Multiple Ankle Injuries Are Associated With an Increased Risk of Subsequent Concussion in National Football League Players

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Abstract

Background: There is a gap in the literature regarding musculoskeletal risk factors for concussion within the National Football League (NFL), which is an avenue that must be explored to promote player safety given the high incidence of both injury types. This study aims to observe if ankle injuries are associated with an increased risk of subsequent concussion in NFL players.

Methods: The public online database ProFootballReference.com was used to identify ankle injuries and concussions in NFL players from the 2009-2010 to 2019-2020 seasons. Multivariable logistic regression for subsequent concussion and ankle injury was performed, adjusting for body mass index (BMI), age, and player position. For descriptive statistics, unpaired t tests with unequal variance were performed for continuous variables, including BMI and age. χ^2 testing was performed for categorical variables, including player position, and whether the position was offensive, defensive, or on special teams.

Results: Of the 5538 NFL players included in the study, 941 had an ankle injury, 633 had a concussion, and 240 had both an ankle injury and a subsequent concussion. The adjusted odds ratio (aOR) for concussion following a single ankle injury was 0.90 (95% CI 0.72-1.14, $P=.387$); however, the aOR for concussion following multiple ankle injuries was 2.87 (95% CI 1.23-6.75, $P=.015$). Special teams players had the lowest risk for concussion (aOR 0.17, 95% CI 0.069-0.36, $P<.001$) following ankle injury, and there was no significant difference in risk between offense and defense (aOR 0.91, 95% CI 0.77-1.08, $P=.295$).

Conclusion: Multiple ankle injuries were associated with an increased risk of a subsequent concussion after adjusting for BMI; player position; and offense, defense, or special teams designation. These findings can inform injury prevention practices in the National Football League.

Level of Evidence: Level III, retrospective comparative study.

Keywords: head injuries/concussion, ankle, general sports trauma, football (American)

Introduction

American football is one of the most popular sports in the United States. The National Football League (NFL) dominates the football landscape, with more than 1500 athletes participating annually and 17.1 million television viewers in 2021.[22,29] Because of the high-contact nature of the sport, tackle football is associated with the highest rates of injury among all organized team sports, and these injuries bring

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scrutiny on the NFL because of its broad viewership and influence.[30] Incidence of injury in NFL players has been extensively recorded, with the anatomical locations most frequently affected being the knee, followed by the ankle, hamstring, shoulder, and head concussion.[15] Ankle injuries have been particularly well documented and are extremely prevalent throughout football players at all levels. In a study of players who attended the NFL combine, 70% had a history of ankle injury, more than any other part of the body.[10] Further, 43% of acute ankle sprains recorded in American football are recurrent injuries, lending support to an established pattern of increased stress on the ankle.[10] Although 91% of NFL players who sustained ankle injuries returned to play, these ankle injuries often hampered performance for years after the initial injury.[7]

Aside from musculoskeletal injuries, concussions are another injury of major concern in the NFL. Safety measures implemented within the last few years have resulted in a decreasing incidence of concussion, going from a one-season risk ranging from 7.4%-8.3% in 2015-2017 to 6.2%-7.1% in 2018-2019.[18] Despite these improvements, concussions remain a pertinent issue. Concussions in NFL players are associated with poorer performance outcomes after return to play, which has been correlated with a higher rate of franchise release, salary reductions, and shorter career span.[21] Beyond the risk to the player's career, there have been significant findings relating concussions in NFL players to Chronic Traumatic Encephalopathy (CTE), a progressive neurodegenerative condition.[16] In 2017, 86% of a convenience sample of deceased former football players were neuropathologically diagnosed with CTE, which prompted increased attention to concussion prevention and identification of factors that increase risk of concussion.[1,20]

There are gaps in the literature studying musculoskeletal injury as a risk factor for concussion, as well as in studying the effects of repeated musculoskeletal injuries. Because of the high prevalence of acute and recurrent ankle injuries in NFL players and the established subsequent negative impacts on performance, the present study aims to investigate the relationship between 1 or more prior ankle injuries and risk of subsequent concussion in NFL players.

