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Evidence that Swimming May be Protective of Knee Osteoarthritis: Data from the Osteoarthritis Initiative

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Abstract

Background: To date, there have not been any epidemiologic studies that have evaluated the association between swimming over a lifetime and knee health.

Objective: We aimed to evaluate the relationship of a history of swimming with knee pain, radiographic knee OA (ROA), and symptomatic knee OA (SOA).

Design: Cross-sectional retrospective study

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Setting: Multi-center observational cohort

Participants: Respondents to the historical physical activity survey within the Osteoarthritis Initiative with knee radiographs and symptom assessments

Methods: In this retrospective study nested within the Osteoarthritis Initiative (OAI), we performed logistic regression with the predictor being swimming over a lifetime and over particular age ranges.

Main Outcome Measurements: Person-based definitions of frequent knee pain, ROA and SOA.

Results: 2637 participants were included, with a mean age of 64.3 years (SD 8.9), BMI of 28.4 kg/m^2 (SD 4.9), and 44.2% male.

Over a lifetime, the adjusted prevalence measures for frequent knee pain, ROA, and SOA for any v. no history of swimming were 36.4% (33.4 – 39.5%) v. 39.9% (37.4 – 42.5%), 54.3% (51.0 – 57.6%) v. 61.1% (58.4 – 63.7%), and 21.9% (19.4 – 24.7%) v. 27.0% (24.7 – 29.4%) respectively.

Conclusions: This is the first epidemiologic study to indicate that swimming is potentially beneficial towards knee health, particularly when performed earlier in life (before age 35). Future prospective studies are needed to confirm these findings and to better scrutinize the associations in older age groups.

Introduction

Osteoarthritis (OA) is the most common arthritis worldwide and a major cause of disability and pain. It ranks high among the causes of disability, medical visits, and both prescription and nonprescription pharmaceutical use among individuals suffering from musculoskeletal conditions[1–3]. The knee is a commonly affected joint[4,5]. Known risk factors for knee OA include female gender[6–8], increased age and BMI[6,8,9], prior history of trauma[8,10], prior ACL tears and meniscal surgery/damage[11,12]. Chronic mechanical overloading has the potential to physically damage structures within the knee[13–16], and can lead to arthritic changes within the joint.

Swimming as a sport has not been studied in any randomized controlled clinical trials in knee OA, but aquatic exercises which have similar attributes to swimming have been studied in arthritis[17,18]. The potential benefits of aquatic exercises include heightened sensory input from water turbulence, pressure and temperature[19]. Additionally, aquatic exercises are felt to provide muscle relaxation and decreased joint compression that may be related to the temperature and buoyancy of being in the water[19]. Due to the non-weight bearing nature of swimming, it is often considered to be a preferred exercise in people who have knee OA or other sources of knee pain[19,20]. Despite this current clinical practice, to date there are no epidemiologic studies that have evaluated the relationship between a lifetime exposure of swimming and knee health. Therefore, systematic evaluation of an association between swimming and knee OA is needed.

The Osteoarthritis Initiative (OAI) is a cohort recruited from the community irrespective of their swimming status. In this cohort, more than 2,000 participants completed a historical physical activity survey and had standardized assessments of knee health related outcomes. We have previously used this dataset to evaluate the relationship of running[21] and American football[22] with knee OA. In this study, we were interested in evaluating the relationship between swimming and knee pain, radiographic knee OA (ROA), and symptomatic knee OA (SOA) in a rigorous manner. We hypothesized that leisure swimming would be associated with less frequent knee pain, ROA, and SOA.

Materials and Methods

Study Design

This is a cross-sectional study nested within the OAI, a multi-center observational cohort of knee OA. An ancillary study to the OAI funded the administration of a modified version of the Historical Physical Activity Survey[23] at the OAI 96-month visit. The OAI 48-month visit had the largest number of standardized knee radiographs read for OA severity that was closest temporally to the 96-month visit, when the historical physical activity survey was administered and therefore, we evaluated outcomes primarily at the OAI 48-month visit.

