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Football Increases Future Risk for Symptomatic Radiographic Knee Osteoarthritis

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Abstract

Introduction: Male youth in the United States commonly participate in gridiron (American) football. There are little data substantiating current popular opinion that it is associated with knee

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pain or osteoarthritis (OA) later in life. We aimed to evaluate the relationship of football with these outcomes in the Osteoarthritis Initiative (OAI).

Methods: This is a study of male OAI participants with knee x-ray readings, symptom assessments, and completed surveys on lifetime physical activity. The OAI is a multi-center, observational cohort recruited from the community not based on football participation status. A history of exposure to American football was ascertained via self-report. Knee radiographs were scored for Kellgren-Lawrence (KL) grade (0–4). Radiographic OA (ROA) was defined as KL ≥ 2 in at least one knee. Frequent knee pain meant at least one knee with frequent knee pain. Symptomatic radiographic OA (SOA) required at least one knee with both ROA and frequent knee pain.

Results: 1166 men had a mean age of 63.7 (SD 9.2) years and body mass index of 28.6 (SD 4.2) kg/m2. 31% (365/1166) played football at some point in their lives, 95% of whom participated from ages 12 – 18 years. The ORs for SOA from lowest to highest football participation were 1.2, 1.5, and 2.2 respectively (p for trend = 0.004). Findings were similar for football from ages 12 – 18 years and for outcomes of knee pain and ROA.

Conclusion: This is the first large epidemiologic study to suggest that football participation, including in the teen years, may be detrimental towards knee health. Prospective studies evaluating football players are warranted.

Keywords

Football (American); knee; osteoarthritis; Knee Pain

Introduction

Many male youth in the United States participate in gridiron (American) football. The National Federation of State High School Associations (NFHS) reports that in the 2014–15 school year, it was the most common high school sport with more than 1 million high school students participating(1).

While it is possible that football participation may promote a healthy active lifestyle, reducing the likelihood of developing knee pain and osteoarthritis (OA); alternatively, there may be greater exposure to OA risk factors, including injury(2). To date, there have been surprisingly few studies evaluating the association between American football participation and OA. Those that are published indicate conflicting results. Additionally, studiesare small in size (n<50)(3), not specific to the knee(4) and do not include a comparator arm(5).

The Osteoarthritis Initiative (OAI) is an observational cohort that has been followed for many years originally designed to help identify biomarkers for knee OA. In this study, standardized data were acquired that assessed symptoms and radiographic evidence of knee OA. Additionally, a survey was administered that evaluated an exposure to leisure physical activities over a lifetime, including participation in American football. Therefore, this cohort provided a unique opportunity to evaluate the relationship of a history of American football participation with knee pain, radiographic OA (ROA), and the combination of the two, symptomatic knee OA (SOA), in a cohort recruited from the community not based on

football participation status. We hypothesized that participation in American football would be associated with a higher prevalence of knee pain, knee OA, and symptomatic knee OA.

Methods

Study Design

This is an observational study of male OAI participants with knee x-ray readings, symptom assessments, and completed surveys on lifetime physical activity. We included those participants who completed a modified version of the historical physical activity survey instrument(6) 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 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.

Parent Study Design

The OAI is 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) with one of 3 disease categories 1) had no evidence of knee OA and were deemed not high risk for SOA, 2) were high risk for SOA or 3) had prevalent SOA. The designation of which subcohort a participant was recruited in was not meant to be used as an outcome, instead the 3 subcohorts were recruited as a means of increasing the breadth of disease of knee OA. The four clinical sites were Memorial Hospital of Rhode Island (Pawtucket, RI) (site PI CBE), Ohio State University (Columbus, Ohio) (site PI RDJ), University of Pittsburgh (Pittsburgh, PA) (site PI CKK), and University of Maryland / Johns Hopkins University (Baltimore, MD) (site PI MCH). The coordinating center was University of California, San Francisco (San Francisco, CA) (site PI MCN).

Approval for this study 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(6, 7), prior to their OAI 96-month visit. At the clinic visit, the clinic staff checked for completeness of the survey and completed the surveys as necessary..

In the questionnaire, participants were asked to identify the 3 most frequently performed activities (from a list of 37 contact and non-contact activities that included “football”) they performed at least 20 minutes within a given day at least 10 times in their lives during each of 4 age periods: ages 12 – 18, 19 – 34, 35 – 49 and ≥ 50 years old. Additional questions established the number of years, months per year and sessions per month the participants engaged in those activities to provide an estimate of the number of times people participated in an activity per age period.

