


# Prevalence of total hip and knee arthroplasty in former National Football League players: comparison with the general US population and other populations of professional athletes

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## ABSTRACT

**Objectives:** To evaluate the prevalence of total hip arthroplasty (THA) and total knee arthroplasty (TKA) in a population of former National Football League (NFL) players. **Methods:** Participants were 3913 former NFL players (participation in years 1960–2019) who completed either an online or mailed survey that included self-reported TKA and THA, year(s) of surgery and date of birth. The prevalence of TKA and THA was reported by age category and compared to published cohorts of athlete populations and general population of non-athletes in the USA. **Results:** 12.3% and 8.1% of sample reported TKA and THA, respectively. The prevalence of both TKA and THA was higher in former NFL players compared to US non-athletes across all ages. Prevalence of TKA was not statistically higher than in other former athlete cohorts but performed at younger ages. The prevalence of TKA and THA was higher than in other cohorts of former NFL players. **Conclusion:** Former NFL players had higher prevalence of arthroplasty than the general population, suggesting prior participation in American-style football may contribute to elevated risk for arthroplasty at younger ages. Understanding risk factors in style of play, lifestyle and other contributors is important to improve joint health of this population.

## INTRODUCTION

There has been a rise in the prevalence of total hip arthroplasty (THA) and total knee arthroplasty (TKA) in the USA over the past 30 years, particularly in younger populations.<sup>1</sup> Studies have examined the prevalence of THA and TKA in former professional athletes including soccer players,<sup>2</sup> rugby players<sup>3</sup> and other athletes in impact sports.<sup>4</sup> To date, two studies have reported on THA and TKA in former National Football League (NFL) players.<sup>5,6</sup> In one study of players who participated in Super Bowl III in 1969 (age 62±3y, n=36), two-thirds reported arthritis, seven had TKA and one had THA.<sup>6</sup> Another study examining data from former players in years 1929–2001 (n=2432) reported age, joint

## What are the new findings

- ▶ The prevalence of total knee arthroplasty and total hip arthroplasty within the cohort of former National Football League (NFL) players was 12.3% and 8.1%, respectively.
- ▶ Findings suggest former NFL players have total knee arthroplasty at younger average age but at similar rates to other sport populations of soccer and rugby.
- ▶ The elevated rate of total hip arthroplasty and total knee arthroplasty of former NFL players compared to the general US population across ages suggests a sport-specific style of play, athlete characteristics, health co-morbidities and other lifestyle factors need to be further explored.
- ▶ The young age of this cohort suggests further translational research is needed to understand methods to optimise non-surgical management of knee and hip injuries.

injuries, weight and playing position as risk factors associated with increased risk of TKA and THA, with reported prevalence of 7.7% and 4.6%, respectively.<sup>5</sup> While both studies provide a historical understanding of the risk of TKA and THA in this population, neither provides recent prevalence in former players, nor compares prevalence rates across age to the general population and other professional athletes. Further studies suggest that high body mass index (BMI),<sup>7,8</sup> weight gain<sup>9</sup> and intensive physical activity at work<sup>7</sup> are risk factors for TKA and THA. Given that former NFL players have some of the highest BMIs among athletes, experience weight gain throughout their careers<sup>10</sup> and regularly engage in intensive physical activity, we hypothesised this population may be at increased risk for total joint arthroplasties, higher than previously reported. To test this hypothesis, we evaluated the prevalence of



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arthroplasty in former NFL players by age and compared the rate of arthroplasty in former NFL players to that in the general US population and other athlete cohorts.

## METHODS

The Football Players Health Study (FPHS) at Harvard University is an ongoing study evaluating health outcomes in former American-style football (ASF) players. The methods of recruitment for this cohort and verification of eligibility to participate have been noted previously.<sup>10</sup> Living former ASF players were identified using the NFL Player Association and online public source Pro Football Reference who participated during years 1960 to present. Former players with verified contact information were each sent a 76-question survey including items regarding their health status. This included report of prior TKA and THA queried as follows: ‘Since *leaving active professional football* have you had any of the following surgical procedures: (knee joint replacement) or (hip joint replacement)?’ Participants who answered ‘Yes’ also reported approximate year(s) of surgery. Responses were collected and tabulated using REDCap (Vanderbilt, Nashville, Tenn)<sup>11 12</sup> for online surveys or Scantron (Scantron Corporation, Tustin, CA, USA) for paper surveys. For participants with history of multiple joint arthroplasties (including the same joint or bilateral joint replacement), the date of initial surgery was used as the index measure to determine the age at the time of arthroplasty. Participants reporting history of both knee and hip arthroplasty were also reported using the date for first surgery as index case for each arthroplasty and were reported in prevalence of hip and knee arthroplasty in the total cohort. Statistical analyses were conducted with R (R Core Team, 2018).

