

Conclusions—Long-distance running among healthy older individuals was not associated with accelerated radiographic OA. These data raise the possibility that severe OA may not be more common among runners.

Introduction

Osteoarthritis (OA) is the most common form of arthritis and contributes substantially to disability among older adults.[1,2] The relationship of physical activity to the development and progression of OA of the knee has been examined in the past with mixed results. Participation in sports and the performing arts at the elite level has been associated with increased risks of OA of lower-extremity joints, especially in contact sports[3–5]; however, there is less consensus about the role of habitual recreational noncontact exercise.[6,7] Data suggest that long-distance

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running may not be associated with increased progression of knee OA in the absence of knee injury, obesity, proprioceptive deficit, or poor muscle tone.[2,8] A prospective longitudinal study of long-distance runners and a similarly aged group of controls is ongoing, with results suggesting that overall disability levels in runners increase with age at 25% of the rate of more sedentary controls.[9,10] Disability was measured using the Health Assessment Questionnaire Disability Index (HAQ-DI), a self-reported instrument assessing functional ability in eight areas: rising, dressing and grooming, hygiene, eating, walking, reach, grip, and activities of independent living.[11,12]

This study examined radiographic knee OA by serial radiographs taken between 1984 and 2002 in long-distance runners aged ≥50 years compared with a similarly matched control group from the community. When the study was designed in 1984, there was concern that running was likely to accelerate OA due to repetitive trauma to the joints. Consistent with this, our original hypothesis was that long-distance runners would develop more prevalent and more severe OA than a similarly aged control population. Herein, the radiographic outcomes are reported of the observational study of runners and controls followed for up to 18 years.

Subjects and Methods

Subjects and Data Collection

The nationwide Fifty-Plus Runners Association provided access to a group of long-distance runners aged ≥50 years; most had been running for over a decade. The control group was drawn from a random sample from the Stanford University Lipid Research Clinics Prevalence Study, begun in 1972.[13] In January 1984, study descriptors were sent to approximately 1500 subjects from these two groups. Based on positive responses to the study descriptors, a cohort of 538 runners and 423 controls were assembled who met eligibility requirements (aged ≥50 years, high school graduate, English as primary language).[10] Subject selection and matching based on age, education level, and occupation have been extensively detailed in previous reports.[9,14–16] A geographically convenient sample from the original cohort of all 113 individuals residing within 100 miles of Stanford University was invited to participate in the radiographic longitudinal study. The sample size was based on the number of participants living within a reasonable distance from the study site rather than on formal sample size calculations.

Bilateral anteroposterior weight-bearing radiographs of the knees were taken in 1984, 1986, 1989, 1993, 1996, and 2002.[9] In earlier years (1984–1993) radiographs were taken with knees in 5 degrees of extension.[14–16] As techniques improved, later waves (1996–2002) of radiographs were taken with knees in semiflexion against the radiocasette.[9] Although the technique varied slightly over the 18-year period of study, radiographs were performed identically for both runners and controls at each time point. The change in technique due to positioning may have influenced the magnitude of change within groups over time; however, this would be nondifferential between groups and not affect between-group analyses. For this reason, final radiographic scores as well as change in radiographic scores were used as outcomes in the analyses. All 51 runners and 62 controls in the original radiographic cohort, with a total of 435 bilateral knee x-rays between 1984 and 2002, were initially evaluated for this study. Fifteen participants had only an initial set of radiographs, and were excluded from further analysis. Data analysis for progression of knee OA was performed on the 98 individuals with at least two sets of radiographs over the 18-year period: 45 runners and 53 community controls. Initial demographic and radiographic data from the 15 participants with only a single radiograph were compared to data from the 98 participants in the final analysis to assess for differential drop-out.

All participants provided information by annual self-reported questionnaire on demographics, medical history, BMI, exercise habits, musculoskeletal injuries, and functional status using the HAQ-DI (range 0 [no difficulty] to 3 [inability to perform daily abilities]).[11,12]

As running is one of many forms of vigorous exercise, data were acquired on the total amount of time spent doing all forms of vigorous exercise. Information regarding exercise intensity was obtained from responses to the question: *How many minutes each week do you exercise vigorously (vigorous exercise will cause you to sweat and your pulse, if taken, will be above 120 beats per minute)*.[17] Types of vigorous exercise reported by participants included running, swimming, cycling, aerobic dance/exercise, racket sports, and brisk walking. The study was approved by the Stanford University IRB, and each subject provided informed consent.