American football participants defined.—Individuals indicating "football" as a top 3 activity (i.e. a person who ranked football as first, second, or third) in a given age period were defined as football participants in those respective age periods. *Any History of Football Participation* included people who indicated football in at least one age period. We also asked whether they participated at a competitive level. Specifically, we asked people the question, "Did you perform this activity competitively? This does not have to mean that you participated in organized competitions but that you participated on a competitive level." Those who answered yes to the question were considered as participating at a competitive level. It was a subjective assessment.

To accommodate incorporation of this instrument within the OAI, it was 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 reporting the top 3 activities people most frequently participated in for each age period.

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 overall radiographic severity using Kellgren-Lawrence grades (0 – 4) based on the Osteoarthritis Research Society International Atlas(10). If the 48-month visit radiographs were not available, 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) (kappa coefficient for intra-rater agreement ranged from 0.70 – 0.80)(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 knee on most days for at least one month? By most days, we mean more than half the days of a month." A similar question was asked for the left knee. 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 / Other Clinical Variables

Dates of birth and of the 48-month visit were used to calculate participant age. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). At the OAI baseline visit, ages of the first three injuries that resulted in an inability to walk for at least 2 days were recorded. The 12-, 24-, 36-, and 48- month follow up visits assessed for injury over the prior year. Total knee replacements (TKRs) were self-reported at baseline and each annual visit, up to the 48-month visit. Self-reported knee ligament repair and meniscal surgeries were ascertained at the OAI baseline visit.

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

Statistical Analysis

Because 98% of people who participated in football were male, we restricted this study to men only. Using logistic regression, we evaluated the association of any history of American football participation during 2 age periods: ages 12 – 18 and over the participants' lifetime, with the prevalence of ROA, frequent knee pain, and SOA as the outcomes.

Outcome Definitions.—All outcomes were person-based definitions. Radiographic OA (ROA) was Kellgren and Lawrence ≥ 2 in at least one knee. Frequent knee pain was having frequent knee pain in at least one knee. Symptomatic radiographic OA (SOA) was having at least one knee with both ROA and frequent knee pain. Because these outcomes were created to ascertain ever having had knee OA symptoms and radiographic changes, those with a history of TKR were classified as having all three outcomes.

Exposure Definitions.—For two age periods, the 12–18 age range and any history of American football participation across a lifespan, we looked at the exposure in two ways: (1) dichotomously (non-participants versus participants) and (2) 4 groups: non-participants and 3 levels of participation (low, medium, and high tertiles of football participation). The Cochran-Armitage trend test was used to evaluate for a dose response.

We performed analyses unadjusted and adjusted for age, BMI, and history of knee injury. When we evaluated football participation from ages 12–18 years old, we only included injury that occurred in that age range.

To test whether we would include any of the remaining 36 leisure physical activities available from the historical physical activity survey as covariates in the final fully adjusted model, we iteratively added one activity at a time to the model adjusted for age, BMI and history of knee injury. Only activities that modified the odds ratio by more than 10% were included in the final fully adjusted model.

To test whether the association between football participation and OA might be related to trauma(4), we ran the logistic regression analyses with only history of injury as a covariate to evaluate whether the odds ratios for football participation for the outcomes were more than 10% different compared to the unadjusted model. Additionally, we tested for interactions between football participation over a lifetime and for ages 12–18 years old with history of injury for all 3 outcomes.

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

Results

Four thousand seven hundred ninety-six participants enrolled in the Osteoarthritis Initiative. Eight hundred forty two (17.6%) did not return to the 96-month visit. From the 3,954 who attended the 96-month visit, 699 (17.7%) had their visit preceding the window when the modified historic physical activity survey was administered; therefore, they did not complete a survey. From the remaining 3,255 participants, 618 (19.0%) did not complete the modified

historic physical activity survey. Of the 2,637 who completed the modified historic physical activity survey, 1166 (44.2%) were men.

