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Osteoarthritis Prevalence in Retired National Football League Players With a History of Ankle Injuries and Surgery

Kyeongtak Song, PhD, ATC*; Erik A. Wikstrom, PhD, ATC, FACSM*; Joshua N. Tennant, MD§; Kevin M. Guskiewicz, PhD, ATC, FNATA, FACSM*†; Stephen W. Marshall, PhD‡; Zachary Y. Kerr, PhD, MPH*†

*Department of Exercise and Sport Science, †Matthew A. Gfeller Sport-Related Traumatic Brain Injury Research Center, §Department of Orthopaedics, and ‡Department of Epidemiology and Injury Prevention Research Center, University of North Carolina at Chapel Hill

Context: Ankle injuries are common at all levels of American football, and retired National Football League (NFL) players have a high prevalence of osteoarthritis (OA), but little is known about how ankle injuries influence OA prevalence and daily activities in this population or how surgical interventions for such injuries alter the risk of OA.

Objective: To examine (1) the association of ankle-injury history with OA prevalence, (2) the association of surgical intervention after ankle injury with OA prevalence, and (3) the relationships among ankle injuries, reported OA, and daily activities in retired NFL players.

Design: Case-control study.

Setting: Survey.

Patients or Other Participants: Data from the Retired NFL Players General Health Survey.

Main Outcome Measure(s): We created a 7-category main exposure variable that differentiated respondents by football-related ankle injury and surgical intervention. Multivariable binomial regression models were used to estimate prevalence ratios and 95% confidence intervals. Among those reporting OA, we examined the distribution of responses regarding whether OA affected daily activities.

Results: Among the 2446 respondents, 920 participants experienced OA in any joint during their lifetime. Compared with those reporting no ankle injuries, the prevalence of OA was higher among those with a history of ankle injury. Also, the prevalence of OA was higher among those who had undergone surgery versus those who had not. The number of retired NFL players who reported that OA *often* affected their daily activities increased with the number of ankle injuries.

Conclusions: Among former NFL players, a history of ankle injury increased the prevalence of OA. More ankle injuries increased the probability that OA negatively affected daily activities. Future prospective research is needed to better determine the influence of surgical intervention at the ankle or foot on OA.

Key Words: professional athletes, daily activities, long-term health

Key Points

- Among former National Football League players, a history of ankle injury was associated with an increased prevalence of osteoarthritis.
- More ankle injuries increased the probability that osteoarthritis was often associated with impairment in daily activity among retired National Football League players.

Osteoarthritis (OA), a common type of arthritis, is a leading cause of physical disability. An estimated 54.4 million adults in the United States were living with physician-diagnosed arthritis from 2013 to 2015.[1] Posttraumatic OA (PTOA) results from acute or recurrent traumatic joint injury,[2] and 80% of all cases of ankle OA are posttraumatic in nature.[2] Common causes of ankle PTOA are a history of fracture, a single ankle sprain, and recurrent ankle instability.[3] These ankle injuries may either damage the articular surfaces directly or change ankle-joint biomechanics, leading to altered cartilage loading over time.[4] Recent researchers[5,6] demonstrated a link between ankle injury and knee-joint OA, indicating that ankle injury may increase the risk of global lower extremity OA. A history of ankle injury has also been shown[7] to negatively influence physical activity and quality of life. However, studies examining the interaction of ankle injuries, reported OA, and the ability to complete daily activities are lacking.

Both conservative and operative procedures have been used in an effort to restore proper joint biomechanics and reduce aberrant joint loading after ankle injury. Given the link between ankle injury and global lower extremity OA, it is logical to assume that restoring proper ankle-joint biomechanics may protect against both ankle and global lower extremity OA. The total number of surgical procedures, with the goals of restoring ankle-joint biomechanics and improving clinical outcomes,[8,9] increased by more than 30% from 2007 to 2011 in the United States.[10] However, such surgical repairs may not mitigate the risk of developing ankle OA.[8,11] Therefore, further investigation is

needed to better determine if surgery to the ankle or foot influences the prevalence of OA in the public and in more active populations, such as elite and tactical athletes, as the demands placed on each population will likely not be generalizable to the others.