Radiographic Scoring

Digitized films of radiographs were read for narrowing, sclerosis, and osteophytes in the medial and lateral compartments of each knee by two independent trained readers, blinded to group membership, using a standard modification of the Kellgren & Lawrence method that has been shown to be reliable for assessing progression of radiographic OA[8,18,19]: joint space narrowing, sclerosis, and osteophytes were each graded on a scale of 0 to 3 (normal, mild, moderate, and severe). The primary outcome measure was the total knee score (TKS), computed as the numerical sum of each of the above scores from medial and lateral compartments of both knees (range 0–36).[9,16] Joint space width (JSW) was determined as the joint width in millimeters of each knee compartment (range 0–6 mm). The worst of the four compartmental values for JSW, representing the knee with the most advanced OA, was used as a secondary outcome measure. In the event of a total knee replacement, a value of 0 for JSW was entered and maximum scores for joint space narrowing, sclerosis, and osteophytes for both compartments were used to calculate TKS (maximum score = 18 per knee). All radiographs were scored at a single time point. Radiographic scores were average scores of two independent readers (rheumatologists) trained in a standard protocol. Inter-reader correlation was 0.86. Readers were blinded to group membership, but not to the temporal order of the radiographs. Prevalent radiographic OA was based on a Kellgren & Lawrence Grade II or higher OA, defined as any definite osteophytes and/or moderate diminution of joint space (JSW <3mm).[20] Severe OA was defined as total knee replacement or JSW=0.

Statistical Analysis

Runners and controls were compared for demographic variables, BMI (kg/m^2), HAQ-DI, TKS, JSW, prevalent OA, and number of knees with severe OA using end-of-study scores and change scores (from first to last radiograph) with chi-square and t-tests where appropriate. Two-tailed comparisons were considered significant at $p<0.05$. Multivariate linear regression analyses were performed to assess the relationship of running to radiographic outcomes adjusting for baseline variables and time from first radiograph. Initial analysis was conducted in 2005, and more-detailed analyses were conducted in 2007.

Results

Study Population

Of the 113 participants in the radiographic study, 98 (45 runners and 53 controls) had at least two sets of radiographs. Drop-out rates did not differ appreciably between runners (6/51) and controls (9/62) despite nearly 2 decades of follow-up. Subjects who had died (1/51 runners, 3/62 controls) or those who did not return for subsequent radiographs tended to be an average of 5 years older, but have fewer previous knee injuries, and lower total knee scores than those with at least two sets of radiographs. Baseline HAQ-DI and amount of time spent in vigorous exercise did not differ appreciably between drop-outs and those with more radiographs.

Participant characteristics at the time of baseline and final radiographs are presented in Table 1. Groups were largely similar at both time points, but runners were slightly younger, had slightly lower BMI at baseline, and had reported a greater prevalence of prior knee injuries than controls. Differences in BMI reached statistical significance although means of both groups remained within the normal range. HAQ-DI scores were similar between runners and controls, increasing over time in both groups (0.06 in runners and 0.10 in controls). Runners had decreased their running time by 55% at the end of the follow-up period but had maintained the time participating in overall vigorous exercise (approximately 300 minutes/week). A small proportion of controls ran for exercise at the baseline, but almost all had stopped running by the final radiograph. However, controls had increased the average time spent in other vigorous activities by 100 minutes/week at the final radiograph. The increased nonrunning exercise for both runners and controls consisted mainly of brisk walking. Significant differences in time spent running and other vigorous activities between runners and controls persisted throughout the time of follow-up.

Radiographic Outcomes

Most subjects showed little radiographic OA at initial and final radiographs. Groups had little prevalent radiographic OA at the baseline. Total knee scores were worse at the time of initial radiograph in runners compared to controls (1.29 vs 0.40, p=0.018), but were similar in both groups at the end of the study (3.60 vs 4.21, p=0.60), reflecting a greater overall progression in controls. Similarly, JSW of the worst knee was slightly worse among runners than controls at the initial radiograph, but were nearly identical at the final assessment. While a higher proportion of controls had prevalent OA by the final radiograph compared to runners, this difference was not significant.

The number of knees with severe OA (single most-damaged knee for each participant) as measured by JSW or knee replacement at the end of the study in each cohort is shown in Table 2. Two participants, both in the control group, had undergone total knee replacement, one unilateral and one bilateral. Three other controls had JSW of 0. In comparison, no runners had undergone knee replacement and one had a JSW of 0 mm. Only 10 participants (six controls and four runners) had JSW in the worst knee of ≤1 mm. None of the differences between groups were significant.