The Osteoarthritis Initiative (Parent Study)

The OAI is a prospective study of men and women aged 45 to 79 who were recruited between 2004 and 2006. The four clinical centers were Memorial Hospital of Rhode Island / Brown University, Ohio State University, University of Pittsburgh, and the University of Maryland (subcontract site: Johns Hopkins University). There were 3 groups of participants targeted for this cohort, (1) those who had no evidence of knee OA or symptoms, (2) those who had risk factors for SOA but did not meet the criteria for this designation in either knee[24], (3) and those who had SOA in at least one knee. Inclusion into the middle group was based on a complicated age-specific eligibility criteria where with greater age, fewer putative risk factors were required with a goal in mind to balance effectiveness in enriching each stratum with incident events of OA and facilitating recruitment[24]. All participants had standardized knee radiographs obtained and knee symptom assessments.

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

Participants were asked to complete a self-administered modified version of the Historical Physical Activity Survey instrument[23] prior to the OAI 96-month visit. In this instrument, participants reviewed 37 leisure time physical activities, including “swimming”, and were asked to identify which activities they performed at least 10 times in their lives for at least 20 minutes within a given day. The questionnaire asked about four distinct age ranges: 12–18, 19–34, 35–49, and ≥50 years old, specifically to identify up to three of the most frequently performed activities during each of those age ranges. Modifications from the original Historical Physical Activity Survey involved the questionnaire being self-administered, similar to what was previously done by Chasan-Taber[25]. Also, in order to limit response burden, ordinal categories were used for each of the frequency and duration selections and comments were limited to the three activities endorsed as most frequent in each age range. Individuals who indicated swimming as a top 3 activity were categorized as swimmers during that particular time period. The "Any history of swimming" category included participants who were swimmers in at least one age range. Data on the number of swimming sessions per age period was established through additional questions ascertaining the number of years, months per year, and sessions per month the participants engaged in the activity.

Knee Radiographs

At the OAI 48-month visit standardized bilateral, weight-bearing, posteroanterior semi-flexed radiographs of knees were obtained and read. If readings were not available at this time then readings from the most proximate prior visit were used instead (36-, 24-, or 12-month, or baseline). Radiographic OA severity was scored utilizing central readers[26], with the Kellgren/Lawrence (K/L) grades (0–4) based on the Osteoarthritis Research Society International Atlas[27]. ROA was defined as KL ≥ 2. The reliability for these readings (read-reread) was substantial[28]: weighted kappa for intrarater agreement ranged from 0.70 – 0.80.

Pain Assessment

At the parent study 48-month visit, participants were asked to self-report knee-specific pain using the following question: "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 response was not available then the response from the most proximate prior visit were used instead (36-, 24-, or 12-month, or baseline).

Covariates

Participant date of birth and date of 48-month visit were used to calculate age. Body mass index was measured at the 36-month OAI visit (closest visit to the 48-month visit where both height and weight were measured) and was calculated using the standard formula: weight divided by height squared (kg/m^2). 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. We also calculated participants' body mass index at age 25 using reported height and weight at age 25.

Statistical Analysis

Logistic regression was performed with predictors being swimming status defined as any history of swimming, and history of swimming during particular age periods (ages 12–18, 19–34, 35–49, and ≥50 years).

Outcome definitions.—We used person-based outcomes of frequent knee pain, ROA and SOA. Frequent knee pain was defined by endorsing knee pain in at least one knee. ROA was defined as a K/L grade 2 or higher in at least one knee. SOA was defined as having at least one knee with both frequent knee pain and ROA. 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. Participants with total knee replacements (TKRs) were classified as having all 3 outcomes of interest. If outcomes from the 48 month visit were not available, then we used data from the most proximate visit that occurred before the 48 month visit and carried those values forward.