$\chi^2$  tests were used to identify differences in arthroplasty prevalence between the FPHS cohort and the general population and other athlete populations, using published values in other cohorts. Date of birth and year of arthroplasty were used to determine approximate age at the time of arthroplasty. The study was approved by the institutional review board (IRB) at Harvard T.H. Chan School of Public Health (Protocol:18-1365) and Beth Israel Deaconess Medical Center (2014P000308). Waiver

of documentation of consent was obtained from the reviewing IRBs. All participants received a copy of the consent and participation was optional.

## RESULTS

Of 15 643 eligible former players, 3913 agreed to participate (average age 52.4 years). TKA and THA were reported in 12.3% and 8.1% of participants, respectively (tables 1 and 2). The prevalence of arthroplasty increased across age and was higher for TKA compared to THA (figure 1). The prevalence of TKA was higher than THA for all age groups above 60 years.

When compared to the prevalence of arthroplasty in the general population,<sup>1</sup> the prevalence in the FPHS cohort was significantly higher in each age category (table 3). The prevalence of THA reported in FPHS cohort age 50–59 years exceeded the prevalence for nearly every age category in the general population, including the 90+ category.<sup>1</sup>

Former players in the FPHS cohort were, on average, younger than other professional athlete populations in which joint arthroplasty has been studied, including another cohort of former NFL players (all  $p < 0.05$ , figure 2). Despite being younger, the overall prevalence of TKA for former NFL players (12.3%) was non-statistically higher than 9% reported in rugby players<sup>3</sup> and 11.1% reported in soccer players<sup>2</sup> ( $p = 0.1235$  and  $0.1794$ , respectively). The FPHS cohort also had a higher prevalence of both reported knee (12.3% vs 7.7%,  $p < 0.001$ ) and hip replacement as compared to the Davies cohort of former ASF players (8.1% vs 4.6%,  $p < 0.001$ ).<sup>5</sup>

## DISCUSSION

Our results demonstrate that former NFL players have an overall prevalence of 12.3% and 8.1% for TKA and THA, respectively. This study adds to the limited reports of arthroplasty in former NFL players and is the largest cohort report to date. Furthermore, this study expands upon findings of Davies *et al*<sup>5</sup> with rates of TKA and THA higher in the current study population than previously observed in former NFL players participating in a more distant era from 1929 to 2001.<sup>5</sup>

**Table 1** Prevalence of knee and hip joint replacement by age at the time of the survey in FPHS cohort

Age category (years)	Knee joint replacement (89 responses missing)		Hip joint replacement (114 responses missing)	
	Yes	No	Yes	No
<50	24 (1.48%)	1596 (98.52%)	27 (1.68%)	1584 (98.32%)
50–59	69 (7.60%)	839 (92.40%)	68 (7.53%)	835 (92.47%)
60–69	180 (23.14%)	598 (76.96%)	104 (13.54%)	664 (83.85%)
70–79	170 (36.96%)	290 (63.04%)	90 (20.85%)	367 (79.15%)
80+	28 (46.67%)	32 (53.33%)	18 (29.51%)	43 (70.49%)
Total	471 (12.31%)	3355 (87.71%)	307 (8.08%)	3492 (91.92%)

FPHS, Football Players Health Study.

**Table 2** Prevalence of knee and hip joint replacement by reported age at the time of surgery in FPHS cohort

Age category (years)	TKA	THA
<40	24 (5.10%)	19 (6.19%)
40–49	55 (11.68%)	42 (13.68%)
50–59	135 (28.66%)	90 (29.32%)
60–69	147 (31.21%)	90 (29.32%)
70–79	56 (11.89%)	27 (8.79%)
80+	1 (0.21%)	3 (0.98%)
Total	418 (53, or 11.25%, missing year of TKA)	271 (36, or 11.73%, missing year of THA)

% Reflects the percentage of joint replacement that occurred in that age category.  
FPHS, Football Players Health Study; THA, total hip arthroplasty; TKA, total knee arthroplasty.

