Video Analysis of Achilles Tendon Ruptures in the National Football League

Situational Patterns, Injury Mechanisms, and Paths for Injury Prevention

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Background: Achilles tendon ruptures (ATRs) are rare but severe injuries for players in the National Football League (NFL). Systematic video analysis of these injuries, combined with player tracking data and epidemiological analysis, can provide critical insight into the circumstances surrounding ATRs in the NFL and inform potential injury mitigation strategies.

Purpose: To characterize the injury scenarios and situational patterns associated with ATRs in the NFL through a retrospective review of all in-game ruptures over 7 seasons.

Study Design: Descriptive epidemiology study.

Methods: All ATRs from 7 seasons (2018-2024) of NFL games were identified through the NFL's league-wide electronic medical records and reviewed to identify the time of injury, player-to-player contact, and injury scenario. These data were integrated with player and game information to evaluate injury rates across player characteristics and game variables. Time-aligned player tracking metrics, including speed and direction of motion, were also calculated to evaluate player movements at the time of injury.

Results: A total of 77 ATRs occurred during NFL games from 2018 to 2024. These were primarily noncontact (64%) or indirect contact (35%) injuries that occurred at relatively low translational player speeds. Overall, 3 primary injury scenarios accounted for 97% of ATRs: change of direction (40%), overload (30%), and rock back (27%). Players typically had a similar body position at the time of injury. In most cases, the injured leg was extended behind the body, with the ankle dorsiflexed and the hip and knee extended. Defensive players and those with >3 years of NFL experience had a higher injury rate.

Conclusion: This study presents a comprehensive analysis of how ATRs occur in NFL games. The relatively low player speeds and predominantly noncontact nature of these injuries indicate that the high tendon loads that contribute to rupture are likely driven by player body positioning and propulsive push-off mechanics. Interventions that target high-risk player movement patterns could be effective injury prevention strategies, especially for rock back injury scenarios in which player motion appears to be more of a planned movement strategy rather than a reaction.

Keywords: football; Achilles tendon injury; video review; epidemiology

The Achilles tendon is the largest and strongest tendon in the human body, composed of 3 twisted subtendons: 2 originating from the medial and lateral heads of the gastrocnemius muscle and 1 from the soleus muscle.[13,41] It plays a critical biomechanical role in ankle function by transmitting force from the calf muscles to the calcaneus, enabling ankle plantarflexion.[13] The Achilles tendon, despite its exceptional tensile strength, is the most frequently ruptured tendon in the human body.[46] Most ruptures occur during athletic activities, affecting both recreational and professional athletes.[25,46]

In the National Football League (NFL), Achilles tendon ruptures (ATRs) are rare but devastating injuries for players. In terms of days lost due to injury, ATRs rank among the most severe musculoskeletal injuries in the NFL, comparable to anterior cruciate ligament (ACL) tears.[31] The mean time to return to play after an ATR exceeds 8 months, with many players requiring significantly longer recovery periods and some injuries proving to be career-ending.[5,31,33,47]

Several previously published studies have described the incidence and epidemiology of ATRs in the NFL using data sourced from publicly reported injury information.[24,40,43,47]

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While valuable, these studies are often limited by the nature of open-source reporting, which presents challenges with data completeness that can contribute to inaccuracies in reported results.[1,21,22,39] Additionally, these prior works have not included systematic analysis of injury videos, which can provide insight into the mechanism of injury and allow the identification of potential causal factors. Systematic video analysis has been used to investigate other high-impact injuries within football, as well as in other sports, to identify situational patterns and factors predictive of injury risk.[6,16,18,27,29,38] Outside of football, systematic video analysis has been applied to ATRs to better understand injury mechanisms and scenarios in professional basketball[23,26,42] and soccer.[11,20] To date, however, no such comprehensive video-based studies currently exist for ATRs in NFL athletes.

Additionally, the use of wearable technology to track on-field player movements has become widespread across professional sports leagues, including the NFL.[45] Typical outcome metrics derived from these player tracking technologies include position, speed, acceleration, and direction of travel, which can be used to quantify player movement demands and track player training loads.[44] By fusing time-synchronized player tracking data with systematic video analysis, researchers can analyze player movements leading up to and at the time of injury, providing additional insight into factors predictive of injury.