Exposure Definitions: For any history of swimming, and each of the 4 age periods, exposure to swimming was explored in 2 ways. First, swimming status was dichotomized into swimmers v. non-swimmers. Second, participants were separated into four groups: (1) non-swimmers and (2) low, (3) medium, and (4) high tertiles of swimming based on an estimate of the number of sessions people participated in. We performed analyses both unadjusted and adjusted for covariates of age, sex, BMI, reported BMI at age 25, all leisure activities significantly associated with swimming during the relevant age range, and prior history of knee injury.

We also evaluated swimming status based on the number of age periods people swam during the earlier two age ranges as an additional method of measuring dose response. We excluded the latter to age ranges to minimize the likelihood of confounding by indication as there are already current recommendations to advise swimming as a physical activity for those who have arthritis[19,20].

Participants without data from the modified Historical Physical Activity Survey were not included in the analyses. Trends were tested using the Cochrane-Armitage test[29,30]. Analyses were performed using SAS, version 9.4. P-values less than 0.05 were considered statistically significant.

Results

4,796 participants were enrolled in the OAI database. 842 did not return to the 96 month visit (17.6%). Out of the 3,954 participants who returned for the 96 month visit, 699 participants had this visit before we began administering the modified Historic Physical Activity Survey (17.7%) and therefore did not complete a survey. Of the remaining 3,255 participants, 618 did not complete the modified Historic Physical Activity Survey (19.0%). This left 2,637 of the original 4,796 who completed the modified Historic Physical Activity Survey (55.0%)[21]. Those who did not complete the lifetime historical physical activity question tended to be older, female, more likely to have radiographic OA and knee pain, and more likely to have a history of TKR and injury.

55.8% of the 2,637 participants were female. The mean age was 64.3 (SD 8.9) years, and the mean BMI was 28.4 (SD 4.9) kg/m^2 (*see* Table 1). The demographic characteristics were similar between included males and females with the exception that the history of knee injury was more common in males (53.5%) than females (43.5%). 1,062 out of 2,637 participants (40.3%) participated in swimming at some point in their lives. Of those swimmers, 738 (28.0%) identified swimming in the 12–18 age range, 519 (19.7%) in the 19–34 age range, 409 (15.5%) in the 35–49 age range, and 363 (13.8%) in the ≥ 50 age range. Activities that were positively correlated with any history of swimming included bicycling/spinning, canoeing/rowing/kayaking, dancing, gardening/yardwork, ice skating, sailing, snow skiing, table tennis/ping pong, singles tennis, water aerobics, yoga, and walking. Activities that were negatively correlated included baseball/softball, basketball, bowling, fishing, and football. Of the 2,637 participants, 10% required imputation of data. For radiographic OA status, 193 participants had data imputed from the 36 month visit, 55 from the 24 month visit, and 44 from the 12 month visit. For frequent knee pain, 17 participants required imputation, 9 from the 36 month visit, 5 from the 24 month visit, and 1 from the 12 month visit.

Exposure to any history of swimming was associated with lower prevalence of having frequent knee pain, 37.2% (34.3 – 40.1%) v. 41.2% (38.8 – 43.6%). However after adjusting for age, sex, BMI, BMI at age 25, leisure physical activities that significantly correlated with swimming during the relevant time frame, and prior knee injury this difference in prevalence was no longer statistically significant 36.4% (33.4 – 39.5%) v. 39.9% (37.4 – 42.5%). The results for all other age ranges were not statistically significant except for the age range of 19–34 where the p-value for trend was statistically significant at p=0.02 but this was no longer statistically significant once we the model was adjusted (*see* Table 2).

For the outcome of ROA, any history of swimming was associated with a decreased prevalence. Those with a history of swimming had an unadjusted ROA prevalence of 54.4% (51.4 – 57.4%) compared to those without having a prevalence of 60.3% (57.8 – 62.7%). The p-for trend across the groups of swimmers was also statistically significant with a p = 0.007. The adjusted results were similar except that the p for trend was higher at 0.02. For the age range-specific analyses, the 12–18 and the 19–34 age range unadjusted results were statistically significant for a lower prevalence of ROA among those who had a history of swimming. However, for the adjusted results, only the 19–34 age range results remained statistically significant (*see* Table 3).

