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Joint Injury, Osteoarthritis, and Cardiovascular Disease Risk Factors in Former National Football League Athletes: An NFL-LONG Study

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Context: Individuals with lower extremity osteoarthritis (OA) have a 25% greater risk of cardiovascular disease (CVD) than those without OA. The prevalence of traumatic joint injuries among National Football League (NFL) players exposes these athletes to an elevated risk for OA and potentially a greater risk of cardiovascular risk factors (CRFs) and CVD.

Objectives: To examine the associations between a history of lower extremity joint injury, lower extremity OA, and the prevalence of CRFs and CVD among former NFL athletes.

Design: Cross-sectional study.

Patients or Other Participants: Former NFL players completed a comprehensive health questionnaire that was used in an ongoing study, the Neurologic Function Across the Lifespan: A Prospective, Longitudinal, and Translational Study for Former NFL Players (NFL-LONG). A subsample of 1738 former players reported lifetime medical diagnoses including CVD or CRFs.

Main Outcome Measure(s): Crude and adjusted prevalence ratios (PRs_{adj}) characterized the associations between CVD or CRFs and injury, OA diagnosis, or both among athletes who reported (1) no history of lower extremity joint injury or surgery and no diagnosed OA, (2) a history of lower extremity joint injury or surgery and no diagnosed OA, and (3) a history of lower extremity joint injury or surgery and diagnosed OA.

Results: Neither a history of lower extremity joint injury ($PR_{adj} = 1.34$; 95% CI = 0.86, 2.07) nor a history of lower extremity joint injury and diagnosed OA ($PR_{adj} = 1.41$; 95% CI = 0.89, 2.25) was significantly associated with CVD. However, CRFs were 30% and 53% more prevalent in former players with lower extremity joint injury and no diagnosed OA ($PR_{adj} = 1.30$; 95% CI = 1.12, 1.50) and those with lower extremity joint injury and diagnosed OA ($PR_{adj} = 1.53$; 95% CI = 1.31, 1.78), respectively, versus athletes with no history of either condition.

Conclusions: The prevalence of CRFs was highest among former NFL athletes with a history of lower extremity joint injury and diagnosed OA. These findings provide insight regarding the potential pathways to chronic diseases that may be initiated by joint injury early in life.

Key Words: hyperlipidemia, myocardial infarction, hypertension, sleep apnea, diabetes mellitus II, anterior cruciate ligament, knee surgery

Key Points

- Knee and hip osteoarthritis (OA) have been linked to a greater risk of developing cardiovascular disease over the lifespan. Former National Football League players with a history of lower extremity joint injury were at greater risk for the development of OA and cardiovascular risk factors than those without a lower extremity joint injury.
- After accounting for demographic factors, isolated lower extremity joint injury and posttraumatic OA significantly associated with the prevalence of risk factors for cardiovascular disease among former National Football League athletes.

Musculoskeletal conditions are a leading cause of global disability, and joint injury at the knee is most commonly linked to individual disability.[1] Knee injury is also associated with decreased health-related quality of life,[2] decreased participation in organized sport and physical activity,[3] and an increased risk of chronic diseases (eg, osteoarthritis [OA] and obesity) within 1 decade after surgery.[4,5] This is despite the frequently

reported patient goal of returning to the preinjury level of activity after joint injury or surgery.[3] Among professional American football players, the single-season risk of lower extremity injury is 41%, which includes a 29.3% risk of knee injury.[6] These injuries may lead to time loss from sport,[7] diminished performance,[8] and reduced career length.[9] Little attention has been paid to the potential long-term health-related consequences of lower extremity joint injury among this population despite the outsized risk of injury throughout the playing career.