Ankle injuries are common at all levels of American football, one of the sports with the largest number of players in the United States.[12] Lateral and high ankle sprains are the most common types of ankle injury in football.[12,13] Approximately 6% to 17% of American football athletes who have had an ankle injury sustain the same type of recurrent injury, which may result in chronic instability.[12] Previous researchers[14] found that retired National Football League (NFL) players had a higher prevalence of early-onset OA in any joint compared with males in the general US population. Despite the common occurrence of ankle injuries in American football players, little is known about how these injuries influence the prevalence of OA or how surgical interventions for ankle injuries alter the risk of OA in this population. Also, few authors have explored how OA, with or without ankle injury, may be related to long-term function during daily activities. Retired professional football players represent a large and unique cohort of athletes who are known to have commonly sustained ankle injuries (eg, ankle sprains, fractures), which allows us to examine associations among ankle injuries, OA, and ankle or foot surgical interventions.

The primary aim of our analysis was to investigate the association of a history of ankle injury with OA prevalence in retired NFL players. Our secondary purpose was to examine the association of ankle or foot surgical intervention after ankle injury with OA prevalence in retired NFL players. Our third goal was to determine the relationships among ankle injuries, reported OA, and daily activities in retired NFL players. We hypothesized that (1) individuals who had sustained more ankle injuries during their careers would have a higher OA prevalence than individuals who had sustained no or fewer ankle injuries, (2) retired NFL players who had sustained ankle injuries during their careers that required surgery would have a higher OA prevalence than those who had ankle injuries but did not undergo surgery, and (3) reported OA in those who sustained more ankle injuries would be associated with a greater decline in the ability to complete daily activities than in those who sustained no or fewer injuries.

METHODS

For this retrospective study, we used data from the Retired NFL Players General Health Survey (GHS).[15] The cohort comprised retired NFL football players who participated from the 1940s to the early 2000s. The GHS captured data on demographics, history of play, general medical and injury history, and overall health status. This study was approved by the university's institutional review board.

In May 2001, the Center for the Study of Retired Athletes at the University of North Carolina at Chapel Hill physically mailed the GHS instrument to all living members of the NFL Retired Players Association (n = 3729). Follow-up reminders were sent to nonrespondents in August 2001 and February 2002, with additional telephone follow-up afterward. In total, 2536 (68.7%) of the retired players completed the GHS.

Respondents were asked to consider any *serious musculoskeletal injury* as follows: fracture, torn ligament, or ruptured muscle; a condition that required surgery; or a condition that caused them to miss at least 2 games or 2 weeks of practice. Using this operational definition, respondents reported the number of ankle injuries they had sustained during their high school, collegiate, and professional football careers. They were asked whether they had undergone surgery to the ankle or foot during their professional career or since retirement. We defined the exposure in this manner because of the large number of ankle injuries to high school and collegiate players but the low prevalence of ankle or foot surgery during these years. Because of the combined (ie, ankle or foot) surgical response option, a more specific surgical location within the ankle-foot complex was not possible. Data on surgical interventions before respondents' professional careers were not obtained in the survey. Also, data were collected at the aggregate level, so surgical details such as the specific procedure or when the surgery was performed were not available via medical records.

Respondents were questioned as to whether they had ever been told by a physician or health care professional that they had or have OA (including degenerative arthritis). The questionnaire did not specifically ask which joint was affected by OA. If respondents had OA, they were asked if it was affecting their daily activities at the time of reporting (*never*, *some*, *often*). They also provided demographic information on age and race or ethnicity. In addition, current body mass and height were measured to allow us to calculate a body mass index (BMI). Survey responses were anonymous, so BMIs during their professional careers could not be estimated. Last, we collected information on participation history, including the number of years played, number of years retired, and primary position played.

Analyses were conducted using SAS (version 9.4; SAS Institute Inc, Cary, NC), and the level of significance for all analyses was set a priori at $P < .05$. We included a respondent's data only if he had provided complete answers for the outcome measures (ie, OA prevalence), the main exposure measures (ie, ankle-injury history and surgical intervention), and covariates (ie, demographics and playing history). When examining correlations among the exposure variables, we opted to remove age, given its strong correlation with number of years retired ($r = 0.96$). All other variables were retained for inclusion in the multivariable model.