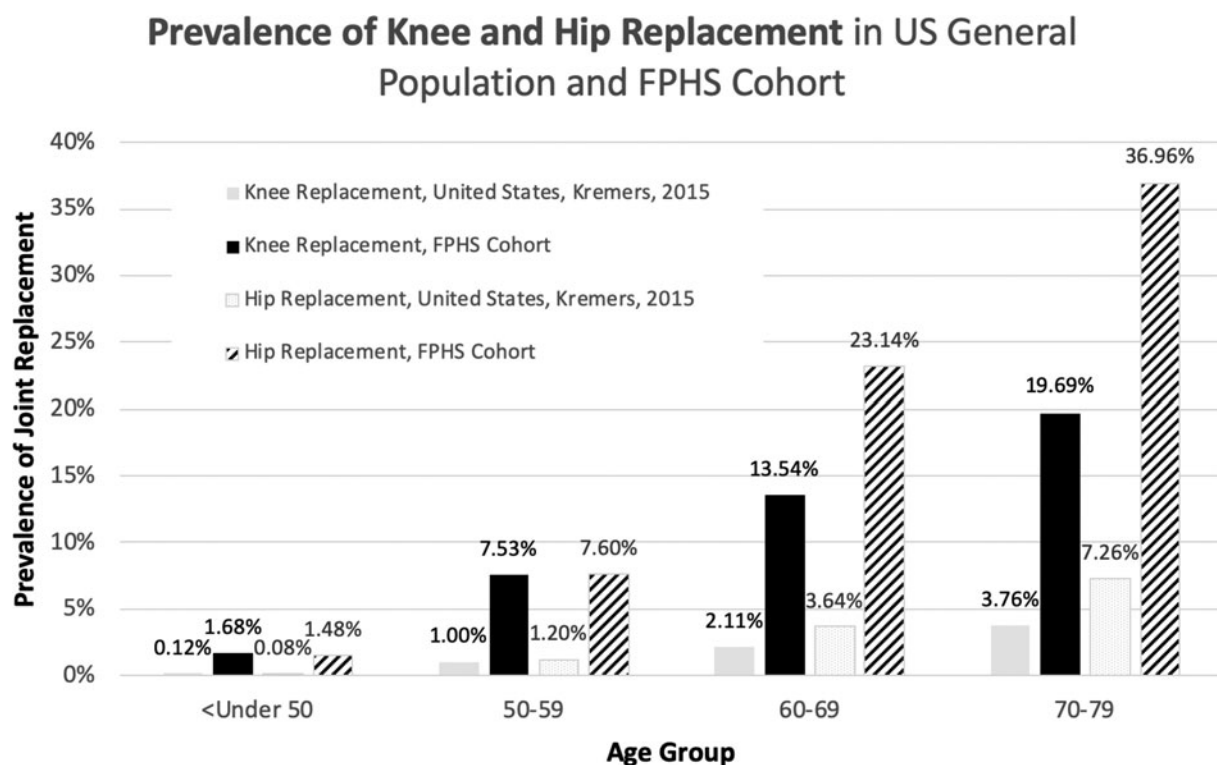
### Differences in TKA between sports

The prevalence of TKA was similar to other non-ASF athlete populations but performed at a younger age. Compared to the general population, former NFL players had higher rates of TKA and THA across all ages. The mechanism for higher rate of arthroplasty in former NFL players is unknown; we hypothesise that the combination

of traumatic joint injuries, higher playing weight and other factors may contribute. Previous studies suggest that the combined effects of physical activity at work,<sup>7</sup> BMI,<sup>7 8</sup> joint injuries associated with osteoarthritis<sup>5</sup> and weight gain are risk factors for arthroplasty.<sup>9</sup>

### Future directions

The current report expands on earlier findings from an ongoing study evaluating the largest cohort of former NFL players, the FPHS at Harvard University. An earlier report identified early-life weight gain during the time of high school to college was independently associated with the development of cardiometabolic disease, sleep apnoea and chronic pain.<sup>10</sup> When separated by field position, linemen gained greater weight than non-linemen and were also more likely to be classified as having chronic pain.<sup>10</sup> The current findings from this report on high rate of arthroplasty, along with prevalence of potential risk factors from other populations, illustrate the need for translational strategies to address the high and premature rate of arthritis and joint disease. Treatment should address modifiable risk factors in this cohort and include lifestyle factors of diet and exercise to lower BMI. However, the interconnectivity of other disease states suggests a model of care addressing obstructive sleep apnoea,<sup>13</sup> metabolic syndrome,<sup>14</sup> along with mood and neurocognitive issues, which may influence pain experience and thresholds. Addressing inflammation burden



**Figure 1** Prevalence of total knee arthroplasty and total hip arthroplasty was reported by age category of former NFL Players with the Football Players Health Study (FPHS) cohort and general US population. Knee arthroplasty was more common than hip arthroplasty for both populations. Arthroplasty was more common for FPHS cohort than general US population across all ages. NFL, National Football League.