Any history of swimming was associated with decreased prevalence of having SOA, with a prevalence of 24.4% (21.9 – 27.1%) v. 29.5% (27.3 – 31.8%) with a significant p for trend across the levels of swimming. The fully adjusted model showed a similar direction, just meeting statistical significance, with a prevalence of 21.9% (19.4 – 24.7%) v. 27.0% (24.7 – 29.4%) but the p for trend across the levels of swimming was 0.08, which did not meet the level of statistical significance. The p for trend of the 19–34 age range across the levels of swimming for both the crude and adjusted results were significant (*see* Table 4).

We additionally evaluated swimming status based on the number of age periods people swam including only the earlier two age ranges as an additional method of measuring dose response. The p-for trend for unadjusted analyses were statistically significant for all three outcomes, frequent knee pain, ROA, and SOA though only the ROA results remained statistically significant in the fully adjusted model (*see* Table 5).

Discussion

In this first epidemiologic study of swimming as it relates to knee OA, people with any history of swimming had a statistically significant lower adjusted prevalence measure of

ROA though admittedly, the absolute difference was modest with a difference of 5.7%. The result for SOA was just missed the level of statistical significance though the dose-response analyses were significant. There was no clear difference by swimming status in regards to difference in frequent knee pain. We observed similar findings with a modest dose-responses in the younger age ranges but not the older age ranges. These findings support the notion that swimming may be beneficial towards knee health, particularly in younger age ranges. In the older age ranges, swimmers and non-swimmers did not have significant differences in the outcomes of interest. Further prospective studies are needed to address whether there are associations between swimming and frequent knee pain, ROA, and SOA, particularly in these age groups.

A limitation to our study is the retrospective nature of the modified Historical Physical Activity Survey and the inclusion of multiple activities, limiting acquisition of more detailed information about swimming and there is a possibility that we may be observing a "healthy, active" effect rather than an effect that is specific to swimming. However, were this the case, and we were observing a "healthy, active" effect, then we would find the same pattern of association with all physical activities that were evaluated using this instrument. Instead, we have published a prior study evaluating running where there was a decreased risk of frequent knee pain and SOA but not for ROA[21]. Additionally, we have also reported that American football was associated with a greater prevalence of frequent knee pain, ROA, and SOA and most of the participation of that sport was during the youngest age range[22]. Thus, although the ascertainment of data on swimming is imperfect, it is likely that we are evaluating a particular effect of swimming. To date, this is the best data that currently exists evaluating swimming over a life time as it relates to knee OA. Our study provides initial data evaluating the association between swimming and knee OA that supports the need for future studies evaluating the relationship in a prospective longitudinal manner.

Swimming might be associated with lower BMIs which would serve as potential mechanism towards reducing chronic loading through weight-bearing joints on a regular basis. We acknowledge that within the OAI, we did not see a difference in BMIs between those who did and did not swim, but this is potentially related to the fact that this is an observational study where the exposure of swimming was not ascertained prospectively.

Some theoretical benefits of swimming for knee health include that it facilitates muscle strengthening and endurance training without bearing weight on joints that normally experience load-bearing, such as the hip, knee, ankle and joints of the feet. It is also possible that it provides similar benefits to what has been seen in aquatic therapy including improved sensory input from water turbulence, pressure and temperature, muscle relaxation and decreased joint compression[19]. Swimming may have other benefits including improved proprioception and maintenance of range of motion of joints.

It is also known that swimming is an aerobic activity that reduces all-cause mortality by improving both endurance and cardiovascular health[31] and there is a growing idea that there might be a link between cardiovascular health and OA[32–36]. There are also other purported benefits to swimming including improved mental health[37]. It has been established that depression is associated with symptoms in patients with knee OA[38], and that treatment of the depression can improve symptoms from OA[39].