The purpose of this study was to characterize ATRs in the NFL by identifying and quantifying the scenarios and situational patterns in which these injuries occur. To do so, this study leveraged comprehensive video analysis of all ATRs sustained during NFL games from 2018 to 2024, merged with time-synchronized player tracking metrics as well as game and player epidemiological variables. By integrating multiple data sources, this study aimed to provide a robust characterization of how ATRs occur in NFL games to inform future evidence-based injury mitigation strategies.

METHODS

Inclusion Criteria and Injury Identification

This study retrospectively reviewed all ATRs that occurred over 7 seasons (2018-2024) of NFL games. Injuries sustained in preseason, regular season, and postseason games were all included. ATRs that occurred during the offseason, during practices, or outside of live game play were excluded. Injuries were identified through the NFL's centralized electronic medical record (EMR) system. Mandated injury reporting practices, as well as access to and use of the EMR system, are established by the collective bargaining agreement between the NFL and the NFL Players Association.[30] Injuries documented in EMR as either an "Achilles Tendon Rupture" or "Achilles Tendon Avulsion/Insertional Rupture" were included in this analysis. This retrospective observational study was reviewed and approved through the NFL's medical research approval process,[30] with oversight provided by the Mount Sinai Health System's Institutional Review Board.

Video Analysis and Injury Scenarios

Video analysis of each ATR was performed by 2 independent reviewers (R.H.T., B.G.) with expertise in musculoskeletal biomechanics. The reviewers were provided with all existing video feeds recorded by the NFL from the game associated with each injury, including broadcast, unaired, and fixed stadium views. For each game play, the reviewers typically had between 5 and 20 unique video views, captured at 30 to 60 frames per second. The reviewers used custom software to time-synchronize the multiple camera feeds, allowing the same instant to be reviewed across all available angles. The reviewers independently analyzed each injury using a standardized set of instructions and definitions. They marked the time of injury and initial foot contact and classified the player-to-player contact type and injury scenario (Table 1). For the time of injury, the reviewers marked the video frame in which they believed that the ATR occurred by first identifying the injurious step and then choosing the frame in which maximum dorsiflexion occurred if they could not visibly see the tendon recoil. Maximum dorsiflexion of the ankle was chosen to determine the timing of injury based on existing literature indicating that ATRs most often occur near peak dorsiflexion.[11,12,28] The player-to-player contact definitions (Table 1) are consistent with injury reporting recommendations and previous video analysis

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Ethical approval for this study was obtained from NFL's medical research approval process with oversight provided by the Mount Sinai Health System's Institutional Review Board.

TABLE 1
Definitions of Player-to-Player Contact Types and Injury Scenarios[a]

Contact Type	Description
Noncontact	The injured player was not in contact with any other player at the time of injury.
Indirect contact	The injured player was in contact with another player at a location outside the region of direct contact at the time of injury.
Direct contact	The injured ankle, ipsilateral leg, or ipsilateral foot was contacted by another player at the time of injury.
Injury Scenario	**Description**
Change of direction	The injured player changed direction, faked cut, or decelerated in response to another player or the football, with the intention of creating or closing space. There was no direct contact to the injured body region; thus, all loading was sustained through the cleat-surface interaction. There may be indirect contact, such as pushing or hand fighting.
Overload	Another player indirectly contacted the injured player, often upper body to upper body, typically through an intended action, such as blocking or tackling. In this scenario, the other player grabbed and maintained contact with the injured player during the injury. There was no direct contact to the injured body region; thus, all loading was sustained through the cleat-surface interaction.
Rock back	The injured player attempted to propel himself forward by pushing off his back foot. This movement strategy is typically preceded by a small hop and/or a drop in the center of mass (pelvis) to increase loading of the back foot and prepare for forward acceleration. In some cases, this is the very first motion made by the player after the ball is snapped. There was no direct contact to the injured region. Typically, this is a noncontact injury, but there may be indirect contact, such as pushing or hand fighting.
Landing	The injured player was injured while landing after a jump or dive. Typically, the injured player jumped to contest for the football (potentially to catch or block the football) and then landed, resulting in an injury. There was no direct contact to the injured body region; thus, all loading was sustained through the cleat-surface interaction.
Misstep	This scenario typically involves cleat-to-cleat contact in which another player directly contacted the injured player's ipsilateral foot, through an unintended action, either by stepping on the cleat of another player or having his cleat stepped on. The directly contacting body region was a small external mass, typically a foot, resulting in an additional external load to the injured aspect.

