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Permalink
https://escholarship.org/uc/item/5422n7x8

Journal
Arthritis Care & Research, 69(2)

ISSN
2151-464X

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Publication Date
2017-02-01

DOI
10.1002/acr.22939

Peer reviewed

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HHS Public Access
Author manuscript
Arthritis Care Res (Hoboken). Author manuscript; available in PMC 2018 February 01.

Published in final edited form as:
Arthritis Care Res (Hoboken). 2017 February ; 69(2): 183–191. doi:10.1002/acr.22939.

History of Running is Not Associated with Higher Risk of Symptomatic Knee Osteoarthritis: A Cross-Sectional Study from the Osteoarthritis Initiative

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Abstract

Objective—Regular physical activity, including running, is recommended based on known cardiovascular and mortality benefits. However, controversy exists regarding whether running can

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be harmful to knees. The purpose of this study is to evaluate the relationship of running with knee pain, radiographic osteoarthritis, and symptomatic osteoarthritis.

Methods—This was a retrospective cross-sectional study of Osteoarthritis Initiative participants (2004 – 2014) with knee x-ray readings, symptom assessments, and completed lifetime physical activity surveys. Using logistic regression, we evaluated the association of history of leisure running with the outcomes of frequent knee pain, radiographic osteoarthritis, and symptomatic osteoarthritis. Symptomatic osteoarthritis required at least one knee with both radiographic osteoarthritis and pain.

Results—Of 2637 participants, 55.8% were female; mean age was 64.3 (SD 8.9) years; body mass index was 28.5 (SD 4.9) kg/m^2; 29.5% ran at some time in their lives. Unadjusted odds ratios of pain, radiographic osteoarthritis, and symptomatic osteoarthritis for those prior runners and current runners compared to those who never ran were 0.83 and 0.71, p for trend = 0.002, 0.83 and 0.78, p for trend = 0.01, and 0.81 and 0.64, p for trend = 0.0006 respectively. Adjusted models were similar except radiographic osteoarthritis results were attenuated.

Conclusions and Relevance—There is no increased risk of symptomatic knee osteoarthritis among self-selected runners compared with non-runners in a cohort recruited from the community. In those without osteoarthritis, running does not appear detrimental to the knees.

Introduction

Controversy exists regarding whether running is harmful to the knee[1]. Chronic mechanical overloading could physically damage structures within the knee. Alternatively, runners generally have a lower body mass index compared to non-runners[2] which could be protective of knee osteoarthritis (OA).

Addressing whether running increases the risk for knee OA is of relevance as U.S. Department of Health and Human Services 2008 physical activity guidelines include an option to participate in vigorous intensity aerobic activity for 75 minutes per week, where running is an example of this type of activity[1]. These recommendations have been based on overwhelming evidence that increased physical activity reduces the risk for cardiovascular disease and all-cause mortality[3–6].

In the Osteoarthritis Initiative (OAI), a cohort of people recruited in the community irrespective of their running status, more than 2000 of those participants completed a survey of exposure to leisure physical activities. In this cohort, standardized radiographs and questionnaires were administered to these participants, allowing for uniform definitions of radiographic knee OA (ROA) and symptomatic knee OA (SOA) to be assessed in these participants. This cross-sectional study provided a unique opportunity to evaluate the relationship of history of leisure running with knee pain, ROA, and SOA in broad range of people who ran at some time in their lives in a setting where the highest quality clinical and radiographic assessments of knee OA were obtained and compared them to those who never ran. Based on the existing literature (see eTable 1), we hypothesized that a history of leisure running may increase the risk for knee symptoms and ROA, even at lower levels.

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Methods

Study Design

This is a cross-sectional study nested within the OAI, a prospective multi-center observational study of knee OA including men and women ages 45 to 79 years old at the time of enrollment (2004 – 2006) who 1) had no evidence of knee OA and were not deemed at high risk, 2) were at high risk of developing symptomatic knee OA or 3) had prevalent symptomatic knee osteoarthritis. The four clinical sites were Memorial Hospital of Rhode Island (Pawtucket, RI,) Ohio State University (Columbus, Ohio), University of Pittsburgh (Pittsburgh, PA), and University of Maryland / Johns Hopkins University (Baltimore, MD).

We studied OAI participants who completed a modified version of the historical physical activity survey instrument at the 96-month visit (the only time point that this instrument was deployed in this cohort) and who had knee-specific pain data and/or knee x-ray readings at the 48-month visit (the latest time point with the greatest number of readings and data points available) or at a visit proximate to that visit. Approval was obtained from the institutional review board at each participating OAI site and at Baylor College of Medicine. Each participant provided written informed consent.