The prevalence of lower extremity OA among former National Football League (NFL) players with a history of lower extremity injury ranges from 29.6% to 44.4%, depending on the age of the athlete, the number of injuries sustained, and other health-related factors that may moderate the development of OA.[10] In a separate analysis, former NFL players with a history of anterior cruciate ligament (ACL) injury had a 54% greater risk of developing OA and a 120% greater risk of knee-joint replacement when compared with former players who did not sustain an ACL injury during their playing career.[11] Similarly, among former players with a history of ankle injury, 37.6% reported a subsequent OA diagnosis despite the fact that only 11.9% and 10.9%, respectively, indicated that the injury was severe enough to require surgery during or after the playing career.[12] Between 40.4% and 56.0% of former NFL players who described an OA diagnosis in the ankle, knee, or hip stated that their OA often affected their daily activities.[12]

Functional limitations and decreased participation in physical activity are common among individuals diagnosed with lower extremity joint injury[13,14] and OA.[15,16] This decrease in exercise may result in individuals with OA developing risk factors for cardiovascular disease (CVD), such as excess weight, hypertension, hyperlipidemia, and type II diabetes mellitus.[17] Consistent with this hypothesis, lower extremity OA was associated with a 25% greater risk of CVD.[18,19] Regardless of injury history or the presence of lower extremity OA, current NFL players have been shown to experience a high prevalence of hypertension (75%)[20] and sleep-disordered breathing (34%),[21] and former NFL players with body mass index (BMI) >30 during their playing career experienced a 50% increased risk of cardiovascular mortality.[22] Although their investigation was limited in scope, Meehan et al[11] found that former NFL players with a history of ACL injury had a 52% greater risk of myocardial infarction, indicating a preliminary link between lower extremity injury and CVD among former NFL players with lower extremity joint injury. However, this higher risk of morbidity and mortality is not unique to former NFL players. The greater risk of injury and subsequent OA in former NFL players compared with nonprofessional athletes highlights a possible initiating factor in this population that may result in the development of cardiovascular risk factors (CRFs) and subsequent CVD.

Individuals who participate in professional American football are at an elevated risk for lower extremity injury and OA,[10,12] and the occurrence of specific lower extremity injuries (ie, ACL injury) may be associated with a greater risk of CVD or CRFs.[11] Yet whether this association is limited to individuals who have experienced knee injury or surgery and the role of OA in the association between lower extremity joint injury or surgery and CVD in this high-risk population remain unclear. Therefore, the primary purpose of our study was to evaluate the associations among lower extremity joint injury or surgery, OA, and the prevalence of CVD and CRFs among former NFL players.

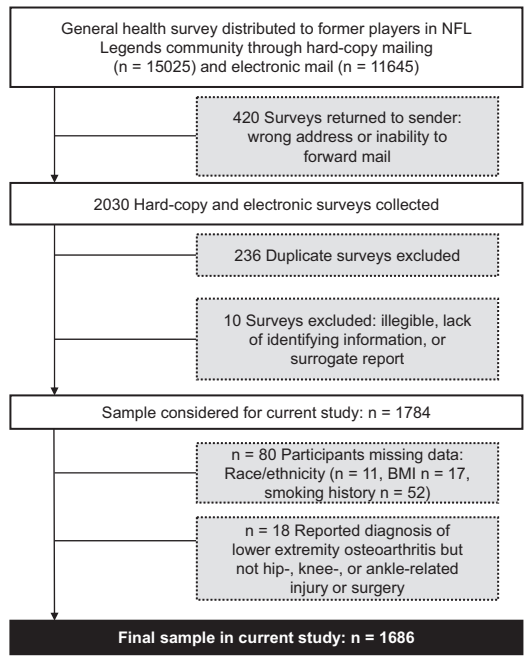

Figure. Flowchart summarizing participant recruitment, enrollment, and inclusion. Abbreviations: BMI, body mass index; NFL, National Football League.

METHODS

Former NFL players completed a general health questionnaire either online (Qualtrics; SAP America Inc) or via hard copy. This cross-sectional study was approved by the Institutional Review Board at The University of North Caroline at Chapel Hill, and all recruits provided written informed consent before participation.

Participants and Recruitment

More than 15 000 former NFL players were contacted via mail, and a subset of these same individuals (n = 11 645) were also contacted via electronic mail (Figure). Former players were eligible to participate if they had played ≥1 full seasons in the NFL. Recruitment took place from January 1, 2019, to February 14, 2020, and data analysis took place from August 11, 2020, to May 17, 2021.