Although future longitudinal studies are needed to firmly establish the relationship between swimming and knee health, findings from this study do indicate a decreased association with ROA and perhaps SOA, particularly when people participated in the activity at younger ages. This is pertinent as swimming is the fourth most common sports activity in the United States[40].

In summary, this is the first epidemiologic study to indicate that swimming is potentially beneficial towards knee health, particularly when performed earlier in life (before age 35). Future prospective studies are needed to evaluate populations at risk for developing knee OA and confirm that swimming is beneficial from a knee health perspective. Nevertheless, it is reassuring that the findings from our study support the likelihood that swimming may, in fact, be protective of knee OA.

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Table 1.

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

Participant Characteristics	**Non-Swimmers (n = 1575)**	**Swimmers (n =1062)**	**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) (at the OAI 48 month visit)*	64.1 (9.0)	64.7 (8.9)	64.3 (8.9)	65.4 (8.5)	67.0 (9.4)
Sex *(% Male)*	48.5%	37.9%	44.2%	32.5%	38.8%
Body Mass Index *(kg/m²) (at the OAI 36 month visit)*	28.7 (4.8)	28.1 (4.9)	28.4 (4.9)	28.7 (5.1)	29.1 (5.2)
Body Mass Index at age 25 *(kg/m²)*	23.2 (3.2)	22.8 (3.3)	23.0 (3.2)	22.7 (3.5)	23.1 (3.4)
Frequent knee symptoms *(at the OAI 48 month visit) (%)**	40.1%	36.9%	39.3%	50.4%	48.5%
Radiographic Knee Osteoarthritis *(at the OAI 48 month visit) (%)**	59.5%	53.9%	57.3%	65.7%	62.9%
Symptomatic Knee Osteoarthritis *(at the OAI 48 month visit) (%)**	29.4%	24.4%	27.4%	37.0%	38.7%
History of Total Knee Arthroplasty *(by the OAI 48 month visit) (%)**	4.6%	3.2%	4.0%	7.0%	6.2%
History of Knee Injury *(%)**	48.0%	47.0%	47.6%	55.5%	47.6%

*Knee-based characteristic (within person measure)

Table 2.

Prevalence of Frequent Knee Pain in Non-Swimmers compared to Swimmers (dichotomous). Prevalence of frequent knee pain among those participating in 3 levels of activity: low, middle, and high. Results are presented unadjusted and adjusted with 95%CIs.