Table 3 shows results of multivariate linear regression for TKS and for JSW at the final radiograph in the 98 subjects with at least two radiographs. The final model included the following covariates: runners versus controls, age at initial radiograph, gender, education level, BMI at initial radiograph, prior knee injury, degree of damage at initial radiograph, and time between initial and final radiograph. Most variables were not associated with a difference in final TKS or JSW, including runner status, gender, age at first radiograph, education, or previous knee injury. Greater BMI at the baseline was associated with less JSW at the final radiograph by approximately 0.1 mm per unit (p=0.045); however, BMI was not associated with final TKS. Greater damage at initial radiograph and time from initial radiograph were both associated with worse radiographic OA at the final x-ray as measured by both TKS and JSW. These results were unchanged with the inclusion of HAQ-DI and the amount of weekly running or vigorous exercise in the model. Similar results were found when change scores (TKS and JSW) between initial and final radiographs were used as dependent variables (data not shown).

Discussion

We had originally hypothesized that long-distance running may be associated with increased incidence and severity of OA when compared to a similar cohort of nonrunners. However, the results are not consistent with this hypothesis. In this analysis, long-distance running was not associated with accelerated incidence or severity of radiographic OA. Over the prolonged period of observation (mean 11.7 years) and despite more prevalent OA and worse radiographic scores at the baseline, runners did not have more-severe OA or replaced knees than controls. Although there were some suggestions that runners may have less OA than controls, these did not meet statistical significance, possibly because of the lower-than-expected number of serious events and relatively mild OA among most participants throughout the observation period. Therefore, we were unable to conclude that membership in the runners' club was either a risk or protective factor with respect to radiographic knee OA.

These results are consistent with other studies of long-distance running and vigorous activity in independent cohorts of aging subjects.[21–23] Even at the elite-athlete level, data suggest that running may not be an independent risk factor for knee OA.[4] Together with observations from this study, the data suggest that long-distance running as an intense recreational activity may not confer additional risk for knee OA

In contrast, a number of studies have shown that participation in specific sports at the elite level does increase the risk of knee OA. Associations are most pronounced for premature symptomatic and radiographic OA among participants in professional ballet dancing, soccer, and weight lifting.[3–5,24] Additionally, a prospective study of Framingham data found heavy physical activity among elderly individuals, in the absence of participation in elite-level sports, was an independent risk factor for incident radiographic OA.[25]

The strengths of this study lie in the prospective observational study design utilizing standard radiographic measures over nearly 2 decades of observation, designed to compare two groups that provided large differences in the independent variables of interest: long-distance running and other aerobic activities while retaining similarities in geographic location, education, and BMI. Drop-out rates from first to subsequent radiographs were relatively low and were similar in both groups. Similar results were found from an analysis of a composite score of both knees as well as a more conservative worst-knee analysis.

There are several limitations to this study. Radiographic OA was evaluated without including analysis of clinical symptoms. Studies have shown a relative lack of concordance between degree of radiographic damage and symptoms.[8,26,27] Nevertheless, the number of replaced knees, generally replaced due to function-limiting symptomatology including pain, may be considered a surrogate measure for severe symptomatic disease. Additionally, the HAQ-DI, without exclusively evaluating knee disease, is a validated measure of functional limitation which incorporates lower extremity activities within a broader context of disability. No statistical differences in knee replacements or HAQ-DI were found in comparisons of runners and controls.

Only tibiofemoral disease was evaluated in this study, so associations between running and patellofemoral OA could not be investigated. Although almost all studies of vigorous activity and knee OA have been concerned primarily with tibiofemoral disease, at least one previous report had suggested that patellofemoral disease may be more prevalent in runners, particularly in women.[24]

It must be recognized that this study is subject to possible selection bias as the runners were all healthy individuals who continued running at least into the 6th decade of life, most of whom had been running for nearly a decade prior to study entry. Therefore, these results may not be generalizable to individuals who begin long-distance running in their later years, or to those who had previously discontinued running for injuries or other reasons. The increased time spent in nonrunning vigorous activities, approximately 100 minutes/week in each group, was spent engaged in brisk walking. While this may be reflective of secular trends in more recent decades given wide publicity of the health benefits of cardiovascular exercise, it also raises the possibility that the increase in vigorous activities may have predisposed these subjects to a slightly accelerated progression of OA compared to sedentary subject who maintained or decreased time spent in vigorous activities.