Mean age was 63.7 (SD 9.2) years; BMI was 28.6 (SD 4.2) kg/m^2. Thirty one percent (365/1166) played football at some time in their lives. Ninety-five percent (346/365) played during the 12–18 year-old age range, with 65% (223/346) playing at least 5 years during that age range. Twenty-five percent (90/365), 5% (17/365), and 2% (7/365) identified football as an activity during the 19–34, 35–49, and ≥50 year old age ranges respectively. Seventy-five percent (273/365) participated at a competitive level; 82% (223/273), 15% (42/273), and 3% (8/273) participated competitively for 1, 2, and 3 age periods respectively. Male participants who missed the window to complete the historical physical activity survey were similar to those who are included in our study except TKR and history of injury were more common among the former (Table 1). Compared to those who did not participate in football, those who participated tended to be younger, had a higher prevalence of prior injury, and had more ligamentous repairs and meniscal surgeries (Table 1).

The 3 groups of participation over a lifetime from the lowest to highest groups had estimated number of times people participated in football ranging from 7.5 – 97.5, 104 – 254, and 255 – 3360 times respectively (Table 2). For the age range of 12 – 18 years old, those ranges were 7.5 – 87.5, 97.5 – 150, and 227 – 630 respectively. Ten percent of participants required use of information from a proximate visit for all three outcomes.

Any history of football participation was associated with an odds ratio of 1.6 (95%CI: 1.3–2.1) for frequent knee pain, with a significant dose response. These findings persisted after adjusting for age, BMI, and history of knee injury (Table 2) with odds ratios of 1.4, 1.6, and 2.2 from lowest to highest football participation, with a p for trend of 0.0008. The results for football participation during ages 12–18 years old were similar (Table 2).

The association between any history of football participation (dichotomous) and radiographic knee OA was not statistically significant; but there was dose response observed, where the highest football participation tertile had an odds ratio of 1.9 (95%CI: 1.2–3.2) and the p for trend was 0.04 (Table 2). The results for football participation restricted to ages 12–18 years old were similar (Table 2).

Any history of football participation over a lifetime and for ages 12–18 years old was associated with a 1.5 (95% CI 1.1–2.0) adjusted odds ratio for SOA with significant a dose response observed (Table 2).

For all models, the individual addition of the remaining 36 leisure physical activities into the model did not modify the point estimates by more than 10% so none was included in the final adjusted models.

When evaluating any history of football, injury was a significant covariate with ORs of 1.4 (95%CI 1.1 – 1.8), 2.8 (95%CI 2.1 – 3.6), and 2.0 (95%CI 1.5 – 2.6) for the outcomes of frequent knee pain, ROA, and SOA, respectively. For football exposure between ages 12–18 years old, injury had ORs of 1.6 (95%CI 1.1 – 2.2), 1.3 (95%CI 0.9 – 1.9), and 1.7 (95%CI 1.2 – 2.5) for the outcomes of frequent knee pain, ROA, and SOA, respectively. The

inclusion of only injury as a covariate to football over a lifetime and from ages 12–18, did not modify the ORs of football for the 3 outcomes of interest by more than 10% for any outcome. Interactions between injury and football exposures were not statistically significant for any outcome.

Discussion:

This is the first large epidemiologic study to suggest that football, mostly occurring during the teen years, may be harmful towards knee health. In this U.S. based study, we found that a history of football participation was associated with an increased prevalence of frequent knee pain, ROA, and SOA in a dose-dependent manner, after adjustment for age, BMI, and even injury. These findings are particularly salient given the recent concern related to other poor long-term health outcomes; including neurologic consequences associated with this sport(13–16).

Our findings corroborate existing literature regarding the association between football and knee OA. In a recent meta-analysis by Driban et al evaluating associations of different sport participation with knee OA(17), only one study of football was of sufficient quality to be included, a study by Moretz et al(3) evaluating 23 people who participated in competitive high school football 20 years prior and compared them to 11 age-matched controls. The crude odds of radiographic knee OA was 9.17 (95% CI: 1.00 – 83.77)(17); the wide confidence bounds resulted from the small sample size.

Important to understanding the relationship between football and OA, Golightly et al published a large epidemiologic study of retired National Football League (NFL) players, using a self-reported diagnosis of arthritis, not specific to the knee; these participants were compared to a general United States male population using the National Health Interview Survey(4). The prevalence of arthritis was greater in the retired NFL players compared to the general US male population with a prevalence ratio of 2.2 (95% CI: 2.1 – 2.3)(4). While the Golightly study indicated a higher risk of arthritis in elite football players, our study included people who participated at a much lower participation level, and identified that they are also at greater risk for knee OA.