Data Collection

The comprehensive questionnaire we used has been described elsewhere as part of an ongoing study: Neurologic Function Across the Lifespan: A Prospective, Longitudinal, and Translational Study for Former National Football League Players (NFL-LONG).[23,24] This survey acquires information about former players' personal demographics, football playing history, medical history, concussion history, musculoskeletal injury and surgery history, self-reported functioning, health-related quality of life, current substance use, and health-related behaviors.

Outcome Measures: Cardiovascular-Related Conditions

Outcomes of interest were self-reported lifetime medical diagnoses of CVD (coronary heart disease, myocardial infarction, and peripheral vascular disease) and, separately, CRFs (hypertension, hypercholesterolemia, diabetes mellitus type II, sleep apnea, chronic obstructive pulmonary disease). For each diagnosis, participants were asked, "Have you ever been told by a physician or health professional that you had/have any of the following conditions?"

Predictors: Injury History, Surgical History, and Diagnosis of OA

Lifetime medical diagnosis of OA was ascertained using the same question as above for the CVD and CRF conditions. Before completing questions about musculoskeletal injury and surgical histories, participants were provided the following definition: "*Musculoskeletal injuries* are any injury to the muscles, tendons, ligaments, cartilage, and bones. They can include, but are not limited to sprains, strains, dislocations and fractures." Next, participants were asked if they had ever sustained a musculoskeletal injury when they played football. Individuals with a history of a musculoskeletal injury were also asked to indicate the number of lifetime injuries and surgeries experienced for various body regions. For the present study, only knee, hip, and ankle injuries, surgeries, and OA were examined.

Covariates

Age, race and ethnicity, obesity status, lifetime medical diagnosis of liver or kidney disease, and smoking history were included as covariates. Age was calculated as the number of whole years between the participant's date of birth and the date of survey completion. Racial or ethnic identities were self-reported. To obtain obesity status, each participant's BMI (kg/m^2) was calculated from the self-reported height and weight, and then the individual was classified as either *not obese* (BMI $<$ 30) or *obese* (BMI $\geq$ 30). Liver and kidney disease diagnoses were acquired using the same question shown earlier for CVD, CRF, and OA diagnoses. Smoking history consisted of a *yes* or *no* response to the question, "Have you smoked 100 or more cigarettes in your lifetime? (Note: There are 20 cigarettes in one pack.)"

Statistical Analyses

We used a single contrast predictor variable with 3 categories for injury, surgery, and OA history: (1) those with no injury or surgical history and no OA diagnosis (neither condition was reported; referent category), (2) those with a history of $\geq$1 lower extremity joint injuries or surgeries but no OA diagnosis (reported injury or surgery only), and (3) those with a history of $\geq$1 lower extremity joint injuries or surgeries and a diagnosis of OA (both conditions were reported).

To calculate prevalence ratios (PRs) for CVD, we computed a bivariate log-binomial regression model for the injury, surgery, and OA predictor variable. Next, a multivariable log-binomial regression model was fit to calculate the adjusted PRs (PRs_{adj}) for the predictor contrast variables while covarying for age (continuous), racial or ethnic identity (operationalized dichotomously based on the sample distribution: those who identified as White or non-Hispanic and those who did not), obesity status (obese versus not obese), and liver or kidney disease (dichotomous; lifetime diagnosis of liver disease, kidney disease, or both versus neither diagnosis). Poisson regression models were conducted to determine PRs for the CRF outcome variable, as the log-binomial regression models failed to provide stable solutions.[25] Empirical Wald tests based on the robust sandwich covariance estimator were used to evaluate statistical significance, and effect estimates with 95% CIs excluding 1.0 were considered statistically significant. In post hoc exploratory analyses, we separated the study participants into 2 groups based on age (those $<$50 years of age and those $\geq$50 years of age) and fit the same models to each group separately.

Our secondary aim was to describe the knee-specific injury and surgery history in relation to CVD and CRF prevalence. These analyses mirrored those for the primary aim with the full sample but did not include participants who did not report a history of knee-related injury or surgery. All analyses were performed in SPSS (version 25; IBM Corp).