Frequencies were generated for all variables of interest. A history of football-related ankle injury was recoded from a discrete variable to a 4-category variable (0, 1–2, 3–5, $\geq$6 injuries). Surgical intervention on the ankle or foot was retained as a dichotomous (*yes/no*) variable. From these 2 variables, we created a 7-category main exposure variable that differentiated respondents by first, whether they had an ankle-injury history, and second, whether those with injuries also had a history of surgical intervention. The main outcome, OA prevalence, was retained as a dichotomous (*yes/no*) variable. Race or ethnicity was categorized as white or non-Hispanic and nonwhite. Primary position played was categorized as cornerback or safety, defensive line, linebacker, offensive line, quarterback, running back, special teams, tight end, or wide receiver. Current BMI at reporting, the number of years of professional play, and the

number of years retired at the time of reporting were treated as discrete variables in regression analyses; however, for frequencies, these variables as well as the age at reporting were clustered into categories.

We used classical tabular methods to estimate the prevalence of OA overall and by ankle-injury and surgery group. Next, multivariable binomial regression models were calculated to model the OA prevalence and estimate prevalence ratios (PRs) and 95% confidence intervals (CIs). Crude PRs were computed alongside adjusted PRs controlling for years retired, race or ethnicity, primary position played, and years of professional play. All binomial regression models used Poisson residuals and robust variance estimation to stabilize the model fit.[16] Lastly, among those reporting OA, we examined the distribution of responses regarding whether OA was affecting the daily activities of respondents at the time of reporting by ankle-injury and surgery group.

RESULTS

The characteristics of the retired NFL players can be found in Table 1. Among the 2446 respondents included in the analyses, 920 participants (37.6%) had experienced OA in any joint during their lifetime.

Although 41.9% (n = 1026) reported no history of ankle injury, 31.5% (n = 771), 16.6% (n = 407), and 9.9% (n = 242) reported histories of 1–2, 3–5, and ≥6 ankle injuries, respectively (Table 2). Of those who had incurred ankle injuries (n = 1420), 89.1% (n = 1265) reported no history of ankle or foot surgery during or since their professional careers. In contrast, 10.9% (n = 155) reported ankle or foot surgery during or since their professional careers. Regardless of surgical intervention, the percentage of retired NFL players who reported that OA often affected their daily activities increased with the number of ankle injuries (Figure).

Among those with no history of ankle injury, 33.1% (n = 340) reported OA. The proportion that reported OA increased with the number of ankle injuries among those who did not require ankle or foot surgery during or after their professional careers (Table 2). These numbers ranged from 37.0% for those reporting 1–2 ankle injuries to 42.7% for those reporting ≥6 ankle injuries.

Multivariable models were used to estimate the prevalence of OA while controlling for years retired, race or ethnicity, primary position played, and years of professional play (Table 2). Compared with those who had no history of ankle injury, the OA prevalence was higher among those with a history of ankle injury, regardless of the number of injuries. However, those with 3–5 ankle injuries who underwent surgical intervention were the exception, as they did not have a higher OA prevalence than those with no ankle injuries (PR = 1.23; 95% CI = 0.84, 1.80).

When comparing strata of ankle-injury history by the presence of ankle or foot surgery, multivariable models estimated that the OA prevalence was higher among those who had ankle or foot surgery versus those without, particularly in the group with 1–2 ankle injuries (PR = 1.45; 95% CI = 1.16, 1.81) and the ≥6 ankle-injuries group (PR = 1.64; 95% CI = 1.26, 2.15). The single exception was the group with 3–5 ankle injuries (PR = 0.97; 95% CI = 0.66, 1.44).