[a]All categories align with prior video analysis studies, with the exception of the rock back scenario.

studies.[3,11,20] The injury scenarios were defined by building on an existing list of scenarios used for video analysis of other football-related lower extremity injuries[37,38] and are intended to categorize injuries by their mechanism and football situation (Table 1). The definitions for change of direction, overload, landing, and misstep are in agreement with prior work analyzing other lower extremity injuries in the NFL.[37,38] An initial review of a subset of the ATR videos informed the addition of the rock back injury scenario. After incorporating this scenario, the full dataset was reviewed using the finalized classification framework (Table 1).

After an independent review, any conflicting responses between reviewers were discussed by a committee composed of the 2 independent reviewers and 3 additional experts in musculoskeletal biomechanics (C.M.O.C., L.C.S., E.M.S.) to reach a consensus decision. Interrater reliability between the primary reviewers, before the committee review, was quantified using percentage agreement and further evaluated with Cohen's kappa for injury contact and scenario.[34]

Epidemiological Variables and Injury Rates

Game, player, and participation information was obtained from the NFL's Game Statistics and Information System (GSIS). Injury incidence and rates were calculated and compared across key categorical player and game situation variables. These variables were selected for their relevance to potential intervention strategies and because they have been characterized in prior epidemiological studies of ATRs in professional sports.[11,19,20,24,42] Game situation characteristics obtained through the GSIS include season type (preseason, regular season, postseason), team phase (offense, defense, special teams), and play type (pass, rush, special teams). Player characteristics derived from the EMRs and GSIS include side of injury (left or right), experience (number of years in the NFL), age, and position. Player position was divided into 10 standard football position groups: defensive lineman, linebacker, cornerback, safety, offensive lineman, quarterback, running back, tight end, wide receiver, and special teams specialist (includes punter, kicker, and long snapper).[6,37,39]

Injury rates were calculated per 10,000 player-plays using the injury incidence (obtained from EMRs) and participation details for every NFL player in every game within the 7-season study window (obtained from the GSIS). A player-play was defined as one player's exposure during one play. There are 22 player-plays per down in the NFL (because 22 players are on the field for each down), approximately 160 plays per game, and 332 to 334 scheduled games per season, resulting in approximately 1 million player-plays per NFL season. In total, there were approximately 8 million player-plays during NFL games between 2018 and 2024. Injury rates were accompanied by a 95% confidence interval (CI) that was calculated using an exact Poisson CI rather than a normal approximation because of the extremely small event rate of ATRs. For select scenarios, exact Poisson regression was used to calculate incidence rate ratios (IRRs) to examine if there was a statistically significant association between the injury rate and the variable of interest. Statistical significance was set with an alpha of 0.05. All statistical analyses were performed using RStudio (Version 2024.12.0.467).

Player Tracking Data

Starting in 2018, standardized player tracking data have been collected during all NFL games using Next Gen Stats (NGS), a local positioning system developed by Zebra Technologies. This system uses ultra-wideband receivers and radiofrequency identification tags installed in every player's shoulder pads to capture on-field positions and movements during games. Tags are sampled at 10 Hz, and output metrics, including position, speed, and direction of motion, can be used to analyze player locomotion during games.[44]

The injury time marked by reviewers was synchronized with NGS tracking data to analyze player movements during the injurious play. Player speed (m/s) and direction of motion were computed for the moment of injury. Additionally, time to injury (s) and distance traveled before injury (m) were computed from ball snap to the moment of injury.

For further analysis, player speed at injury was normalized to each player's maximum positional speed and reported as a percentage of this value. The positional maximums used were those established by Sanchez et al[44] and defined as the 75th percentile of peak speeds observed across all player-games over 3 seasons of NFL play. This normalized metric provides a measure of intensity that accounts for the distinct movement demands of different player groups based on their football position. Coaches and trainers often interpret the speed, movement intensity, and effort of athletes using a framework of "zones" defined by percentage thresholds.[7,14,15,17] To align with this framework, the normalized speed at injury was combined with this zone framework to provide a practical interpretation of these results and relevant insights for coaches and trainers. Based on data from Sanchez et al[44] and expert opinion, 5 speed zones were established with thresholds at 15%, 35%, 60%, and 85% of maximum positional speed. The 5 zones were defined as follows: Z1, walking (<15%); Z2, jogging ($\geq$15%-<35%); Z3, striding ($\geq$35%-<60%); Z4, running ($\geq$60%-<85%); and Z5, sprinting ($\geq$85%).