Historical Physical Activity Survey Instrument

Between September 12, 2012 and October 31, 2014, participants were asked to complete a self-administered modified version of the historical physical activity survey instrument[7], prior to their OAI 96-month visit. At the time of the clinic visit, if the survey was incomplete, participants were invited to complete the survey with assistance from the clinic staff.

In the questionnaire, participants were asked to review 37 leisure physical activities, including “jogging or running (outdoor or indoor treadmill or track)”. Then participants were asked to identify all activities they performed at least 20 minutes within a given day at least 10 times in their lives during 4 age periods: ages 12 – 18, 19 – 34, 35 – 49 and > 50 years old. Then they identified the 3 most frequently performed activities during those age periods. Additional questions ascertained the number of years, months per year and bouts per month the participants engaged in those activities to provide an estimate of bouts of an activity per age period. Similar questions regarding walking as a leisure activity were administered.

Runners defined—Individuals indicating running or jogging as a top 3 activity were defined as runners in those age periods. “Any history of running” included people who were runners in at least one age period. We also asked people whether they participated in the activity at a competitive level.

To accommodate incorporation of this instrument within the OAI, the instrument was given as a self-administered questionnaire, a deviation from the original instrument, similar to what was done by Chasan-Taber previously[8]. Other modifications were implemented to limit response burden including use of ordinal categories for each of the frequency/duration selections and only commenting on 3 most frequently participated activities in each age

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period. Not included in the original version, we asked whether they participated on a competitive level or not (dichotomous question) and we included walking as an activity of interest for all age ranges.

Knee Radiographs

Weight-bearing, bilateral, fixed-flexion, posterior-anterior radiographs of knees were obtained at the 48-month visit, the most current OAI visit with the largest number of radiographic readings at the time of this analysis. Central readers[9] scored for overall radiographic severity using Kellgren-Lawrence grades (0 – 4) based on the Osteoarthritis Research Society International Atlas[10]. If the 48-month visit readings were not available, readings from the most proximate radiographs available (baseline, 12-, 24-, or 36 month visits) were used instead. The reliability for these readings (read-reread) was substantial[11] (weighted kappa for intra-rater reliability = 0.71 [95%CI 0.55 – 0.87])[12].

Pain Assessment

At the 48-month visit (contemporaneous with the radiographs described above), participants were asked to self-report knee-specific pain, "During the last 12 months, have you had pain, aching, or stiffness in or around your right/left knee on most days for at least one month? By most days, we mean more than half the days of a month." If the 48-month visit responses were not available, the responses from most proximate prior in-person visit (baseline, 12-, 24-, 36-, month visits) were used instead.

Covariates

Date of birth and date of the 48-month visit were used to calculate participant ages. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2), measured at the 36-month OAI visit, the closest visit to the 48-month visit where both height and weight were measured. If the BMI was missing at the 36-month visit, the most proximate annual visit BMI was used instead. History of knee injuries and total knee replacements (TKRs) were self-reported at baseline and at all annual visits up to the 48-month visit.

All publicly available data were accessed from OAI website (http://oai.epi-ucsf.org/datarelease/).

Statistical Analysis

Using logistic regression, we evaluated the association of any history of running and during 4 age periods: ages 12 – 18, 19 – 34, 35 – 49 and > 50 years old with the prevalence of ROA, frequent knee pain, and SOA.

Outcome Definitions—All outcome definitions were person-based definitions. Radiographic OA (ROA) was Kellgren and Lawrence ≥ 2 in at least one knee. Frequent knee pain was answering affirmative to the knee pain question regarding at least one knee. Symptomatic radiographic OA (SOA) was having at least one knee with both ROA and frequent knee pain. Because we were interested in an assessment of ever having had knee OA symptoms or radiographic evidence of knee OA related to running exposure, those with a history of TKR were classified as having all three outcomes.

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If participants had one knee with the outcome of interest, they were classified as having the outcome, even if data from the contralateral knee was missing. If participants had one knee without the outcome of interest and the data for the contralateral knee was missing, those participants were excluded from the analyses.

Exposure Definitions—For each of the 4 age ranges and any history of running, we looked at the exposure of running in two ways: (1) dichotomizing into those who were runners v. non-runners and (2) including 4 groups: non-runners and 3 levels of running (low, medium, and high based on tertiles of running bouts in runners).

We performed the analyses unadjusted and then adjusted for age, sex, BMI, prior knee injury and leisure physical activities that were statistically significantly associated with running (to account for activities correlated with running). The leisure physical activity variables were binary variables if they occurred less frequently than in 33% of the cohort; if they were more common than 33%, they were included as tertiles of participation for the particular activity. We tested whether there was an interaction between running with injury and running with BMI. Participants missing the historical physical activity survey were excluded from the analyses.