Finally, after nearly 2 decades of observation, there were no significant differences in radiographic outcomes between long-distance runners and controls. As many participants in the original cohort were included as was feasible given geographic restrictions imposed by the requirement to have all radiographs performed in a standardized manner by trained personnel at our site. It was originally anticipated that far more cases of severe OA and knee replacements would be seen after 18 years in this elderly cohort. Surprisingly, only six cases of severe OA were identified including three knee replacements among 98 participants. Additionally, TKS remained low for all participants at the final radiographs. At the last radiograph, the mean TKS was 3.6 for runners and 4.2 for controls, although the range of possible scores spanned 0 to 36.

This study was unable to document that long-distance running among older adults confers any deleterious or protective effects on the development of radiographic OA. Much larger studies involving hundreds to thousands of healthy older adults followed for several decades are needed to determine if long-distance running may be associated with a modest decrease in incidence or severity of radiographic OA. Long-distance running or other routine vigorous activities should not be discouraged among healthy older adults out of concern for progression of knee OA.

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Table 1

Characteristics and outcomes (mean and SE) of participants with at least two radiographs

	First radiograph		Last radiograph	
	Runners' club	Community controls	Runners' club	Community controls
Number of participants	45	53	45	53
Age (years)	59.8 (0.98)	60.2 (0.88)	71.2 (0.92)	72.2 (0.89)
Men (%)	64.4	69.8		
Education (years)	16.9 (0.35)	16.7 (0.29)		
Previous knee injury (%)	44.4	35.9		
BMI (kg/m^2)	22.3 (0.33)**	24.0 (0.47)	23.1 (0.39)*	24.8 (0.64)
HAQ-DI (0–3)	0.03 (0.01)	0.05 (0.01)	0.09 (0.03)	0.15 (0.05)
Vigorous exercise (minutes/week)	296.2 (25.6)***	100.6 (16.4)	293.8 (32.2)*	199.0 (24.7)
Running (minutes/week)	213.9 (18.7)***	28.8 (11.2)	94.8 (23.5)***	0.9 (0.7)
Current runners (%)	97.8***	17.0	55.6***	3.8
Time from first radiograph (years)			11.3 (0.8)	12.0 (0.8)
Total knee score	1.29 (0.37)*	0.40 (0.13)	3.60 (0.52)	4.21 (0.98)
Prevalent radiographic OA (%)	6.7	0	20.0	32.1
Joint space width (worst knee), mm	4.54 (0.09)*	4.84 (0.07)	3.82 (0.19)	3.80 (0.22)

* $p<0.05$ compared to community controls

** $p<0.01$ compared to community controls

*** $p< 0.001$ compared to community controls

HAQ-DI Health Assessment Questionnaire Disability Index

Table 2

Knee damage (in the worst knee) at final radiograph in participants with at least two radiographs

	n	Joint space width = 0 mm or knee replacement *n* (%)*	Joint space width ≤ 1 mm *n* (%)	Joint space width ≤ 2 mm *n* (%)	Joint space width ≤ 3 mm *n* (%)
Runners' club	45	1 (2.2)	4 (8.9)	5 (11.1)	11 (24.4)
Community controls	53	5 (9.4)	6 (11.3)	7 (13.2)	12 (22.6)
Total	98	6 (6.1)	10 (10.2)	12 (12.2)	23 (23.5)

* p=0.21 comparing runners' club to community controls

Table 3

Multivariate linear regression of covariates associated with radiographic outcomes at final assessment

Covariate	Total knee score (*n*=98) Estimate	95% CI	Joint space width (*n*=98) Estimate	95% CI
Community controls	0.72	−1.64, 3.08	−0.15	−0.71, 0.41
Female	0.12	−2.59, 2.83	−0.38	−1.02, 0.25
Age at first radiograph	0.04	−0.16, 0.24	−0.04	−0.08, 0.01
Education level	0.13	−0.38, 0.65	−0.06	−0.18, 0.06
BMI at first radiograph	0.18	−0.22, 0.59	−0.10*	−0.19, −0.002
Outcome score at first radiograph	0.79*	0.17, 1.41	1.10***	0.63, 1.58
Prior knee injury	−0.47	−2.79, 1.85	0.03	−0.52, 0.57
Time from first radiograph (years)	0.36**	0.12, 0.59	−0.06*	−0.12, −0.01

Variables included in final model: group (controls versus runners), gender, age at initial radiograph, BMI at initial radiograph, total knee score at initial radiograph, history of knee injury prior to initial radiograph, and time interval (years) from initial to final radiograph

* $p<0.05$

** $p<0.01$

*** $p<0.001$