**Table 3** Prevalence of knee and hip joint replacement in age-comparable males in the general population and in the FPHS cohort

	Kremers, 2015 (general population)		FPHS cohort N=3,913		P value
	n	%	n	%	
<b>Knee replacement</b>					
<50					
Yes	85 195	0.08	24	1.48	<0.005
Total	105 709 894		1620		
50–59					
Yes	245 935	1.20	69	7.60	<0.005
Total	20 512 532		908		
60–69					
Yes	510 244	3.64	180	23.14	<0.005
Total	14 029 131		778		
70–79					
Yes	541 038	7.26	170	36.96	<0.005
Total	7 447 964		460		
	Kremers, 2015 (general population)		FPHS cohort N=3,913		
	n	%	n	%	P value
<b>Hip replacement</b>					
<50					
Yes	122 401	0.08	27	1.68	<0.005
Total	105 709 894		1611		
50–59					
Yes	205 995	1.00	68	7.52	<0.005
Total	20 512 532		904		
60–69					
Yes	295 869	2.11	104	13.54	<0.005
Total	14 029 131		768		
70–79					
Yes	280 383	3.76	90	19.69	<0.005
Total	7 447 964		457		

FPHS, Football Players Health Study.

may be important given the known association to disease states including metabolic syndrome,<sup>14</sup> obstructive sleep apnoea<sup>15</sup> and neuroinflammation that has been postulated to contribute to widespread pain.<sup>16</sup> In addition, new treatments that address the underlying inflammatory joint catabolic pathways may be targets for early intervention with new injectable medications and orthobiological agents.<sup>17–19</sup>

### Limitations

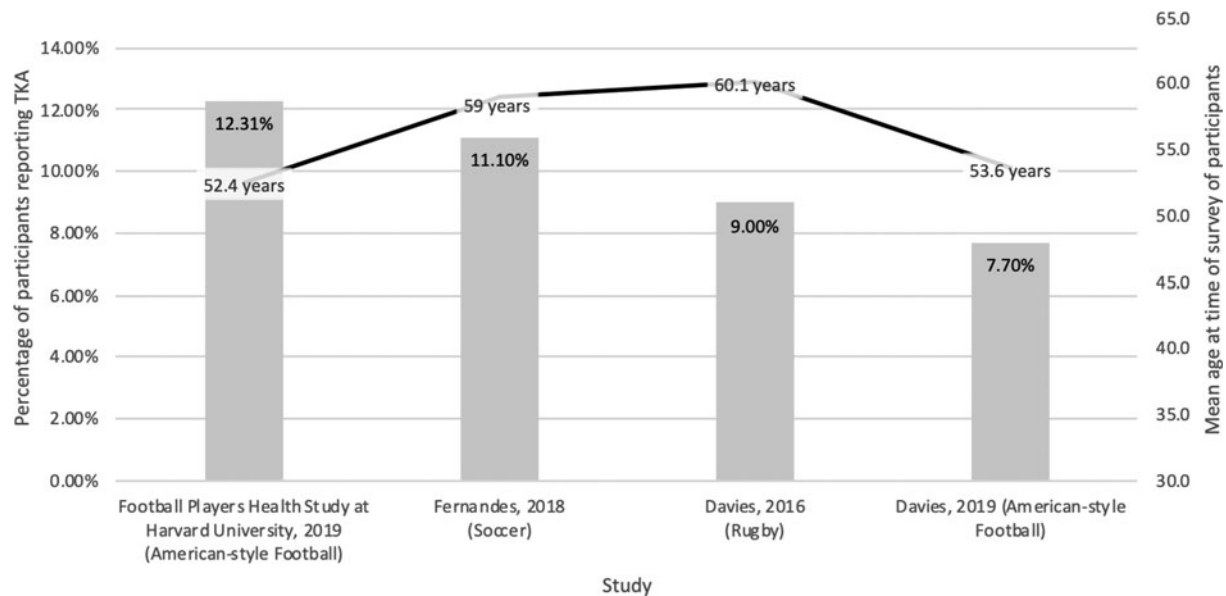
Limitations include the possibility of selection bias. It is not possible to know whether players who underwent arthroplasty were more or less likely to enrol in this study. The self-reported data in our study may overestimate the true prevalence of TKA and THA. However, there appears to be good agreement between self-reported data and hospital data in TKA and THA.<sup>9</sup> Our cross-sectional design and comparison to former athlete populations precludes determination of explanatory mechanisms specific to sport, including forces sustained during sport, differences

in pain threshold and documented weight gains through sports participation. The study design limits accounting precisely for determinants of health that influence the outcome of having an arthroplasty, both in the general US population and within our former NFL population studied. Despite these limitations, this study represents the largest study to date to report prevalence rates for TKA and THA in former NFL players.