Table 1. Characteristics of Retired National Football League Players in Cohort

Characteristic	No. (%)
Current age (as of 2001)	
≤40	488 (20.0)
41–50	536 (21.9)
51–60	673 (27.5)
61–70	446 (18.2)
71–80	238 (9.7)
>80	61 (2.5)
Missing	4 (0.2)
Race or ethnicity	
White or non-Hispanic	1725 (70.5)
Nonwhite	721 (29.5)
Current body mass index (as of 2001)	
≤24.9	140 (5.7)
25.0–29.9	1107 (45.3)
30.0–34.9	871 (35.6)
35.0–39.9	253 (10.3)
≥40.0	75 (3.1)
Years played professionally	
≤5	978 (40.0)
6–10	1100 (45.0)
11–15	344 (14.1)
>15	24 (1.0)
Years retired (as of 2001)	
≤10	450 (18.4)
11–20	527 (21.5)
21–30	654 (26.7)
31–40	491 (20.1)
41–50	235 (9.6)
>50	89 (3.6)
Primary position played	
Quarterback	133 (5.4)
Running back	306 (12.5)
Wide receiver	233 (9.5)
Offensive line	588 (24.0)
Tight end	128 (5.2)
Defensive line	288 (11.8)
Linebacker	317 (13.0)
Cornerback or safety	329 (13.5)
Special teams	124 (5.1)

DISCUSSION

A history of ankle injury was associated with an increased risk of OA prevalence among retired NFL players, regardless of the number of ankle injuries experienced during their careers. This finding is consistent with previous results[3,17] that demonstrated a relationship between a history of ankle sprain and degenerative changes in the ankle. Lateral and high ankle sprains are the most common ankle injuries in American football players.[12,13] Similarly, Saltzman et al[3] observed that both single and recurrent lateral ankle sprains were the most prevalent causes of ankle PTOA in the general population. Further supporting the link between ligamentous trauma and early signs of ankle OA, cartilage degeneration at the ankle joint in young athletes with single and recurrent lateral ankle sprains has been quantified using compositional imaging.[17] The exact ways in which single or recurrent sprains contribute to the development of ankle OA are unknown. Sensorimotor, mechanical, and biomechanical changes

Table 2. Crude and Adjusted Prevalence Ratios and 95% Confidence Intervals (CIs) of Osteoarthritis Prevalence[a] by History of Ankle Injury or Ankle or Foot Surgery Among Retired National Football League Players

Ankle Injury and Ankle or Foot Surgery Group	No.	Reported Osteoarthritis,[a] No. (%)	Prevalence Ratio and 95% CI	
			Crude	Adjusted[d]
No ankle injuries[b]	1026	340 (33.1)	1.00	1.00
No history of ankle or foot surgery,[c] No. ankle injuries				
1–2[c]	689	255 (37.0)	1.12 (0.98, 1.27)	1.16 (1.02, 1.32)
3–5	370	152 (41.1)	1.24 (1.07, 1.44)	1.26 (1.09, 1.46)
≥6	206	88 (42.7)	1.29 (1.08, 1.54)	1.34 (1.12, 1.59)
History of ankle or foot surgery, No. ankle injuries				
1–2	82	45 (54.9)	1.66 (1.34, 2.05)	1.68 (1.35, 2.09)
3–5	37	15 (40.5)	1.22 (0.82, 1.82)	1.23 (0.84, 1.80)
≥6	36	25 (69.4)	2.10 (1.66, 2.65)	2.19 (1.73, 2.79)
Total	2446	920 (37.6)		
Comparison: surgery versus no surgery within stratum of ankle injuries, No.				
1–2			1.48 (1.19, 1.85)	1.45 (1.16, 1.81)
3–5			0.99 (0.66, 1.49)	0.97 (0.66, 1.44)
≥6			1.63 (1.24, 2.13)	1.64 (1.26, 2.15)

[a] Includes degenerative arthritis.
[b] Professional, high school, or collegiate.
[c] Professional or postprofessional.
[d] Adjusted for years retired, race or ethnicity (white or non-Hispanic versus nonwhite), primary position played, years of professional play; age was not included due to high correlation with years retired ($r = 0.96$).

after ligamentous trauma have been theorized to alter joint-contact stress and lead to early degenerative changes of the talar articular carilage.[4,18] Although not conclusive, a growing body of evidence[7,19] supports this hypothesis.