RESULTS

As of February 2020, a total of 1784 former NFL football players had completed the initial questionnaire. Among those respondents, 98 (5.5%) did not provide a response to $\geq$1 variables of interest in the present study: injury or surgery information (n = 18), racial or ethnic identity (n = 11), height or weight (from which we calculated BMI; n = 17), and smoking history (n = 56). Only 6% (n = 18) of participants reported an OA diagnosis but no history of lower extremity joint injury or surgery; this group was excluded from our analyses. Thus, 1686 former players were included in the current analyses (Table 1), of whom more than half had a history of lower extremity surgery (Table 2).

Regarding CVD diagnoses, 145 participants in this sample (8.6%) reported a diagnosis of coronary heart disease or heart attack but not peripheral vascular disease, 17 (1.0%) indicated a diagnosis of peripheral vascular disease but not coronary heart disease or heart attack, and 9 (0.5%) cited both diagnoses. A total of 899 participants (53.3%) reported $\geq$1 CRF. More specifically, 458 (27.2%) described only 1 diagnosis, 291 (17.3%) indicated 2 diagnoses, 131 (7.8%) cited 3 of the diagnoses, and 19 (1.1%) reported having all 4 CRF diagnoses (hypertension, hypercholesterolemia, type II diabetes, and sleep apnea).

Neither a history of lower extremity injury or surgery without OA nor a history of both lower extremity injury or surgery and diagnosed OA was significantly associated with CVD after controlling for age, racial or ethnic identity, obesity status, and diagnoses of liver disease, kidney disease, or both when compared with those reporting no prior injuries, surgeries, or OA diagnosis (Table 3). This lack of a relationship with CVD prevalence remained even when participants were separated into older and younger age groups (ie, those $\geq$50 years of age and those $<$50 years old, respectively).

Conversely, the prevalence of reporting a diagnosis of $\geq$1 CRFs was higher among former players with a history of

Table 1. Participant Characteristics

Characteristic	Full Sample (N = 1686)	Group: No History of Injury or Surgery and No Osteoarthritis (n = 262)	Group: History of Injury or Surgery Without Osteoarthritis (n = 1125)	Group: History of Injury or Surgery With Osteoarthritis (n = 299)
Age, mean ± SD, y	51.9 ± 16.3	48.8 ± 18.6	50.5 ± 15.7	59.8 ± 13.8
Race or ethnicity, No. (%)				
Non-White[a]	686 (40.7)	137 (52.3)	455 (40.4)	94 (31.4)
White or non-Hispanic	1000 (59.3)	125 (47.7)	670 (59.6)	205 (68.6)
Current obesity classification, No. (%)				
Current BMI, mean ± SD	30.8 ± 4.6	30.9 ± 4.7	30.7 ± 4.5	31.0 ± 4.7
Underweight (BMI < 18.5)	1 (0.1)	0 (0)	1 (0.1)	0 (0)
Normal (BMI = 18.5–24.99)	97 (5.8)	14 (5.3)	63 (5.6)	20 (6.7)
Overweight (BMI = 25.0–29.99)	752 (44.6)	121 (46.2)	510 (45.3)	121 (40.5)
Obesity class I (BMI = 30.0–34.99)	563 (33.4)	74 (28.2)	380 (33.8)	109 (36.5)
Obesity class II (BMI = 35.0–39.99)	193 (11.4)	42 (16.0)	121 (10.8)	30 (10.0)
Obesity class III (BMI ≥ 40.0)	80 (4.7)	11 (4.2)	50 (4.4)	19 (6.4)
Smoked ≥100 lifetime cigarettes, No. (%)	244 (14.5)	36 (13.7)	144 (12.8)	64 (21.4)
Lifetime physician diagnoses, No. (%)				
Coronary heart disease/heart attack	154 (9.1)	19 (7.3)	94 (8.4)	41 (13.7)
High blood pressure/hypertension	621 (36.8)	77 (29.4)	402 (35.7)	142 (47.5)
Hypercholesterolemia/high cholesterol	411 (24.4)	43 (16.4)	265 (23.6)	103 (34.4)
Peripheral vascular disease	26 (1.5)	1 (0.4)	17 (1.5)	8 (2.7)
Diabetes type II	99 (5.9)	19 (7.3)	59 (5.2)	21 (7.0)
Sleep apnea	378 (22.4)	38 (14.5)	229 (20.4)	111 (37.1)
Liver disease	16 (0.9)	1 (0.4)	9 (0.8)	6 (2.0)
Kidney disease	46 (2.7)	6 (2.3)	26 (2.3)	14 (4.7)
Chronic obstructive pulmonary disease	19 (1.1)	2 (0.8)	11 (1.0)	6 (2.0)