Swimming Time Period	Unadjusted Prevalence of Frequent Knee Pain (95% CI)	Adjusted* Prevalence of Frequent Knee Pain (95% CI)
Any History of Swimming		
Non-Swimmers (n = 1567)	41.2% (38.8 – 43.6%)	39.9% (37.4 – 42.5%)
Swimmers (n = 1055)	37.2% (34.3 – 40.1%)	36.4% (33.4 – 39.5%)
Low (n = 398)	39.2% (37.3 – 41.1%)	37.2% (35.1 – 39.3%)
Middle (n = 304)	37.5% (34.8 – 40.3%)	36.0% (33.1 – 39.0%)
High (n = 353)	35.8% (31.2 – 40.0%)	35.9% (31.7 – 40.4%)
	p for trend = 0.05	p for trend=0.8
Ages 12 – 18 years old		
Non-Swimmers (n = 1889)	40.5% (38.3 – 42.7%)	39.4% (37.1 – 41.8%)
Swimmers (n = 733)	37.2% (33.8 – 40.8%)	36.5% (32.9 – 40.2%)
Low (n = 295)	39.1% (37.0 – 41.2%)	36.0% (33.8 – 38.4%)
Middle (n = 223)	38.1% (34.7 – 41.5%)	38.3% (34.7 – 42.0%)
High (n = 215)	37.1% (32.1 – 42.3%)	37.2% (32.0 – 42.7%)
	p for trend = 0.3	p for trend=0.8
Ages 19 – 34 years old		
Non-Swimmers (n = 2107)	40.7% (38.6 – 42.8%)	39.6% (37.4 – 41.8%)
Swimmers (n = 515)	35.0% (31.0 – 39.2%)	34.8% (30.6 – 39.2%)
Low (n = 181)	37.9% (35.7 – 40.2%)	37.8% (35.3 – 40.3%)
Middle (n = 142)	35.3% (31.6 – 39.3%)	32.9% (29.1 – 37.0%)
High (n = 192)	32.8% (27.5 – 38.6%)	33.7% (28.1 – 39.8%)
	p for trend = 0.02	p for trend=0.2
Ages 35 – 49 years old		
Non-Swimmers (n = 2215)	39.8% (37.8 – 41.9%)	39.0% (36.8 – 41.1%)
Swimmers (n = 407)	38.0% (33.5 – 42.9%)	37.2% (32.4 – 42.3%)
Low (n = 143)	38.7% (36.3 – 41.3%)	37.4% (34.7 – 40.2%)
Middle (n = 142)	37.6% (33.3 – 42.2%)	35.9% (31.3 – 40.7%)
High (n = 122)	36.5% (30.2 – 43.5%)	36.3% (29.6 – 43.5%)
	p for trend = 0.4	p for trend=0.5
Ages > 50 years old		
Non-Swimmers (n = 2260)	39.7% (37.7 – 41.7%)	38.7% (36.6 – 40.8%)
Swimmers (n = 362)	39.0% (34.1 – 44.1%)	38.4% (33.3 – 43.8%)
Low (n = 132)	39.2% (36.6 – 41.8%)	39.5% (36.6 – 42.5%)

Swimming Time Period	Unadjusted Prevalence of Frequent Knee Pain (95% CI)	Adjusted* Prevalence of Frequent Knee Pain (95% CI)
Middle (n = 115)	38.6% (34.0 – 43.4%)	37.7% (32.8 – 42.8%)
High (n = 115)	38.1% (31.3 – 45.4%)	37.8% (30.6 – 45.5%)
	p for trend = 0.7	p for trend=0.8

*Adjusted for age, sex, BMI, BMI at age 25, history of knee injury, and all other leisure activities correlated with swimming during the respective age ranges.

Table 3.

Prevalence of Radiographic Osteoarthritis (ROA) in Non-Swimmers compared to Swimmers (dichotomous). Prevalence of ROA among those participating in 3 levels of activity: low, middle, and high. Results are presented unadjusted and adjusted with 95%CIs.