It is important to acknowledge that we lacked information about the location of each player's reported OA. The joint that incurs the trauma commonly develops PTOA, yet recent researchers[5,6] have highlighted a link between ankle injury and knee OA, which suggests that an ankle injury may increase the risk of global lower extremity OA. For example, foot and ankle symptoms (eg, pain) are associated with the development of knee OA.[5] Similarly, Hubbard-Turner et al,[6] using a mouse ankle-sprain model, found that a single lateral ankle sprain led to a reduction in knee-joint space across the lifespan relative to a sham group. The mechanisms of these proximal degenerative changes

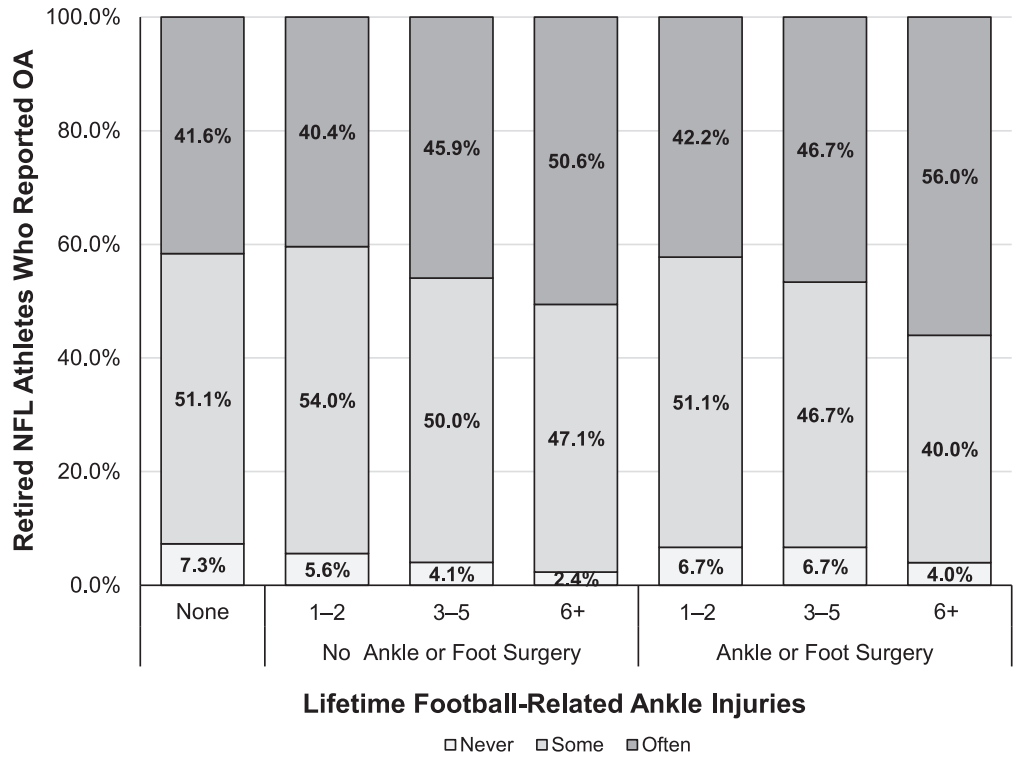

Figure. Distribution of whether osteoarthritis (OA; including degenerative arthritis) affected the daily activities of retired National Football League (NFL) players. Retired NFL players who did not report OA were not included.

remain unknown, but lateral ankle sprains and chronic ankle instability result in proximal adaptations (eg, kinematic alterations at the knee during walking and jump landing) that may lead to aberrant joint loading[20,21] and increased vertical ground reaction forces,[22] which could facilitate degenerative changes at the knee and other lower extremity joints.

Given these links between ankle injury and knee OA, the restoration of mechanical stability via ankle or foot surgery may protect against OA. Thus, we sought to determine if ankle or foot surgery altered the prevalence of OA among former NFL players with a history of ankle injury. Former NFL players with 1–2 or $\geq$6 ankle injuries who underwent surgical intervention showed 45% and 64% higher prevalences, respectively, of OA than those who did not. This is consistent with a previous result[23] of shorter mean latency time from ankle ligamentous injury to the development of ankle OA in a group that underwent surgical ligament repair versus nonoperative treatment. However, the group with 3–5 ankle injuries that had surgery of the ankle or foot did not show a higher prevalence of OA than those with 3–5 ankle injuries and no surgical intervention. No biological reason is likely responsible, but sampling and low statistical power in this ankle injury strata may explain this finding. Cumulatively, our results suggested that surgical intervention may not protect against PTOA, but given our retrospective design and limited information about the surgical procedures, they should be interpreted cautiously.