Abbreviation: BMI, body mass index.

[a] Among those identifying as non-White in the full sample, 593 (35.2%) identified as Black or African American, 12 (0.7%) as Native Hawaiian or Pacific Islander, 4 (0.2%) as American Indian or Alaska Native, 3 (0.2%) as Latino, 25 (1.5%) as Asian, and 57 (3.4%) as mixed race/ethnicity or "*other*," subsequently reporting Moor (1 [0.1%]), Haitian (1 [0.1%]), Hebrew (1 [0.1%]), or undefined (2 [0.1%]).

lower extremity injury or surgery with or without diagnosed OA versus athletes with neither condition (Table 4; PRs adjusted for the prevalence of each individual CRF diagnosis are presented in Supplemental Table 1, available online at http://dx.doi.org/10.4085/1062-6050-0437.22.S1). When relationships with the prevalence of any CRF were explored by age group, participants ≥50 years who had both a history of injury or surgery and a diagnosis of OA had a higher prevalence of ≥1 CRFs compared with those who had neither diagnosis, but this was not true for those with a history of injury or surgery without an OA diagnosis. Younger participants (<50 years of age) exhibited significant PRs in both injury and OA contrast conditions compared with those who had no injury, surgery, or OA diagnosis. Further, the magnitude of the PR_{adj} for CRFs in younger participants with an injury or surgery history and a diagnosis of OA was twice as large as the PR_{adj} for CRFs in older participants.

Finally, we repeated our primary analyses (excluding exploratory models by age) only in participants who had a history of injury or surgery to the knee with or without OA anywhere in the lower extremity. Of note, former players with OA were approximately 20 years older than former players without OA on average (Supplemental Table 2). Former players with a history of knee injury or surgery, whether or not they reported OA, had a higher prevalence of reporting a CVD diagnosis after we controlled for age, racial or ethnic identity, obesity status, and diagnosis of liver disease, kidney disease, or both (Supplemental Table 3). However, CRFs were more prevalent among former players with a history of knee injury or surgery and those with a history of knee injury or surgery and diagnosed OA

Table 2. Frequency of Injury, Surgery, and Osteoarthritis Diagnosis by Lower Extremity Region

Region	History, No. (%): ≥1 Injuries[a]	Osteoarthritis[b]	≥1 Surgeries	No. of Surgeries, Median (IQR)[c]
Total	1452 (84.5)	243 (14.4)	971 (57.6)	2 (1, 4)
Knee	1224 (72.6)	224 (13.3)	827 (49.1)	2 (1, 3)
Hip	500 (29.7)	90 (5.3)	147 (8.7)	0 (0, 0)
Ankle	1025 (60.8)	91 (5.4)	260 (15.4)	0 (0, 1)

Abbreviation: IQR, interquartile range.

[a] The number of participants reporting having sustained ≥1 injuries to each region and the number of participants who endorsed a specific number (eg, 1, 2, 3, ≥10) did not agree; some responses were "a lot" or "too many" or "missing." Because of this and the fact that participants could endorse ≥10, the median and IQR for the number of injuries were not calculated.

[b] Osteoarthritis was indicated in only 1 region by 108 participants, in 2 regions by 108, and in all 3 regions by 27.

[c] Median and IQR for the number of surgeries were calculated only among those reporting ≥1 surgeries (n = 971).