Golightly also observed that among retired football players, those who had knee injury were more likely to have knee OA(4); therefore, they concluded that perhaps more OA was seen in retired NFL players because of their high rate of injury(4). Interestingly, in our study, the interactions between injury and football participation were not significant for any outcomes, perhaps because the intensity of the sport is higher when played professionally compared to recreationally. Also, after adjusting for a history of knee injury, the odds ratios for football participation's associations with all 3 outcomes only changed minimally. Thus, the greater risk of knee OA related to football participation does not appear related to the associated increased risk of injury, at least in our study. It is a limitation that trauma was self-reported in our study and perhaps we did not capture all the situations where trauma occurred. A prospective study that evaluates episodes of trauma systematically could address this limitation. An alternate explanation may be that although there is an increased risk for trauma when participating in football, there were other mechanisms that contributed

to the increased risk of knee pain, ROA, and SOA in our study. Perhaps, besides injuries themselves, treatment of injuries may also be important. It is notable that both ligamentous repair and meniscal surgeries were more common among those reporting a history of football participation compared to those who did not (Table 1). Additionally, given the highly physical nature of football, it is likely that biomechanical stresses play an important role in the development of knee OA. Furthermore, the biomechanical forces at play are likely different depending on their player position (e.g., lineman, running backs, wide receivers, quarterbacks, kickers) and the amount of time play during practice or during a game may also be a critical factor (e.g. does greater playing time and/or scrimmage or drills in certain positions lead to greater risk). Thus, future prospective studies evaluating whether specific positions confer differential risks for knee pain, ROA, and SOA will potentially provide important insights into the associations between football participation and knee OA.

It is important to recognize that participants in this study played football 30–40 years ago, so it is likely that there have been changes surrounding the sport since then. Some might encourage joint health but others may be harmful. For example, players are now physically larger, which increases the risk of OA. Alternatively, healthcare in sports medicine has improved (e.g. greater access to certified athletic trainers both on and off the field), which may decrease the risk. The findings from our study stress the importance of initiating new studies evaluating the long-term knee health of current and retired football players, not just at the elite level but also including those who participated during their high school and college years.

There are important limitations to this study, including the retrospective ascertainment of the exposure of football at a timepoint after the outcomes were assessed. Although this study design was not ideal, the participants of the study were not aware of this specific hypothesis that we were testing so it is less likely that their responses would be biased based on our hypotheses.

In conclusion, football participation over a lifetime and between the ages of 12–18 years old were associated with an increased prevalence of frequent knee pain, ROA, and SOA. This is the first large epidemiologic study to suggest that casual football participation, mostly occurring in the teen years, may be harmful towards knee health. High quality prospective studies of both a control population unexposed to football and of people participating in football, beginning as young as age 12, are needed to better understand the risk of football on overall health outcomes, cognitive and mental health outcomes, and knee health.

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Table 1.

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

Participant Characteristics	**No Football (n = 801)**	**Any Football (n =365)**	**Participants in our study (n = 1166)**	**OAI Participants seen at 96-month visit before 9/12/12 who did not complete the historic physical activity survey (n = 227)**	**OAI Participants eligible for the historic physical activity survey, but did not complete questionnaire on or after 9/12/12 (n = 240)**
Age (years)	64.2 (9.2)	62.6 (9.0)	63.7 (9.2)	66.4 (8.7)	66.4 (10.0)
Body Mass Index (kg/m^2)	28.3 (4.2)	29.1 (4.3)	28.6 (4.2)	28.6 (4.1)	29.5 (4.5)
Total Knee Replacement (%) *	3.8%	4.9%	4.1%	8.4%	4.6%
Ligamentous Repairs (%) *	3.3%	8.5%	4.9%	5.3%	5.0%
Meniscal surgeries (%) *	19.1%	28.5%	22.0%	26.4%	25.4%
History of Knee Injury (%) *	50.1%	61.1%	53.5%	58.2%	51.7%
History of Knee Injury between ages 12 – 18 (%) *	10.9%	15.9%	12.4%	13.2%	14.6%

* within person measures

Table 2.

Table of knee pain, knee OA, and symptomatic knee OA prevalence based on football participation status and associated odds ratios.