Methods

Data Source

This study was a retrospective review of data from the open-access online database Pro Football Reference, published by Sports Reference LLC.[31] Pro Football Reference collects and reports statistics on >23 000 past and present NFL players dating as far back as 1920, as well as a repository of historical injuries from the 2009 season onward.[14,31] Every team has an injury database for each season, and for each player, the database includes any injuries that the team listed on weekly injury reports. Each injury is classified by general anatomical location. The injury database tracks the status of the injury week to week, distinguishing if the injury resulted in the player being unable to participate in a game, and if so, how many games were missed. Many peer-reviewed studies have used data from this source.[2-4,6,7,14,32]

The Pro Football Reference injury databases from the 2009-2010 to 2019-2020 seasons for all 32 NFL teams were queried for ankle injuries and concussions. The injury classifications included in the study were "ankle" and "concussion"; injuries classified as "head" or "neck" were excluded from the injured cohort because they did not specifically confirm a concussion occurred. To confirm each injury, we searched for corresponding media reports on a reputable sports news website, such as ESPN, CBS Sports, Bleacher Report, and The Score, among others. For each ankle injury, we recorded the injury type as one of 2 classifications: high ankle sprain, or other ankle injury.

Outcome Measures

The primary outcome of this study was risk of concussion after 1 or multiple ankle injuries. In this case-control study, for both single and multiple ankle injuries, the players were divided into the following groups: (A) + ankle injury + concussion, (B) + ankle injury – concussion, (C) – ankle injury + concussion, and (D) – ankle injury – concussion. Players were excluded if they had an ankle injury that occurred after their concussion. Players with only 1 ankle injury were excluded from the cohort with multiple ankle injuries prior to concussion, and vice versa. In addition to this data, demographic information was collected, including body mass index (BMI), age, player position, and whether the position was offensive (offensive line, quarterback, running back, tight end, wide receiver), defensive (defensive back, defensive line, linebacker), or special teams (kicker, long snapper, punter). As the study period extended over 11 years, the players' ages were recorded as their age during the first year they appeared on an NFL roster during the study period.

Statistical Analysis

For descriptive statistics, unpaired *t* tests with unequal variance were performed for continuous variables, including BMI and age. χ^2 testing was performed for categorical variables, including player position and offense, defense, or special teams designation. Multivariable logistic regression for subsequent concussion and ankle injury was performed, adjusting for BMI, age, and player position. The threshold for statistical significance for all analyses was set at a *P* value of <.05. All statistical analysis for this study was conducted with Stata statistics software.

Table 1. Two-Sample Wilcoxon Rank-Sum Test for Continuous Descriptive Cohort Characteristics.

Variable	Mean (SD)	*P* Value[a]
BMI	31.06 (4.55)	**.0013**
Age, y	24.41 (3.63)	**.0011**