Direction of motion at injury was computed to characterize if a player was moving forward, backward, or laterally at the time of injury. This metric was calculated as the difference between the player's orientation angle and direction of travel angle, both reported by NGS within a field-based coordinate frame. Taking the difference between these 2 angles provides the player's direction of motion in the local player-based coordinate frame in which 0° indicates that the athlte is moving straight forward and 180° indicates that the athlete is moving straight backward. The derived direction of motion at injury was binned into 45° categories and reflected with values between 180° and 360°, mirrored to be between 0° and 180° (eg, 270° became 90°). This simplification allowed left and right movements to be grouped as more general lateral motion to aid in visualization and interpretation.

RESULTS

Video Analysis

Between the 2018 and 2024 seasons, 78 ATRs occurred during NFL games. These injuries occurred to 77 unique players, with 1 player sustaining 2 in-game ATRs (1 in each leg) 3 seasons apart. Video was available for all 78 ATRs, and the 2 independent reviewers identified and agreed on the injury play in 100% of cases. One injury, which occurred as the player was running onto the field between plays, was excluded from further analysis because it did not happen during live play. Therefore, this analysis characterized 77 of 78 ATRs that occurred during NFL games between 2018 and 2024.

Reviewers agreed on the exact step when the injury occurred in 78% (60/77) of cases. For these 60 injuries, the 2 reviewers were within 0.05 ± 0.04 seconds for marking the time of injury, which is equivalent to 1 to 2 video frames. Agreement on player-to-player contact was 92% (71/77), with a kappa statistic of 0.84 (95% CI, 0.71-0.96), suggesting "almost perfect" interrater relability.[34] Agreement on injury scenario was 75% (58/77), with a kappa statistic of 0.65 (95% CI, 0.52-0.79), suggesting "substantial" agreement.[34] In total, 32 injuries were reviewed by the committee to reach consensus for time of injury, player-to-player contact, and injury scenario.

Across the 77 injuries, the ATR occurred, on average, 0.12 ± 0.05 seconds after initial foot contact with the ground. Overwhelmingly, ATRs did not involve direct player-to-player contact. Most injuries were noncontact (64%), with indirect contact (35%) accounting for nearly all others (Table 2). Only 1 injury involved direct contact from another player to the injured player's foot at the time of injury.

Overall, 3 injury scenarios, change of direction, overload, and rock back, accounted for 97% of all ATRs (75/77) (Table 2). Change of direction injuries were primarily (87%) noncontact (Table 2). By definition (Table 1), all overload injuries involved indirect contact, typically in the form of upper body contact during blocking. All 21 rock back ruptures were noncontact injuries (Table 2). One injury resulted from landing (1%), and the only direct contact injury was a misstep (1%).

For most injuries, a consistent sequence of movements and body positioning was identified leading up to the time of injury (Figure 1). In most cases, players took a backward step with the injured limb, placing it far behind their center of mass. At the time of injury, the injured ankle had a high degree of dorsiflexion, and the hip and knee of the

TABLE 2
Achilles Tendon Ruptures in NFL Games (2018-2024)[a]