Swimming Time Period	Unadjusted Prevalence of ROA (95% CI)	Adjusted* Prevalence of ROA (95% CI)
Any History of Swimming		
Non-Swimmers (n = 1554)	60.3% (57.8 – 62.7%)	61.1% (58.4 – 63.7%)
Swimmers (n = 1052)	54.4% (51.4 – 57.4%)	54.3% (51.0 – 57.6%)
Low (n = 397)	57.4% (55.5 – 59.5%)	55.7% (53.5 – 57.9%)
Middle (n = 305)	55.1% (52.2 – 57.9%)	54.0% (50.8 – 57.2%)
High (n = 350)	52.7% (48.4 – 57.0%)	54.1% (49.4 – 58.8%)
	p for trend=0.007	p for trend=0.02
Ages 12 – 18 years old		
Non-Swimmers (n = 1873)	59.7% (57.5 – 61.9%)	60.3% (57.8 – 62.7%)
Swimmers (n = 733)	53.3% (49.7 – 56.9%)	53.4% (49.5 – 57.3%)
Low (n = 296)	56.7% (54.6 – 58.9%)	52.7% (50.3 – 55.3%)
Middle (n = 222)	54.1% (50.6 – 57.6%)	55.0% (51.2 – 58.8%)
High (n = 215)	51.5% (46.1 – 56.8%)	52.8% (47.1 – 58.6%)
	p for trend=0.01	p for trend=0.2
Ages 19 – 34 years old		
Non-Swimmers (n = 2093)	59.2% (57.1 – 61.3%)	59.9% (57.6 – 62.2%)
Swimmers (n = 513)	52.4% (48.1 – 56.7%)	52.3% (47.6 – 57.1%)
Low (n = 179)	56.1% (53.8 – 58.4%)	57.1% (54.4 – 59.7%)
Middle (n = 144)	53.1% (49.2 – 57.1%)	51.0% (46.6 – 55.4%)
High (n = 190)	50.1% (44.2 – 56.0%)	50.7% (44.1 – 57.2%)
	p for trend=0.007	p for trend=0.01
Ages 35 – 49 years old		
Non-Swimmers (n = 2201)	57.9% (55.8 – 59.9%)	58.3% (56.0 – 60.5%)
Swimmers (n = 405)	58.0% (53.2 – 62.7%)	59.2% (53.9 – 64.3%)
Low (n = 143)	57.9% (55.3 – 60.4%)	57.6% (54.6 – 60.5%)
Middle (n = 140)	57.8% (53.2 – 62.3%)	57.5% (52.3 – 62.4%)
High (n = 122)	57.8% (50.8 – 64.4%)	60.5% (52.9 – 67.6%)
	p for trend=1.0	p for trend=0.9
Ages > 50 years old		
Non-Swimmers (n = 2248)	58.0% (55.9 – 60.0%)	58.4% (56.1 – 60.6%)
Swimmers (n = 358)	57.5% (52.4 – 62.6%)	58.0% (52.3 – 63.4%)
Low (n = 129)	58.0% (55.3 – 60.7%)	56.9% (53.7 – 60.0%)
Middle (n = 114)	58.1% (53.2 – 62.8%)	56.1% (50.7 – 61.4%)

Swimming Time Period	Unadjusted Prevalence of ROA (95% CI)	Adjusted* Prevalence of ROA (95% CI)
High (n = 115)	58.2% (50.8 – 65.2%)	61.0% (53.0 – 68.4%)
	p for trend=0.9	p for trend=0.7

*Adjusted for age, sex, BMI, BMI at age 25, history of knee injury, and all other leisure activities correlated with swimming during the respective age ranges.

Table 4.

Prevalence of Symptomatic Osteoarthritis (SOA) in Non-Swimmers compared to Swimmers (dichotomous). Prevalence of SOA among those participating in 3 levels of activity: low, middle, and high. Results are presented unadjusted and adjusted with 95%CIs.