Abbreviation: BMI, body mass index.
[a]Boldface indicates significance (*P* < .05).
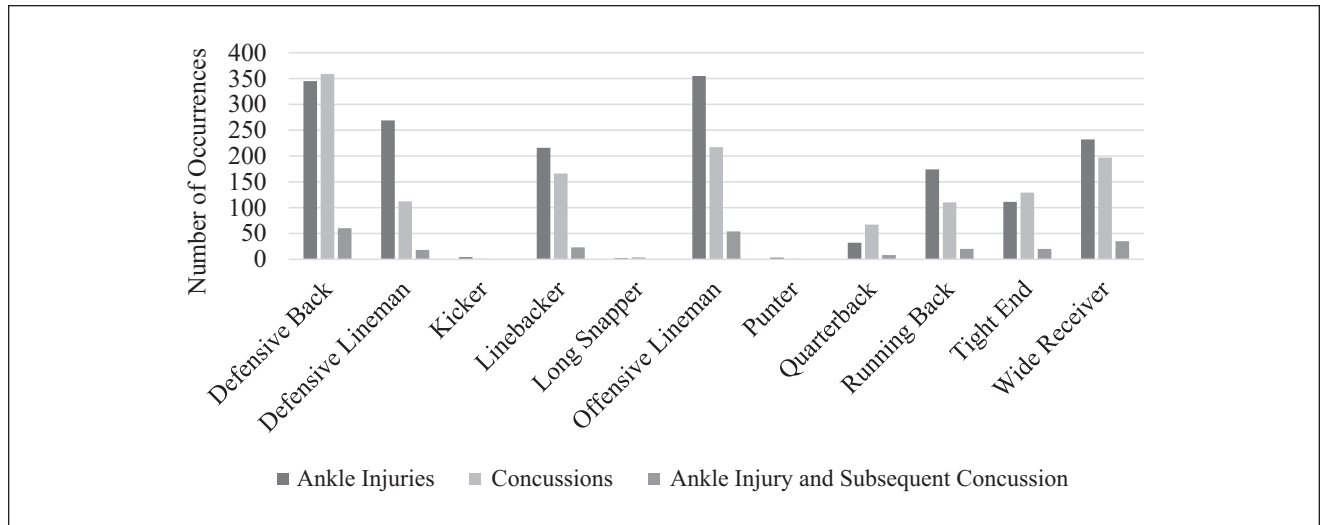
Figure 1. Incidence of each injury category by player position.

Results

Player Demographics

In total, 5536 players named to an NFL roster between the 2009-2010 and 2019-2020 seasons were included in the study. Of all the players, the mean BMI was 31.06 (SD 4.55) and the mean age was 24.41 years (SD 3.63). The 2-sample Wilcoxon rank-sum test for these continuous variables is summarized in Table 1. Between the 2579 offensive players, 2709 defensive players, and 248 special teams players, there was a significant difference in each group's rate of concussion, $\chi^2(2, 5536) = 21.61$, $P < .001$. There was also a significant difference in the rate of concussion between each individual player position, $\chi^2(9, 5536) = 68.14$, $P < .001$, including 1083 defensive backs, 875 defensive linemen, 98 kickers, 777 linebackers, 60 long snappers, 798 offensive linemen, 90 punters, 191 quarterbacks, 537 running backs, 330 tight ends, and 697 wide receivers. The quantity and proportion of each type of injury, stratified by player position, are detailed in Figure 1 and Table 2, respectively. Among players with ankle injuries, there was not a significant difference in concussion rate between types of ankle injury, $\chi^2(2, 941) = 0.019$, $P = .89$.

Risk of Concussion Following Ankle Injury

During the study period, 941 players had an ankle injury, of which 28 players had multiple ankle injuries, 633 players had a concussion, and 240 players had both an ankle injury and a subsequent concussion. The adjusted odds ratio (aOR) of any NFL player sustaining a concussion after a single ankle injury was 0.90 (95% CI 0.71-1.13, $P = .364$). When stratified by injury type, the aORs of sustaining a concussion after a high ankle sprain and a non–high ankle sprain injury were 0.89 (95% CI 0.61-1.30, $P = .56$) and 0.91 (95% CI 0.69-1.19, $P = .49$), respectively. Conversely, the aOR of any NFL player sustaining a concussion after multiple ankle injuries was 2.87 (95% CI 1.23-6.74, $P = .015$). BMI and age were not significant predictors of concussion risk. The kicker position was determined to have the lowest risk for concussion following ankle injury, and the positions with comparatively greater risk were defensive back, linebacker, offensive lineman, quarterback, running back, tight end, and wide receiver. Offensive and defensive players did not have significantly different risks for concussion following ankle injury, but both groups had significantly higher risks than special teams players. The results of the multivariable logistic regression are detailed in Table 3.