Table 3. Prevalence Ratios for Predictors of Cardiovascular Disease[a]

Predictor/Covariate	Prevalence Ratio (95% CI)		
		Age Group, y	
	Full Sample (N = 1686)	≥50 (n = 914)	<50 (n = 772)
Crude model			
Injury, surgery, OA history group			
No history of injury or surgery and no OA	1.0	1.0	1.0
History of injury or surgery without OA	1.22 (0.77, 1.94)	1.05 (0.65, 1.70)	1.64 (0.49, 5.46)
History of injury or surgery and OA	2.01 (1.23, 3.32)	1.35 (0.81, 2.26)	1.88 (0.39, 9.10)
Adjusted model			
Injury, surgery, OA history group			
No history of injury or surgery and no OA	1.0	1.0	1.0
History of injury or surgery without OA	1.34 (0.86, 2.07)	1.27 (0.77, 2.07)	1.31 (0.36, 4.76)
History of injury or surgery and OA	1.41 (0.89, 2.25)	1.39 (0.84, 2.29)	1.11 (0.19, 6.61)
Age, y (continuous; 1-y increase)	1.05 (1.04, 1.06)	1.04 (1.02, 1.06)	1.07 (1.02, 1.13)
Race or ethnicity: identified as White or non-Hispanic			
Yes	1.0	1.0	1.0
No	0.78 (0.56, 1.07)	1.37 (1.03, 1.83)	1.13 (0.50, 2.58)
Obesity status			
Not obese (BMI < 30)	1.0	1.0	1.0
Obese (BMI ≥ 30)	1.45 (1.11, 1.90)	1.37 (1.03, 1.83)	2.01 (0.81, 5.00)
Liver and kidney disease			
No liver or kidney disease	1.0	1.0	1.0
Diagnosed with liver or kidney disease	1.77 (1.14, 2.75)	1.73 (1.07, 2.80)	4.04 (0.91, 17.98)
Smoked ≥100 lifetime cigarettes			
No	1.0	1.0	1.0
Yes	1.17 (0.85, 1.60)	1.21 (0.87, 1.69)	0.70 (0.16, 3.07)

Abbreviation: BMI, body mass index; OA, osteoarthritis.

[a] Adjusted models consisted of the injury, surgery, and OA history contrast variable as the predictor while controlling for age, race or ethnic identity, obesity status, diagnosis of liver or kidney disease, and smoking history. Significant values do not include 1.00 in their 95% CIs.

versus those with no history of either condition (Supplemental Table 4).

DISCUSSION

Risk factors for CVD are more prevalent among former NFL players with a history of lower extremity injury or surgery. The PRs reported in Table 4 indicate that the association between injury or disease status and CRFs appears to be consistently higher in individuals with a history of injury or surgery and OA as compared with individuals who had a history of injury or surgery without OA; however, it should be noted that the CIs of these estimates overlap in all cases. More specifically, lower extremity joint injury or surgery alone was associated with a 30% greater prevalence of ≥1 CRFs, and individuals with lower extremity joint injury or surgery and OA reported a 53% greater prevalence of CRFs versus former players without a history of lower extremity joint injury, surgery, or OA. These findings are consistent with the literature describing an association of knee and hip OA with both hypercholesteremia and obesity status in other populations.[26]

Elevated CRFs (eg, elevated systolic blood pressure) have been described among former athletes, and an elevated risk of CVD among former athletes was associated with an elevated BMI.[27] Our study furthers this work by demonstrating a greater risk of CRFs among former athletes with a history of lower extremity joint injury or surgery in the absence of OA. Although our research did not allow us to establish causation or the mechanisms underlying this association, several groups have indicated that individuals with a history of lower extremity joint injury or surgery had more joint pain,[28] poorer cardiorespiratory fitness,[29,30] greater adiposity[29,31] and participated in less physical activity[13,14] than their peers who had not experienced an injury. Athletic trainers are uniquely positioned within sports organizations to implement evidence-based lower extremity injury-prevention strategies and provide comprehensive rehabilitation for lower extremity joint injuries; however, our results signify that an enhanced focus on patient counseling about risk factors for chronic disease development (eg, OA and CVD) after lower extremity injury may be warranted to improve patient well-being across the lifespan.