To evaluate the differential effect of prior running and current running on the outcomes of ROA, knee pain, and SOA, we categorized participants as never runners, prior runners, and current runners and tested this exposure with the 3 outcomes. *Never runners* were those who did not identify running as a top 3 activity in any age period. *Prior runners* were those who identified running in at least one of the 3 younger periods but not during age > 50 period. *Current runners* were those who identified running during age > 50 period. A significant value for the Cochran-Armitage trend test indicated a dose response.

All analyses were performed using SAS version 9.4. P-values <0.05 were considered statistically significant.

Results

Of 4,796 OAI participants enrolled in the OAI, 843 did not return for the 96-month visit (Figure 1). 699 participants had visits that preceded the window during which the modified historical physical activity survey instrument was administered and therefore did not complete the survey (Figure 1). In total, of the 3,254 eligible to participate, 2,637(81.1%) completed the modified historic physical activity survey (Figure 1). Those who did not complete the lifetime historical physical activity question tended to be older, female, more likely to have ROA and knee pain, and history of TKR and injury. All but one participant who completed the physical activity survey had 48-month visit x-rays measured (99.9% = 2,636/2,637). The remaining participant did not have x-ray readings available from any visits. Frequent knee pain assessments were available for 2,617 participants at the 48-month visit (99.2% = 2,617/2,637). 9, 1, 7, and 3 knee pain assessments were respectively carried forward from the 36, 24, 12 month and baseline visits.

In total, 2,637 participants were included, 55.8% were female, mean age was 64.3 (SD 8.9) years and BMI was 28.5 (SD 4.9) kg/m^2 (table 1). Of the 2,637, 634 were from the

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progression cohort (had SOA at their baseline visit), 1,899 were from the incidence cohort (did not have SOA at baseline but were at high risk of developing SOA during follow-up), and 104 were from the non-exposed controls (did not have SOA at baseline and were not considered at high risk of developing SOA during follow-up). 778 participants (29.5%) ran at some time in their lives; of those, 48.6%, 28.8%, 15.3% and 7.3% identified running in 1, 2, 3, and 4 of the age ranges respectively; 75% reported running at least 250 bouts of running in their lives, 50% ran at least 800 bouts, and 25% ran at least 2,000 bouts. Only a very small percentage of overall participants in each time frame indicated that they ran competitively (2–5%). From lowest to highest BMI tertile, 35.1%, 28.3%, and 25.0% had any history of running.

Any history of running was associated with less frequent knee pain (table 2) in the unadjusted and adjusted models compared to those who never ran. Those who had any history of running had a lower odds of both ROA and SOA compared to those who did not run (tables 3 and 4) in the unadjusted models but these were no longer significant in models adjusted for age, sex, BMI, all leisure physical activities that significantly correlated with running during the relevant time frame, and prior knee injury.

All three outcomes were least to most common in current runners, prior runners, and never runners, respectively except in the fully adjusted model evaluating ROA (Table 5). There was no interaction between running and either injury or BMI for any of the 3 outcomes (data not shown).

Discussion

Our findings support that a history of leisure running is not associated with increased odds of prevalent knee pain, ROA, and SOA. In fact, for knee pain, there was a dose-dependent inverse association with running where runners had less knee pain. With no interaction between running and history of injury or BMI, those with and without knee injury or with greater or lesser BMI did not have a differential association between running and OA. This was an observational study where people chose whether or not they wanted to run; therefore there is always the possibility that people stopped running because they had knee pain. As such, we cannot comment upon the influence of compulsory running on overall knee health. This cohort was not recruited not based on elite running status making these findings potentially more applicable to a broader population than many prior studies (see eTable 1). Frequent knee pain and SOA were observed least to most commonly in current runners, prior runners, and never runners respectively in all models, suggestive that running cessation is not more harmful than never running at all. Running does not appear detrimental from a knee health perspective.