Table 2. Incidence of Each Type of Injury Category, Stratified by Player Position.[a]

Position	Ankle Injuries	Concussions	Ankle Injury and Subsequent Concussion
Defensive back	345 (25.46)	359 (26.49)	60 (4.43)
Defensive lineman	269 (26.40)	112 (10.99)	18 (1.77)
Kicker	4 (4.08)	1 (1.02)	0 (0.00)
Linebacker	216 (23.32)	166 (17.93)	23 (2.48)
Long snapper	2 (3.28)	4 (6.56)	0 (0.00)
Offensive lineman	355 (33.39)	217 (20.41)	54 (5.08)
Punter	3 (3.19)	1 (1.06)	0 (0.00)
Quarterback	32 (13.97)	67 (29.26)	8 (3.49)
Running back	174 (27.02)	110 (17.08	20 (3.11)
Tight end	111 (24.18)	129 (28.10)	20 (4.38)
Wide receiver	232 (26.75)	197 (22.72)	35 (4.04)

[a]Number formatting is total number (percentage of total injuries at that given player position).

Table 3. Multivariable Logistic Regression of Risk Factors for Concussion Following Ankle Injury in NFL Players.

Variable	Adjusted Odds Ratio	95% CI	P Value[a]
Single ankle injury	0.90	0.71-1.13	.364
High ankle sprain	0.89	0.61-1.30	.560
non–high ankle sprain injury	0.91	0.69-1.19	.493
Multiple ankle injuries	2.87	1.23-6.65	**.015**
BMI	0.99	0.95-1.04	.796
Age	0.98	0.97-1.01	.14
Player position[b]			
Defensive back	17.51	2.42-126.52	**.004**
Defensive line	6.84	0.91-51.78	.062
Linebacker	12.89	1.62-87.03	**.015**
Long snapper	7.12	0.77-65.67	.083
Offensive line	13.76	1.81-104.50	**.011**
Punter	1.09	0.067-17.62	.954
Quarterback	18.11	2.43-135.00	**.005**
Running back	12.85	1.75-94.37	**.012**
Tight end	12.8	1.72-95.02	**.013**
Wide receiver	13.23	1.82-96.20	**.011**
Position type[c]			
Defense	0.91	0.77-1.08	.295
Special teams	0.17	0.069-0.36	**<.001**

Abbreviations: BMI, body mass index; NFL, National Football League.
[a]Boldface values indicate statistical significance (*P* < .05).
[b]Reference group: kicker.
[c]Reference group: offense.

Discussion

In this study of 5536 NFL players over the course of 11 seasons, sustaining a single ankle injury was not significantly associated with risk for a subsequent concussion. However, sustaining multiple ankle injuries was shown to increase risk of subsequent concussion by 187%. Type of

ankle injury did not significantly impact risk of subsequent concussion. The player positions significantly associated with an increased risk for concussion following ankle injury were defensive backs, linebackers, offensive linemen, quarterbacks, running backs, tight ends, and wide receivers. Special teams as a group (including the kicker, punter, and long snapper positions) had a significantly lower risk for concussion following ankle injury than offensive or defensive players.

There is extensive literature that associates risk of concussion and risk of ankle injury. Patients with chronic ankle instability (CAI) have demonstrated deficits in excitability of the primary motor cortex, and of the peroneus longus muscle in particular.[27,28] These sensorimotor deficits become especially concerning when considering the high risk for ankle injury recurrence. A systematic review reported that 43% of acute ankle sprains recorded in American football were recurrent injuries.[10] Development of CAI correlates with this high reinjury rate, with one study finding that up to 70% of patients with lateral ankle sprains develop CAI within a short time frame.[9] Notably, CAI can in turn cause recurrent ankle injuries, perpetuating this harmful cycle.[19] The findings of the present study that multiple ankle injuries increase risk of concussion align with this body of literature; players with CAI or high potential to develop CAI are at increased risk of the ankle giving way, as CAI patients have been shown to demonstrate reduced balance when weightbearing on the injured ankle.[8,24] Ankle instability and the associated impediments on balance could increase risk of falls, resulting in sustaining a hard impact on hitting the ground, and increasing risk for concussion.