A history of lower extremity injury or surgery either in isolation or in combination with diagnosed OA was not significantly associated with the prevalence of CVD among this sample of former NFL athletes. We operationally defined *CVD* as the presence of coronary heart disease, myocardial infarction, or peripheral vascular disease, which is an important distinction from previous studies of former NFL players whose authors limited their focus to myocardial infarction.[11] In a meta-analysis of the association between OA and CVD, defined as coronary and ischemic heart disease, myocardial infarction, congestive heart failure, and stroke, individuals who had knee or hip OA experienced a 30% or 23% greater relative risk of CVD, respectively, as compared with healthy individuals.[18] Our PR_{adj} showed that individuals with a history of lower extremity joint injury or surgery and OA had a 41% greater prevalence of CVD (95% CI = 0.89, 2.25) and individuals with a history of lower extremity joint injury or surgery but no diagnosed OA had a 34% greater

Table 4. Prevalence Ratios for Reporting ≥1 Cardiovascular Disease Risk Factors[a]

	Prevalence Ratio (95% CI)		
		Age Group, y	
Predictor/Covariate	Full Sample (N = 1686)	≥50 (n = 914)	<50 (n = 772)
Crude models			
Injury, surgery, OA history group			
No history of injury or surgery and no OA	1.0	1.0	1.0
History of injury or surgery without OA	1.29 (1.10, 1.51)	1.08 (0.93, 1.25)	1.66 (1.17, 2.34)
History of injury or surgery and OA	1.85 (1.57, 2.18)	1.21 (1.04, 1.41)	3.24 (2.26, 4.67)
Adjusted models			
Injury, surgery, OA history group			
No history of injury or surgery and no OA	1.0	1.0	1.0
History of injury or surgery without OA	1.30 (1.12, 1.50)	1.10 (0.95, 1.28)	1.53 (1.11, 2.11)
History of injury or surgery and OA	1.53 (1.31, 1.78)	1.20 (1.03, 1.41)	2.46 (1.72, 3.51)
Age, y (continuous; 1-y increase)	1.02 (1.02, 1.03)	1.01 (1.00,[b] 1.01)	1.05 (1.04, 1.07)
Race or ethnicity: identified as White or non-Hispanic			
Yes	1.0	1.0	1.0
No	1.23 (1.13, 1.35)	1.10 (1.00,[c] 1.20)	1.46 (1.21, 1.77)
Obesity status			
Not obese (BMI < 30)	1.0	1.0	1.0
Obese (BMI ≥ 30)	1.26 (1.16, 1.37)	1.20 (1.10, 1.31)	1.25 (1.03, 1.52)
Liver or kidney disease			
No liver or kidney disease	1.0	1.0	1.0
Diagnosed with liver or kidney disease	1.10 (0.93, 1.30)	1.03 (0.87, 1.22)	2.09 (1.53, 2.86)
Smoked ≥100 lifetime cigarettes			
No	1.0	1.0	1.0
Yes	1.17 (0.85, 1.60)	1.14 (1.04, 1.26)	0.97 (0.71, 1.32)

Abbreviation: BMI, body mass index; OA, osteoarthritis.

[a] Adjusted models consisted of the injury, surgery, and OA history contrast variable as the predictor while controlling for age, race or ethnic identity, obesity status, diagnosis of liver or kidney disease, and smoking history. Significant values did not include 1.00 in their 95% CIs.

[b] Exact value was 1.001.

[c] Exact value was 0.997.

prevalence versus former players with no history of injury, yet these findings were not statistically significant and should therefore be interpreted with caution. The authors of a recent meta-analysis of CVD and CRFs in former athletes found that the prevalence of CVD was comparable with that of the nonathlete population, indicating that postcareer changes in health behaviors may result in a cardiovascular risk profile that is not unlike that of nonathletes.[27] Future studies would benefit from enhanced detail regarding health behaviors (eg, participation in physical activity) that may be negatively affected by joint injury,[13,14] OA,[16] and the end of the playing career to allow us to better understand the role of joint health during the lifespan of former NFL players.