### Conclusion

Our study identified higher rates of THA and TKA within former NFL players than previously reported in a contemporary cohort. Although the rate of TKA was not statistically different compared to former rugby and soccer players, the younger age of our cohort suggests an earlier burden of advanced joint disease and symptomatic joint pain in former NFL players. The high rate of arthroplasty in this population requires further investigation to identify methods for injury prevention and to optimise treatment of arthritis.

## Prevalence of Total Knee Arthroplasty (TKA) in Studies of Athletes



**Figure 2** Total knee arthroplasty was performed at younger ages within the Football Players Health Study (FPHS) compared to studies in other athlete populations and a separate report in former NFL players. Overall prevalence data were non-statistically different between groups. NFL, National Football League.

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#### REFERENCES

- Maradit Kremers H, Larson DR, Crowson CS, *et al*. Prevalence of total hip and knee replacement in the United States. *J Bone Joint Surg Am* 2015 Sep 2;97: 1386–97.
- Fernandes GS, Parekh SM, Moses J, *et al*. Prevalence of knee pain, radiographic osteoarthritis and arthroplasty in retired professional footballers compared with men in the general population: a cross-sectional study. *Br J Sports Med* 2018;52:678–83.
- Davies MAM, Judge AD, Delmestri A, *et al*. Health amongst former rugby union players: a cross-sectional study of morbidity and health-related quality of life. *Sci Rep* 2017 Sep 28;7: 11786.
- Tveit M, Rosengren BE, Nilsson JA, *et al*. Former male elite athletes have a higher prevalence of osteoarthritis and arthroplasty in the hip and knee than expected. *Am J Sports Med* 2012;40:527–33.
- Davies MAM, Kerr ZY, DeFreese JD, *et al*. Prevalence of and risk factors for total hip and knee replacement in retired National Football League athletes. *Am J Sports Med* 2019;47:2863–70.
- Nicholas SJ, Nicholas JA, Nicholas C, *et al*. The health status of retired American football players: Super Bowl III revisited. *Am J Sports Med* 2007;35:1674–9.
- Apold H, Meyer HE, Nordsletten L, *et al*. Risk factors for knee replacement due to primary osteoarthritis, a population based, prospective cohort study of 315,495 individuals. *BMC Musculoskelet Disord* 2014;15:217.
- Changulani M, Kalairajah Y, Peel T, *et al*. The relationship between obesity and the age at which hip and knee replacement is undertaken. *J Bone Joint Surg Br* 2008;90:360–3.
- Apold H, Meyer HE, Nordsletten L, *et al*. Weight gain and the risk of knee replacement due to primary osteoarthritis: a population based, prospective cohort study of 225,908 individuals. *Osteoarthritis Cartilage* 2014;22:652–8.
- Churchill TW, Krishnan S, Weisskopf M, *et al*. Weight gain and health affliction among former national football league players. *Am J Med* 2018;131:1491–8.
- Harris PA, Taylor R, Minor BL, *et al*. The REDCap consortium: Building an international community of software platform partners. *J Biomed Inform* 2019;95:103208.
- Harris PA, Taylor R, Thielke R, *et al*. Research electronic data capture (REDCap): a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42:377–81.
- Kanbay A, Kokturk O, Pihtili A, *et al*. Obstructive sleep apnea is a risk factor for osteoarthritis. *Tuberk Toraks* 2018;66:304–11.
- Courties A, Sellam J, Berenbaum F. Metabolic syndrome-associated osteoarthritis. *Curr Opin Rheumatol* 2017;29:214–22.



- 15 Guven SF, Turkkani MH, Ciftci B, *et al.* The relationship between high-sensitivity C-reactive protein levels and the severity of obstructive sleep apnea. *Sleep Breath* 2012;16:217–21.
- 16 Ji RR, Nackley A, Huh Y, *et al.* Neuroinflammation and central sensitization in chronic and widespread pain. *Anesthesiology* 2018;129:343–66.
- 17 Hochberg MC, Guermazi A, Guehring H, *et al.* Effect of intra-articular sprifermin vs placebo on femorotibial joint cartilage thickness in patients with osteoarthritis: the FORWARD randomized clinical trial. *JAMA* 2019; Oct 8. 322: 1360–70.
- 18 Huebner K, Frank RM, Getgood A. Ortho-biologics for osteoarthritis. *Clin Sports Med* 2019;38:123–41.
- 19 Oo WM, Yu SP, Daniel MS, *et al.* Disease-modifying drugs in osteoarthritis: current understanding and future therapeutics. *Expert Opin Emerg Drugs* 2018;23:331–47.