Our study's results are consistent with previous literature that identifies biomechanical mechanisms that may predispose certain football positions to a higher risk for ankle injury. A 2011 study identified "skill players"—a category including quarterbacks, running backs, wide receivers, tight

ends, defensive backs, and linebackers—as being at higher risk for ankle injury because of increased cutting, or quick changes of direction, and because these players are commonly tackled.[12] The motion of cutting can lead to inversion of the ankle, which could put a player at increased risk for lateral ankle injuries.[13] Other studies have concurred that all offensive positions are at increased risk for ankle injuries because of increased force and torque placed on the ankle during running, cutting, and tackling.[12] These studies are consistent with our findings, but one drawback of our study is that we did not look into external factors that have been shown to increase risk for ankle injury, such as weather conditions and the interaction between player cleats and playing surface.[12,25]

Both intrinsic factors, such as the direction and force of player movement, and extrinsic factors, such as weather and playing conditions, have substantial overlap in their contributions to increasing risk of ankle injuries and concussions. An important mechanistic difference is that the most common cause of concussion across all levels of football has been shown to be contact from other players.[17] In the NFL, concussions have been reported to be most frequent among quarterbacks, wide receivers, tight ends, and defensive backs, with the most common mechanism of concussion involving impact from another player's helmet.[26] The nature of these positions predisposes players to frequent collisions, whether that is from tackling other players or being tackled themselves. The fact that these skill players are often running routes, making cutting motions that increase force across the ankle, when they are tackling or being tackled lends further merit to the association between concussions and ankle injuries.

We found that the special teams unit, including kickers, punters, and long snappers, had a markedly lower risk for concussion following ankle injuries compared with offensive and defensive players. This can be explained when considering the on-field role of special teams players, who have a fraction of the playing time of offensive or defensive players. Further, there are special rules in place to better protect punters and kickers, who are considered "defenseless players," from unnecessary tackles and hits, which decreases their risk for injury.[23] Overall, the results of our study support a reduced injury rate in special teams players, owing to their decreased usage and extra protections.

Our study has several limitations. As this is a retrospective study, these results cannot prove causation, they can only show correlation. The Pro Football Reference database only discloses the anatomic location of the injury, so we were unable to make any conclusions about more specific types of injuries, as well as their differing severities. Some injuries are classified in the database as "head" or "neck," and although those injuries may have resulted in a concussion, they were excluded because concussions were not verified. The database also does not include information about playing conditions that could influence concussion risk, such as playing surface or weather; therefore, these factors were not accounted for in our analysis. The study period does not account for any ankle injuries or concussions sustained prior to the study period's inception, nor ankle injuries and concussions sustained before a player began playing in the NFL, which could impact the results. From the data sources queried, there was no information discovered about ankle injury laterality; therefore, we cannot necessarily classify multiple ankle injuries as being recurrent. However, it must be noted that a history of ankle sprains has been previously found to increase risk of injury to the contralateral ankle.[5,11] Injuries may have been underreported by players, coaches, or medical staff. This study also did not look at return to play nor player performance following ankle injury or concussion, which is an area that should be further explored.

Conclusion

In our study spanning 11 NFL seasons, 941 players had an ankle injury, 633 players had a concussion, and 240 players experienced both an ankle injury and a subsequent concussion. Single ankle injuries were not associated with increased risk of concussion, but multiple ankle injuries were associated with an estimated 187% higher risk of subsequent concussion. Type of ankle injury was not associated with increased risk of concussion. Defensive backs, linebackers, offensive linemen, quarterbacks, running backs, tight ends, and wide receivers were at increased risk for concussion following 1 or more ankle injuries. Special teams had a significantly lower risk for concussion following ankle injury than offensive or defensive players. These results can be used to inform injury prevention practices in the NFL.

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