The historical lifetime physical activity questionnaire used in our study was substantially modified compared to the original instrument designed by Kriska et al[7] that has been validated and used to establish links between lifetime physical activity and bone mineral density[7], decreased risk of diabetes[13] and decreased risk of ovarian cancer[14]. Importantly, it was a self-administered questionnaire, using a similar strategy as Chasan-Taber et al which was reproducible and showed MET-hours/week were lowest in the earliest and oldest age

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periods[8], similar to the observed prevalence of running in our study. The inverse association between BMI and running in our study also lends its construct validity. Using this instrument, we captured activities performed at least 10 times in their lives that were listed as a top 3 activity in at least one of 4 age periods to be considered a runner. Arguably, running only 10 times may not be sufficient to classify participants as runners. However in our study, among those who were identified as runners, 75% reported running at least 250 bouts in their lives, 50% ran at least 800 bouts, and 25% ran at least 2,000 bouts, supporting that most runners ran far more than 10 bouts and were classified correctly. There may have also been some misclassification of runners as non-runners if people participated in many different leisure physical activities where running just did not make the top 3 activities. We addressed this possibility by adjusting for all activities that were correlated with running; notably this adjustment did not alter any results.

A limitation to our study is that the exposure of interest, running, has been retrospectively ascertained. Since we were interested in the exposure of running over a long duration of time, prospective assessment of this exposure would have been much more expensive and cumbersome than the retrospective ascertainment deployed in this study. Although the assessment of running status may have been influenced by recall bias, since it has not been clear whether running is harmful or protective of knee OA, it is unlikely that the recall bias would be differential in either direction. Notably, our response rate was high at 81%, but without knowing the distribution of runners among those who did not provide us with data on physical activity, it is difficult to know how inclusion of all non-participants would have impacted the results of our study. Also, although the questionnaire was not administered to all the participants, approximately half of each of the progression and the incidence cohort responded and nearly all of the non-exposed controls responded. This is a sample enriched with people who had ROA and symptoms at the time of enrollment. For this reason, it is likely that the prevalence of OA could be over-estimated compared to the general population. Also, it may be that the prevalence of running in the general population may be different than what is seen in this group.

In our study we defined our outcomes using 48-month visit measures because this is the time point at which the OAI funded the greatest number of radiographs to be read to date. As consequence, the modified historical physical activity survey instrument, used to define runner status administered at the 96-month visit, was administered at a time point after which all outcomes were assessed. However, since the survey required recall over a long period of time and the results were similar during most age groups of running, this limitation did not likely impact the validity of our results.

The directionality of associations in regards to causation observed in cross-sectional studies generally should not be commented upon; however in the instance of our study, it is unlikely that a diagnosis or symptoms of OA caused people to start running. The hypothesized direction of influence was that running would have an effect on OA. It is important to note that because of the cross-sectional nature of this study, we cannot comment upon the influence of running in those with pre-existing knee OA as in this study we are only evaluating one point in time. The assumption in our study is that prevalence reflects incident symptoms and disease. The findings from this study support the need for larger longitudinal

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studies where the exposure of running, even at lower levels, is evaluated in its effects on incident and progressive knee OA.

Prior studies (eTable 1) evaluating the relationship between running and knee OA have mostly focused on those performing elite or high levels of running (e.g., elite runners[15–18],members of a running club[19–22])[15–18]. These studies have been important from the perspective that they have evaluated a high level of the exposure as a risk factor for knee OA. By studying high levels of running, most of these athletes likely limited the type exercise to running allowing for a more homogenous group of people who run. A limitation to these studies, however is that these results are not generalizable to most adults who run less. Those who run less may respond differently to running than the elite athlete. For instance, they may be less skilled at running since they run less and therefore they may incur different biomechanical stresses compared to those who run more. Alternatively, it could have been that elite runners expose their knees to excessive amounts of loading secondary to their high levels of running which could potentially be harmful to the knee whereas a lower amount of running conversely may not be harmful. Our study findings add to the existing literature by including a large sample within which we were able to assess the influence of running in people who participated in running for shorter amounts of time and perhaps stopped running in a cohort that had high quality of assessments of symptoms and standardized radiographs. We found that runners in this group were not at a higher risk for symptomatic knee OA.

A high level of loading that occurs within the knee during running[23] and runners are prone to knee injury, ranging from 7–50% depending on the study[24], similar to what we observed in our study (table 1). Intuitively, because of these attributes, it might be expected that runners would be at higher risk for knee OA. Instead, in our study, we did not find an increased risk for knee OA. Perhaps the lower BMI seen in runners compared to non-runners[2] which was also seen in our study, balance the effects of running on knee OA. The exact reasons why a higher BMI is a risk factor for knee OA are not entirely clear, but the association of higher BMI with incident knee OA a consistent finding in epidemiologic studies[25]. Running could lead to healthier lifestyle selections, or since running is a strenuous exercise that requires repeated flexion and extension of the knee, it could improve proprioreception and peri-articular muscle strength that may also reduce the risk of knee OA. Irrespective of the biologic pathway, the overall influence of running on knee OA when taking all the evidence into consideration, does not appear to be harmful. In conclusion, running does not appear detrimental for knee health. People with the lowest BMI were most likely to identify running as an activity they participated in sometime in their lives. Although we cannot comment upon the influence of running in those with pre-existing knee OA, among those without OA, running should not be discouraged for a concern of an increased risk for developing knee OA or associated frequent knee pain.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Acknowledgments