Swimming Time Period	Unadjusted Prevalence of SOA (95% CI)	Adjusted* Prevalence of SOA (95% CI)
Any History of Swimming		
Non-Swimmers (n = 1554)	29.5% (27.3 – 31.8%)	27.0% (24.7 – 29.4%)
Swimmers (n = 1052)	24.4% (21.9 – 27.1%)	21.9% (19.4 – 24.7%)
Low (n =397)	26.9% (25.2 – 28.7%)	23.3% (21.4 – 25.2%)
Middle (n = 305)	24.7% (22.3 – 27.3%)	21.5% (19.0 – 24.1%)
High (n = 350)	22.7% (19.3 – 26.5%)	21.2% (17.7 – 25.1%)
	p for trend=0.007	p for trend=0.08
Ages 12 – 18 years old		
Non-Swimmers (n = 1873)	28.7% (26.7 – 30.8%)	26.4% (24.3 – 28.6%)
Swimmers (n = 733)	24.3% (21.3 – 27.5%)	22.2% (19.2 – 25.5%)
Low (n = 296)	26.7% (24.8 – 28.7%)	22.0% (20.0 – 24.1%)
Middle (n = 222)	25.2% (22.3 – 28.5%)	24.3% (21.2 – 27.6%)
High (n = 215)	23.8% (19.7 – 28.7%)	22.7% (18.5 – 27.7%)
	p for trend=0.1	p for trend=0.9
Ages 19 – 34 years old		
Non-Swimmers (n = 2093)	28.6% (26.7 – 30.5%)	26.2% (24.2 – 28.2%)
Swimmers (n = 513)	22.8% (19.4 – 26.7%)	21.1% (17.7 – 25.0%)
Low (n = 179)	25.7% (23.7 – 27.8%)	24.3% (22.1 – 26.7%)
Middle (n = 144)	23.1% (19.8 – 26.7%)	19.8% (16.7 – 23.3%)
High (n = 190)	20.6% (16.3 – 25.8%)	19.7% (15.3 – 25.0%)
	p for trend=0.007	p for trend=0.05
Ages 35 – 49 years old		
Non-Swimmers (n = 2201)	27.7% (25.8 – 29.6%)	25.4% (23.5 – 27.4%)
Swimmers (n = 405)	26.2% (22.1 – 30.7%)	23.8% (19.8 – 28.5%)
Low (n = 143)	26.8% (24.5 – 29.1%)	24.0% (21.7 – 26.6%)
Middle (n = 140)	25.9% (22.0 – 30.1%)	22.7% (18.9 – 27.0%)
High (n = 122)	25.0% (19.5 – 31.4%)	23.4% (17.8 – 30.0%)
	p for trend=0.4	p for trend=0.5
Ages > 50 years old		
Non-Swimmers (n = 2248)	27.7% (25.9 – 29.6%)	25.3% (23.4 – 27.3%)
Swimmers (n = 358)	26.0% (21.7 – 30.8%)	23.6% (19.3 – 28.5%)
Low (n = 129)	26.7% (24.4 – 29.2%)	24.3% (21.8 – 27.0%)
Middle (n = 114)	25.8% (21.7 – 30.3%)	22.2% (18.2 – 26.7%)

Swimming Time Period	**Unadjusted Prevalence of SOA (95% CI)**	**Adjusted* Prevalence of SOA (95% CI)**
High (n = 115)	24.9% (19.1 – 31.7%)	23.4% (17.5 – 30.5%)
	p for trend=0.4	p for trend=0.2

*Adjusted for age, sex, BMI, BMI at age 25, history of knee injury, and all other leisure activities correlated with swimming during the respective age ranges.

Table 5.

Prevalence of Frequent Knee Pain, Radiographic OA, and Symptomatic Knee OA based on the counts of swimming participated in within the earlier age periods (12 – 18 and 19 – 34). Results are presented unadjusted and adjusted with 95%CIs.

Frequent Knee Pain	**Unadjusted Prevalence (95% CI)**	**Adjusted* Prevalence (95% CI)**
Number of time periods of swimming		
0 (n = 1730)	40.1% (38.7 – 43.2%)	40.0% (37.6 – 42.4%)
1 (n = 536)	38.0% (35.7 – 40.3%)	35.7% (33.3 – 38.2%)
2 (n = 356)	35.0% (30.9 – 39.4%)	35.7% (31.3 – 40.3%)
	p for trend=0.03	p for trend=0.6
Radiographic OA		
Number of time periods of swimming		
0 (n = 1730)	60.0% (57.8 – 62.3%)	60.0% (58.5 – 63.4%)
1 (n = 536)	55.6% (53.2 – 57.9%)	53.9% (51.3 – 56.5%)
2 (n = 356)	51.0% (46.5 – 55.5%)	52.2% (47.3 – 57.1%)
	p for trend=0.0008	p for trend=0.03
SOA		
Number of time periods of swimming		
0 (n = 1730)	29.1% (27.1 – 31.2%)	26.9% (24.7 – 29.1%)
1 (n = 536)	25.5% (23.5 – 27.8%)	22.0% (19.9 – 24.2%)
2 (n = 356)	22.2% (18.8 – 26.1%)	21.3% (17.8 – 25.3%)
	p for trend=0.005	p for trend=0.2

*Adjusted for age, sex, BMI, BMI at age 25, history of knee injury, and all other leisure activities correlated with swimming during the respective age ranges.