For example, the current dataset did not indicate the specific location (ankle or foot), type of surgical procedure, or when the procedure was performed. Similarly, we did not consider a history of surgical intervention during a respondent's high school or collegiate playing career. These limitations must be addressed in future research. Still, we are confident that most of the surgical interventions recalled by respondents occurred at the ankle, relative to the foot, given the higher incidence of ankle injuries[24] and the frequency of surgical intervention for ankle injuries relative to foot injuries in football players.[25] Although seemingly counter-intuitive, the lack of specificity as to the type of surgical procedure may allow more generalization of our results. For example, a variety of surgical procedures, including nonanatomic (eg, Evans, Chrisman and Snook, and Watson-Jones procedures) and anatomic (eg, Brostrom, Brostrom-Gould procedures) reconstruction techniques have been used to improve mechanical stability after lateral ankle sprains. These approaches have typically demonstrated high rates of good to excellent patient satisfaction.[26] However, nonanatomic procedures can result in abnormal joint motions and long-term degenerative changes.[27] Anatomic approaches produced better reductions in joint laxity without range-of-motion restrictions,[26] yet they did not fully restore normal contact mechanics of the ankle and hindfoot,[28] which may fail to mitigate the progression of degenerative changes. The dataset also did not indicate the severity of injuries that were treated with or without surgery. The development of ankle OA has been shown to be the result of articular damage at the initial trauma.[29] Thus, the increased prevalence of OA in those individuals who underwent surgery may reflect greater initial injury severity. Further prospective research is needed. Additional limitations of this survey study include a lack of information about the timing of the initial and latest injuries, as well as time since surgery, both of which could influence the progression of OA. Moreover, our outcomes were all based on self-reported responses to the questionnaires and required recall about the participants' status during their careers. We lacked objective documentation of OA (eg, radiography or magnetic resonance imaging), but the survey instructions stated that the OA was required to be diagnosed by a physician or health care professional.

Our results also showed a relationship between a history of ankle injury and daily activities. A higher number of retired NFL players reported that OA more frequently affected their daily activities as the number of ankle injuries increased, regardless of a history of surgical intervention. Cumulatively, our findings suggested that ankle injuries, regardless of the number, were associated with increased OA and that OA often affected daily activities in retired NFL players. Based on the current data, surgical intervention did not appear to lower the OA prevalence in retired NFL players; however, more detailed histories of the players and their procedures are needed to better elucidate the effects of surgical intervention on OA.

Our findings highlight the need for health care providers to be educated on the long-term consequences of ankle injuries as well as the potential benefits and limitations of various treatment strategies. Informed providers will be better able to articulate the potential long-term consequences of ankle injuries during and after their patients' competitive careers. Providers and patients will need to work together to provide patient-centered care that minimizes the risk of PTOA and preserves long-term health. We believe that this examination of historical data provides a strong foundation for future longitudinal research to identify the mechanisms responsible for the identified associations and develop intervention strategies to mitigate the increased OA prevalence after ankle injuries.

CONCLUSIONS

Among former NFL players, a history of ankle injuries had long-term negative effects on joint health and associated impairment of daily activities. A higher prevalence of OA was noted in retired NFL players with ankle injuries who underwent surgical intervention at the ankle or foot. Nevertheless, these results should be interpreted carefully because of the retrospective nature of the study and the limited information available regarding the details of the surgical procedure and location of the OA. Therefore, further research is needed to better understand the effects of ankle injuries and surgical intervention on the prevalence of ankle OA.

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Address correspondence to Kyeongtak Song, PhD, ATC, Department of Exercise and Sport Science, University of North Carolina at Chapel Hill, 209 Fetzer Hall 32, Chapel Hill, NC 27599. Address e-mail to ktsong@email.unc.edu.