Football Time Period	Prev. of outcome	Unadjusted Odds Ratios	Adjusted Odds Ratios*
Lifetime History of Football		**Outcome of Frequent Knee Pain**	
No (n = 801)	35.80%	Referent	Referent
Yes (n = 365)	49.30%	***1.7 (1.4–2.2)***	***1.6 (1.3–2.1)***
Low (n =143) (7.5 – 97.5) δ	44.10%	***1.4 (1.0–2.0)***	***1.4 (0.9–2.0)***
Middle (n = 120) (104 – 254) δ	47.50%	***1.6 (1.1–2.4)***	***1.6 (1.1–2.3)***
High (n = 102) (255 – 3350) δ	58.80%	***2.6 (1.7–3.9)***	***2.2 (1.4–3.4)***
		p for trend<0.0001	***p for trend=0.0008***
Football at Ages 12–18 years old			
No (n = 820)	36.00%	Referent	Referent
Yes (n = 346)	49.70%	***1.8 (1.4–2.3)***	***1.6 (1.3–2.1)***
Low (n = 117) (7.5 – 87.5) δ	45.30%	***1.5 (1.0–2.2)***	***1.4 (0.9–2.1)***
Middle (n = 117) (97.5 – 150) δ	49.60%	***1.8 (1.2–2.6)***	***1.6 (1.1–2.4)***
High (n = 112) (227 – 630) δ	54.50%	***2.1 (1.4–3.2)***	***2.0 (1.3–3.0)***
		p for trend<0.0001	***p for trend=0.001***
Lifetime History of Football		**Outcome of Radiographic Knee OA**	
No (n = 792)	56.70%	Referent	Referent
Yes (n = 360)	63.10%	***1.3 (1.0–1.7)***	**1.2 (0.9–1.6)**
Low (n =142) (7.5 – 97.5) δ	57.00%	1.0 (0.7–1.5)	0.9 (0.6–1.3)
Middle (n = 120) (104 – 254) δ	62.50%	1.3 (0.9–1.9)	1.3 (0.8–1.9)
High (n = 98) (255 – 3350) δ	72.50%	***2.0 (1.3–3.2)***	***1.9 (1.2–3.2)***
		p for trend=0.02	***p for trend=0.04***
Football at Ages 12–18 years old			
No (n = 810)	56.80%	Referent	Referent
Yes (n = 342)	63.20%	***1.3 (1.0–1.7)***	***1.3 (1.0–1.8)***
Low (n = 117) (7.5 – 87.5) δ	59.00%	1.1 (0.7–1.6)	1.0 (0.7–1.5)
Middle (n = 116) (97.5 – 150) δ	62.90%	1.3 (0.9–1.9)	1.3 (0.9–2.0)
High (n = 109) (227 – 630) δ	67.90%	***1.6 (1.1–2.4)***	***1.9 (1.2–2.9)***
		p for trend=0.02	***p for trend=0.04***
Lifetime History of Football		**Outcome of Symptomatic Radiographic Knee OA**	
No (n = 792)	25.00%	Referent	Referent
Yes (n = 360)	35.00%	***1.6 (1.2–2.1)***	***1.5 (1.1–2.0)***
Low (n =142) (7.5 – 97.5) δ	28.90%	1.2 (0.8–1.8)	1.2 (0.8–1.7)
Middle (n = 120) (104 – 254) δ	34.20%	***1.6 (1.0–2.3)***	***1.5 (1.0–2.3)***

Football Time Period	**Prev. of outcome**	**Unadjusted Odds Ratios**	**Adjusted Odds Ratios***
High (n = 98) (255 – 3350) δ	44.90%	***2.5 (1.6–3.8)***	***2.2 (1.4–3.4)***
		p for trend=0.0003	***p for trend=0.004***
Football at Ages 12–18 years old			
No (n = 810)	25.30%	**Referent**	**Referent**
Yes (n = 342)	34.80%	***1.6 (1.2–2.1)***	***1.5 (1.1–2.0)***
Low (n = 117) (7.5 – 87.5) δ	31.60%	1.4 (0.9–2.1)	1.3 (0.8–2.0)
Middle (n = 116) (97.5 – 150) δ	31.00%	1.3 (0.9–2.0)	1.2 (0.8–1.9)
High (n = 109) (227 – 630) δ	42.20%	***2.2 (1.4–3.3)***	***2.3 (1.5–3.5)***
		p for trend=0.002	***p for trend=0.002***

*Adjusted for age, BMI, prior knee injury

δThe estimated number of times people participated in an activity per age period is listed in parenthesis after the n is reported.