	All Ruptures (n = 77)	Change of Direction (n = 31)	Overload (n = 23)	Rock Back (n = 21)
Contact type				
Noncontact	49 (64)	27 (87)	0 (0)	21 (100)
Indirect contact	27 (35)	4 (13)	23 (100)	0 (0)
Direct contact	1 (1)	0 (0)	0 (0)	0 (0)
Team phase				
Offense	31 (40)	11 (35)	13 (57)	7 (33)
Defense	42 (55)	17 (55)	9 (39)	14 (67)
Special teams	4 (5)	3 (10)	1 (4)	0 (0)
Player position				
Cornerback	7 (9)	3 (10)	1 (4)	3 (14)
Defensive lineman	11 (14)	2 (7)	6 (26)	3 (14)
Linebacker	17 (22)	9 (29)	3 (13)	3 (14)
Offensive lineman	14 (18)	2 (7)	11 (48)	1 (5)
Quarterback	3 (4)	0 (0)	1 (4)	2 (10)
Running back	5 (7)	3 (10)	1 (4)	1 (5)
Safety	11 (14)	6 (19)	0 (0)	5 (24)
Tight end	5 (7)	4 (13)	0 (0)	1 (5)
Wide receiver	4 (5)	2 (7)	0 (0)	2 (10)
Play type				
Pass	52 (68)	23 (74)	17 (74)	11 (52)
Rush	21 (27)	5 (16)	5 (22)	10 (48)
Special teams	4 (5)	3 (10)	1 (4)	0 (0)
Season type				
Preseason	11 (14)	3 (10)	5 (22)	3 (14)
Regular season	62 (81)	27 (87)	15 (65)	18 (86)
Postseason	4 (5)	1 (3)	3 (13)	0 (0)
Side of injury				
Right	34 (44)	13 (42)	8 (35)	12 (57)
Left	43 (56)	18 (58)	15 (65)	9 (43)
Age, mean ± SD, y	27.5 ± 3.2	27.2 ± 2.4	28.4 ± 4.1	26.8 ± 2.7
Experience in the NFL				
≤3 years	33 (43)	13 (42)	8 (35)	11 (52)
>3 years	44 (57)	18 (58)	15 (65)	10 (48)

[a]Data are shown as n (%) unless otherwise indicated. Columns for landing (n = 1) and misstep (n = 1) scenarios are not included, but these injuries are included in the all ruptures column. NFL, National Football League.

injured limb were often in extension. When injured, athletes were primarily loading the injured limb, and in many cases, their contralateral foot was completely unloaded and not in contact with the field.

Epidemiological Variables and Injury Rates

Over 7 seasons of NFL play (2018-2024), a mean of 11 in-game ATRs occurred per season (range, 7-15), with the highest number of injuries occurring in 2021 and 2023 (n = 15) (Appendix Table A1 [available in the online version of this article]). Approximately 8 million player-plays occurred in the NFL during these 7 seasons, providing an overall injury rate of 0.10 per 10,000 player-plays (95% CI, 0.08-0.12).

Team Phase and Player Position. Defense accounted for the highest number (n = 42 [55%]) and rate (0.13 injuries per 10,000 player-plays) of ATRs, followed by offense (n = 31 [40%]; 0.09 injuries per 10,000 player-plays) (Table 2 and Figure 2). Special teams plays had the fewest injuries (n = 4 [5%]) and the lowest rate (0.03 injuries per 10,000 player-plays), which was significantly lower than the offensive injury rate (IRR, 0.32 [95% CI, 1.03-2.69]; P = .026) (Appendix Table A2 [available online]). None of the injuries on special teams plays involved special teams–specific players (eg, kicker, punter), as all 4 injured players had designated positions within the other 9 position groups. Safeties and linebackers had the highest positional injury rates (Figure 3). While offensive and defensive linemen had high injury counts (Table 2), their injury rates were lower (Figure 3) because these positions account for a larger share of on-field player exposure.

The elevated injury rate on defense persisted across both change of direction and rock back scenarios (Figure 2). For change of direction injuries, the highest rates were seen among safeties, linebackers, tight ends, and running backs (Figure 3). Every position group had at least 1 rock back injury, with safeties experiencing the highest rate. In contrast to the other injury scenarios, the highest rate of overload injuries was on offense (Figure 2). Offensive and defensive linemen had the highest rate of overload