Dr. Lo is supported by K23 AR062127, an NIH/NIAMS funded mentored award, providing support for design and conduct of the study, analysis, and interpretation of the data; and preparation and review of this work. Dr. Suarez-Almazor is supported by K24 AR053593, funded by NIH/NIAMS. This work is supported in part with resources at the VA HSR&D Center for Innovations in Quality, Effectiveness and Safety (#CIN 13-413), at the Michael E. DeBakey VA Medical Center, Houston, TX. The Osteoarthritis Initiative is a public-private partnership comprised of five contracts (N01-AR-2-2258; N01-AR-2-2259; N01-AR-2-2260; N01-AR-2-2261; N01-AR-2-2262) funded by the National Institutes of Health, a branch of the Department of Health and Human Services, and conducted by the Osteoarthritis Initiative Study Investigators. Private funding partners include Merck Research Laboratories; Novartis Pharmaceuticals Corporation, GlaxoSmithKline; and Pfizer, Inc. Private sector funding for the Osteoarthritis Initiative is managed by the Foundation for the National Institutes of Health. This manuscript has received the approval of the Osteoarthritis Initiative Publications Committee based on a review of its scientific content and data interpretation.

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute of Arthritis and Musculoskeletal and Skin Diseases, the National Institutes of Health, or the Department of Veterans Affairs.

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Significance and Innovations

- Increased physical activity reduces the risk for cardiovascular disease and all-cause mortality. Based on a review of existing studies, running, a common form of leisure physical activity, may be associated with knee osteoarthritis (OA).
- In the Osteoarthritis Initiative, a cohort with standardized questionnaires and radiographs we addressed the question of whether running increases the risk for knee OA.
- In those without osteoarthritis, running does not appear detrimental to the knees.

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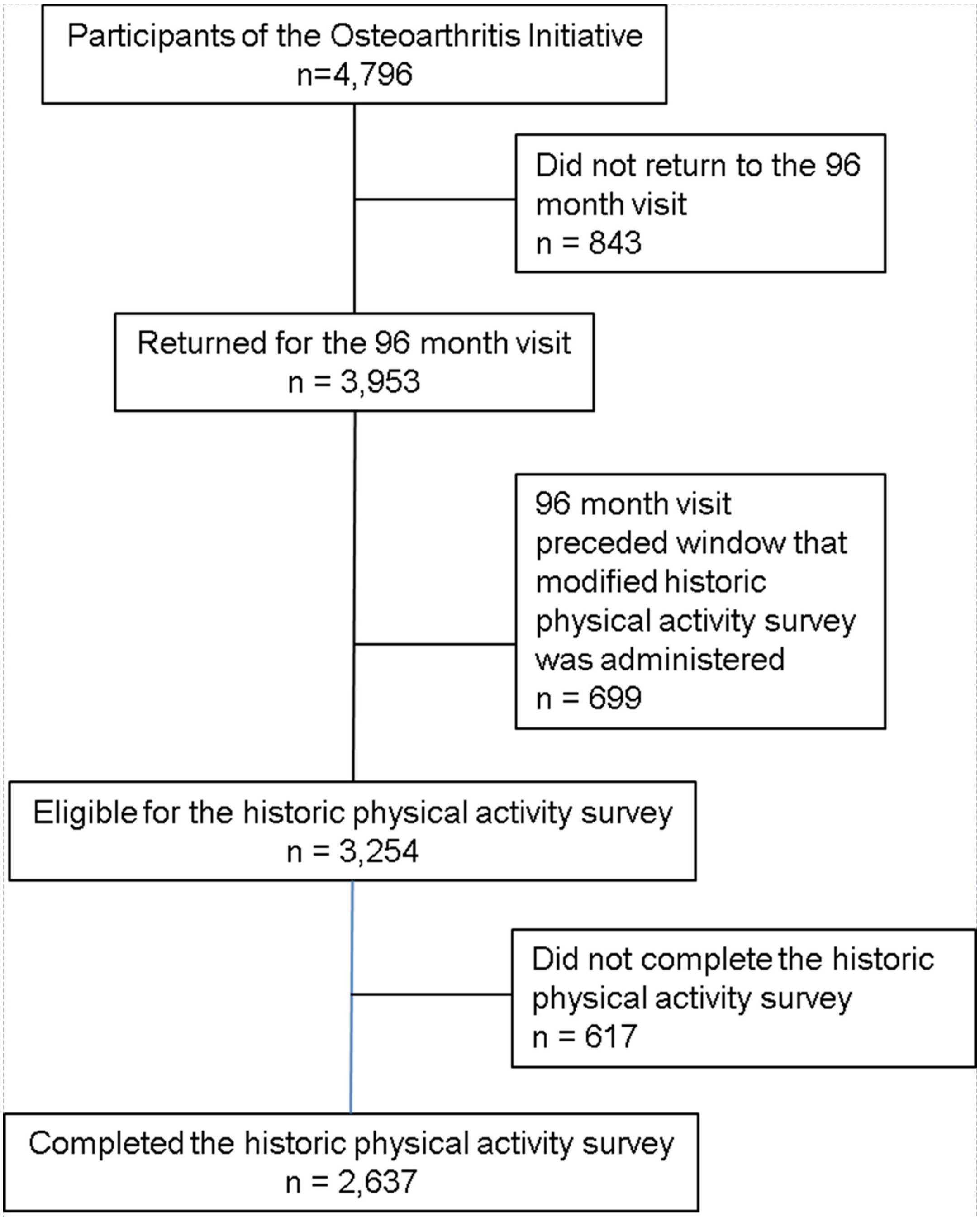