Older individuals are at higher risk for CRFs and CVD.[32] Neither a history of lower extremity injury or surgery without OA nor a history of lower extremity injury or surgery and diagnosed OA were significantly associated with CVD in the older or younger age groups. However, younger individuals (<50 years old) with a history of lower extremity injury or surgery without OA experienced a 53% greater prevalence of CRFs and individuals with a history of both lower extremity injury or surgery and OA experienced a 146% greater prevalence of CRFs when compared with younger individuals who had no history of injury, surgery, or OA (Table 4). Alternatively, older individuals (≥50 years old) who had both a history of injury or surgery and a diagnosis of OA displayed a 20% greater prevalence of CRFs as compared with individuals who had no history of injury, surgery, or OA, whereas injury or surgery in the absence of OA was not significantly associated with a greater prevalence of CRFs. This finding seems counterintuitive, as the prevalence of CRFs is known to increase with age.[33] Nonetheless, older individuals in our cohort were more likely to develop CRFs and CVD independent of injury, surgery, or OA status. Thus, the greater prevalence of CRFs observed before the typical period of highest CVD risk (<50 years old) may reflect an important pathway from lower extremity injury to premature morbidity that requires additional longitudinal examination.

Our knee-specific analysis mirrored our omnibus analysis, which simultaneously considered hip-, knee-, and ankle-joint injuries. This is likely because 91.1% of individuals who reported a diagnosis of OA in the sample stated that their diagnosis involved the knee joint, and 71.6% of individuals who recounted a history of lower extremity joint injury or surgery described ≥1 knee injuries or surgeries. These outcomes are similar to those of previous investigators[6,10] who determined that knee-joint surgery was the most common lower extremity surgery and knee-related posttraumatic OA the most prevalent OA diagnosis among NFL athletes as compared with nonathletes who had similar demographics.

This was a cross-sectional subanalysis of a larger ongoing cohort study. Although the sample of former NFL players in this study was large (N = 1686), we were not able to establish if meaningful differences in demographics or health history existed between individuals who did and those who did not respond to the survey. This may have introduced sampling and response bias, both of which

might have affected the findings. Given the cross-sectional design, we were not able to identify the incidence of CRFs or CVD in our sample, which limited us to reporting the association between injury history and CRF or CVD prevalence. This also restricted our ability to characterize the timing of the injury diagnosis or OA diagnosis relative to the playing career, as well as any change in behavior (eg, change in physical activity level or cessation of smoking) that might have influenced CRFs or the risk of CVD. Health histories were self-reported, and we were unable to confirm responses via chart review or other sources. This is particularly concerning because many of the medical conditions included in the health history can be described using several terms (eg, medical versus layperson), which may have caused confusion among some respondents. Lastly, it is important to consider the generalizability of this study. American football is a unique sport, and the individuals who play football at the NFL level may differ from other athletic and nonathletic populations based on physiology, demographics (eg, all biologically male players), and the number of years participating in sport, among other factors. As a result, these results should not be extrapolated to populations other than former NFL players; however, future authors should consider replicating this approach in various athletic populations.

Former NFL players with a history of lower extremity injury, surgery, or OA had a higher prevalence of CRFs than former players with no such history. The association between lower extremity injury, surgery, or OA and the prevalence of CRFs was stronger among individuals <50 years of age. These findings provide insight regarding the pathway to chronic diseases that may be initiated by joint injury early in life, even among individuals who participate in elite sport.

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SUPPLEMENTAL MATERIAL

Supplemental Table 1. Adjusted Prevalence Ratios (PRs) for Individual Cardiovascular Disease Risk Factors (CRFs).

Supplemental Table 2. Characteristics of Participants With Knee-Related Injury or Surgery.

Supplemental Table 3. Prevalence Ratios (PRs) for Predictors of Cardiovascular Disease in Participants With Knee-Related Injury or Surgery History or No Reported Injury or Surgery History (n = 1486).

Supplemental Table 4. Prevalence Ratios (PRs) for Predictors of Reporting One or More Cardiovascular Disease Risk Factors in Participants With Knee-Related Injury or Surgery History or No Reported Injury or Surgery History (n = 1486).

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