Figure 1.
Flow diagram of participants who completed the modified historical physical activity survey.

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Table 1

Characteristics of those with no history of running, any history of running, all participants, and those excluded from these analyses.

Participant Characteristics	**Non-Runners (n = 1859)**	**Runners (n =778)**	**All Participants (n = 2637)**	**OAI Participants seen at 96-month visit before 9/12/12 who did not complete the historic physical activity survey (n = 699)**	**OAI Participants eligible for historic physical activity survey, but did not complete questionnaire (n = 618)**
Age (years)	65.3 (9.0)	62.0 (8.4)	64.3 (8.9)	65.4 (8.5)	67.0 (9.4)
Sex (% Male)	36.7%	62.2%	44.2%	32.5%	38.8%
BMI (kg/m^2)	28.8 (5.0)	27.9 (4.7)	28.5 (4.9)	28.7 (5.1)	29.1 (5.2)
Frequent knee symptoms (%) *	41.1%	35.1%	39.3%	50.4%	48.5%
ROA (%) *	58.8%	53.5%	57.3%	65.7%	62.9%
SOA (%) *	29.4%	22.8%	27.4%	37.0%	38.7%
TKR (%) *	4.6%	2.6%	4.0%	7.0%	6.2%
Prior Injury (%) *	47.2%	53.0%	48.9%	55.5%	47.6%

* in at least one knee

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Table 2

Odds Ratios of Prevalent Frequent Knee Pain Compared to Non-Runners (referent) for Runners (dichotomous) and Divided into 3 levels of Activity: low, middle, and high.

Running Time Period	Prev. of Frequent Knee Pain	Unadjusted Odds Ratios	Adjusted Odds Ratios*
Any History of Running			
Non-Runners (n = 1859)	41.1%	Referent	Referent
Runners (n = 778)	35.1%	0.78(0.65–0.92)	0.80(0.66–0.97)
Low (n =261)	34.9%	0.77(0.59–1.01)	0.75(0.57–1.00)
Middle (n = 258)	39.2%	0.92(0.71–1.20)	0.93(0.70–1.24)
High (n = 259)	31.3%	0.65(0.49–0.86)	0.71(0.53–0.97)
		p for trend=0.003	p for trend=0.03
Ages 12 – 18 years old			
Non-Runners (n = 2379)	39.7%	Referent	Referent
Runners (n = 258)	35.7%	0.84(0.64–1.10)	0.88(0.66–1.18)
Low (n = 100)	34.0%	0.78(0.51–1.19)	0.88(0.57–1.38)
Middle (n = 78)	34.6%	0.80(0.50–1.29)	0.83(0.50–1.37)
High(n = 80)	38.8%	0.96(0.61–1.52)	0.93(0.57–1.50)
		p for trend=0.4	p for trend=0.5
Ages 19 – 34 years old			
Non-Runners (n = 2242)	40.0%	Referent	Referent
Runners (n = 395)	35.4%	0.82(0.66–1.03)	0.79(0.62–1.01)
Low (n = 129)	35.7%	0.83(0.57–1.20)	0.85(0.58–1.25)
Middle (n = 149)	40.3%	1.01(0.72–1.42)	0.97(0.68–1.39)
High(n = 117)	29.1%	0.61(0.41–0.92)	0.55(0.36–0.84)
		p for trend=0.05	p for trend=0.02
Ages 35 – 49 years old			
Non-Runners (n = 2212)	40.3%	Referent	Referent
Runners (n = 425)	34.1%	0.77(0.62–0.95)	0.83(0.66–1.05)
Low (n = 122)	33.6%	0.75(0.51–1.10)	0.73(0.49–1.09)
Middle (n = 132)	42.4%	1.10(0.76–1.56)	1.21(0.83–1.76)
High(n = 171)	28.1%	0.58(0.41–0.82)	0.66(0.46–0.96)
		p for trend=0.008	p for trend=0.1
Ages > 50 years old			
Non-Runners (n = 2304)	40.2%	Referent	Referent
Runners (n = 333)	33.0%	0.73(0.58–0.93)	0.81(0.63–1.05)
Low (n = 105)	37.1%	0.88(0.59–1.32)	0.86(0.57–1.31)
Middle (n = 121)	33.9%	0.76(0.52–1.12)	0.90(0.60–1.35)
High(n = 107)	28.0%	0.58(0.38–0.89)	0.66(0.42–1.01)
		p for trend=0.05	p for trend=0.07

*Adjusted for age, sex, BMI, all leisure physical activities that significantly correlate with running during the relevant time frame, and prior knee injury.

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Table 3

Odds Ratios of Prevalent Radiographic Knee OA Compared to Non-Runners (referent) for Runners (dichotomous) and then Runners Divided into 3 levels of Activity: low, middle, and high.

Running Time Period	Prev. of ROA	Unadjusted Odds Ratios	Adjusted Odds Ratios*
Any History of Running			
Non-Runners (n = 1859)	58.8%	Referent	Referent
Runners (n = 777)	53.5%	0.81(0.68–0.96)	0.95(0.78–1.16)
Low (n =261)	54.4%	0.84(0.65–1.09)	0.95(0.72–1.26)
Middle (n = 258)	55.4%	0.87(0.67–1.13)	0.98(0.73–1.32)
High (n = 258)	50.8%	0.72(0.56–0.94)	0.92(0.69–1.24)
		p for trend=0.009	p for trend=0.6
Ages 12 – 18 years old			
Non-Runners (n = 2379)	57.9%	Referent	Referent
Runners (n = 257)	51.4%	0.77(0.59–0.99)	1.05(0.78–1.40)
Low (n = 99)	48.5%	0.69(0.46–1.02)	0.98(0.63–1.51)
Middle (n = 78)	48.7%	0.69(0.44–1.09)	1.01(0.61–1.65)
High(n = 80)	57.5%	0.98(0.63–1.55)	1.18(0.73–1.93)
		p for trend=0.2	p for trend=0.6
Ages 19 – 34 years old			
Non-Runners (n = 2242)	58.3%	Referent	Referent
Runners (n = 394)	51.5%	0.76(0.62–0.94)	0.95(0.75–1.21)
Low (n = 129)	52.7%	0.80(0.56–1.14)	0.98(0.67–1.44)
Middle (n = 149)	51.7%	0.77(0.55–1.07)	1.00(0.69–1.44)
High(n = 116)	50.0%	0.72(0.49–1.04)	0.86(0.57–1.30)
		p for trend=0.01	p for trend=0.6
Ages 35 – 49 years old			
Non-Runners (n = 2212)	58.3%	Referent	Referent
Runners (n = 424)	51.9%	0.77(0.63–0.95)	0.91(0.73–1.16)
Low (n = 122)	56.6%	0.93(0.65–1.35)	1.06(0.71–1.57)
Middle (n = 132)	55.3%	0.89(0.62–1.26)	1.03(0.70–1.50)
High(n = 170)	45.9%	0.61(0.44–0.83)	0.75(0.53–1.06)
		p for trend=0.003	p for trend=0.2
Ages > 50 years old			
Non-Runners (n = 2303)	57.9%	Referent	Referent
Runners (n = 333)	52.6%	0.81(0.64–1.01)	0.96(0.74–1.23)
Low (n = 105)	56.2%	0.93(0.63–1.38)	1.09(0.71–1.67)
Middle (n = 121)	54.5%	0.87(0.60–1.26)	1.11(0.75–1.66)
High(n = 107)	46.7%	0.64(0.43–0.94)	0.71(0.47–1.08)
		p for trend=0.02	p for trend=0.4

*Adjusted for age, sex, BMI, all leisure physical activities that significantly correlate with running during the relevant time frame, and prior knee injury.

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Table 4

Odds Ratios of Prevalent Symptomatic Knee OA Compared to Non-Runners (referent) for Runners (dichotomous) and then Runners Divided into 3 levels of Activity: low, middle, and high.

Running Time Period	Prev. of SOA	Unadjusted Odds Ratios	Adjusted Odds Ratios*
Any History of Running			
Non-Runners (n = 1831)	29.6%	Referent	Referent
Runners (n = 775)	23.5%	0.73(0.61–0.89)	0.81(0.65–1.00)
Low (n =260)	22.7%	0.70(0.51–0.95)	0.74(0.53–1.03)
Middle (n = 258)	27.9%	0.92(0.69–1.23)	0.97(0.71–1.33)
High (n = 257)	19.8%	0.59(0.43–0.81)	0.71(0.500–1.02)
		p for trend=0.002	p for trend=0.08
Ages 12 – 18 years old			
Non-Runners (n = 2350)	28.0%	Referent	Referent
Runners (n = 256)	25.8%	0.89(0.67–1.20)	1.13(0.81–1.54)
Low (n = 99)	23.5%	0.79(0.49–1.27)	1.07(0.65–1.76)
Middle (n = 78)	25.7%	0.89(0.53–1.49)	1.14(0.66–1.99)
High(n = 80)	28.8%	1.04(0.63–1.70)	1.14(0.67–1.93)
		p for trend=0.7	p for trend=0.05
Ages 19 – 34 years old			
Non-Runners (n = 2213)	28.9%	Referent	Referent
Runners (n = 393)	21.4%	0.67(0.52–0.87)	0.70(0.53–0.93)
Low (n = 128)	21.9%	0.69(0.45–1.06)	0.75(0.48–1.17)
Middle (n = 149)	22.8%	0.73(0.49–1.08)	0.77(0.51–1.17)
High(n = 116)	19.0%	0.58(0.36–0.92)	0.56(0.34–0.93)
		p for trend=0.003	p for trend=0.01
Ages 35 – 49 years old			
Non-Runners (n = 2184)	28.9%	Referent	Referent
Runners (n = 422)	22.3%	0.71(0.55–0.91)	0.82(0.63–1.07)
Low (n = 121)	23.1%	0.74(0.48–1.15)	0.77(0.49–1.21)
Middle (n = 132)	28.0%	0.96(0.65–1.42)	1.13(0.75–1.72)
High(n = 169)	17.2%	0.51(0.34–0.77)	0.63(0.41–0.98)
		p for trend=0.003	p for trend=0.1
Ages > 50 years old			
Non-Runners (n = 2274)	28.8%	Referent	Referent
Runners (n = 332)	21.1%	0.66(0.50–0.88)	0.81(0.60–1.09)
Low (n = 105)	24.8%	0.82(0.52–1.28)	0.90(0.56–1.45)
Middle (n = 121)	20.7%	0.65(0.41–1.01)	0.85(0.53–1.36)
High(n = 106)	17.9%	0.54(0.33–0.90)	0.66(0.39–1.12)
		p for trend=0.002	p for trend=0.1

*Adjusted for age, sex, BMI, all leisure physical activities that significantly correlate with running during the relevant time frame, and prior knee injury.

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Table 5

Odds Ratios of Prevalent Frequent Knee Pain, ROA, and SOA for Prior Runners and Current Runners compared to Never Runners.

Runner Status	Prev. of Outcome	Unadjusted Odds Ratios	Adjusted Odds Ratios*
Outcome: Frequent Knee Pain			
Never Runners (n = 1859)	41.1%	Referent	Referent
Prior Runners (n = 445)	36.6%	0.83(0.67–1.03)	0.82(0.65–1.04)
Current Runners (n = 333)	33.0%	0.71(0.55–0.90)	0.76(0.58–0.99)
		p for trend=0.002	p for trend=0.02
Outcome: ROA			
Never Runners (n = 1859)	58.8%	Referent	Referent
Prior Runners (n = 444)	54.3%	0.83(0.68–1.03)	0.98(0.78–1.25)
Current Runners (n = 333)	52.6%	0.78(0.61–0.98)	0.91(0.70–1.19)
		p for trend=0.01	p for trend=0.5
Outcome: SOA			
Never Runners (n = 1859)	29.6%	Referent	Referent
Prior Runners (n = 443)	25.3%	0.81(0.64–1.02)	0.88(0.67–1.14)
Current Runners (n = 332)	21.1%	0.64(0.48–0.84)	0.71(0.53–0.97)
		p for trend=0.0006	p for trend=0.03

*Adjusted for age, sex, BMI, all leisure physical activities that significantly correlate with running during the relevant time frame, and prior knee injury.