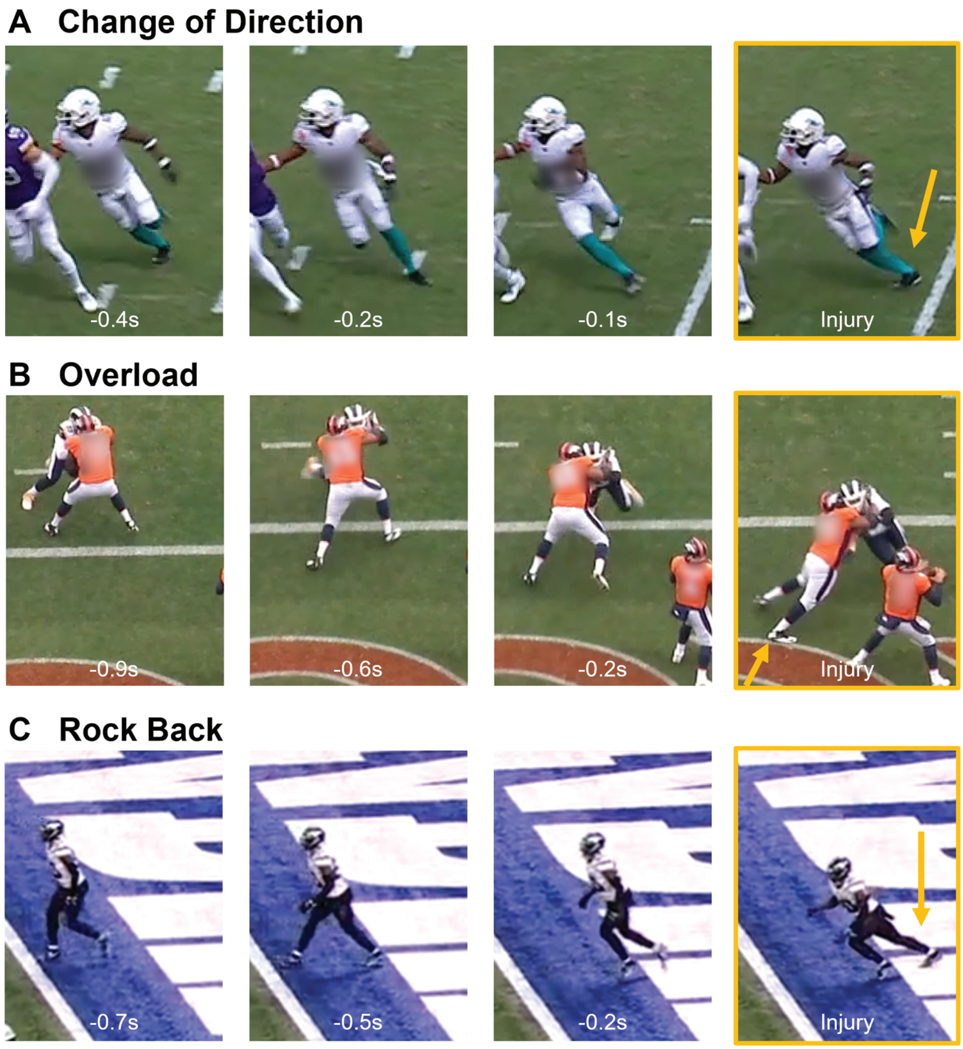

Figure 1. Images of a representative Achilles tendon rupture for each of the 3 primary injury scenarios: (A) change of direction, (B) overload, and (C) rock back. Moving from left to right, the images in each row show the player's motion leading up to the marked time of injury. The right image of each row displays the moment of injury.

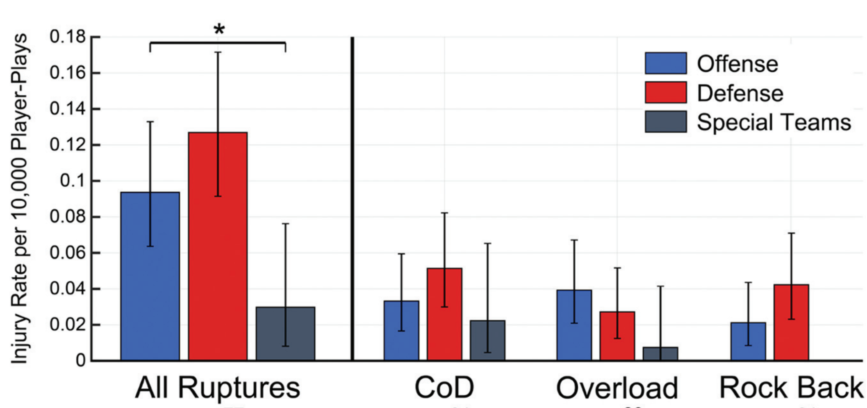

Figure 2. Injury rate by team phase displayed per 10,000 player-plays with 95% confidence intervals. Injury rates are shown for all Achilles tendon ruptures (n = 77) and for the 3 main injury scenarios: change of direction (CoD; n = 31), overload (n = 23), and rock back (n = 21). *Significant difference detected between the injury rate on offense and special teams (*P* = .026).

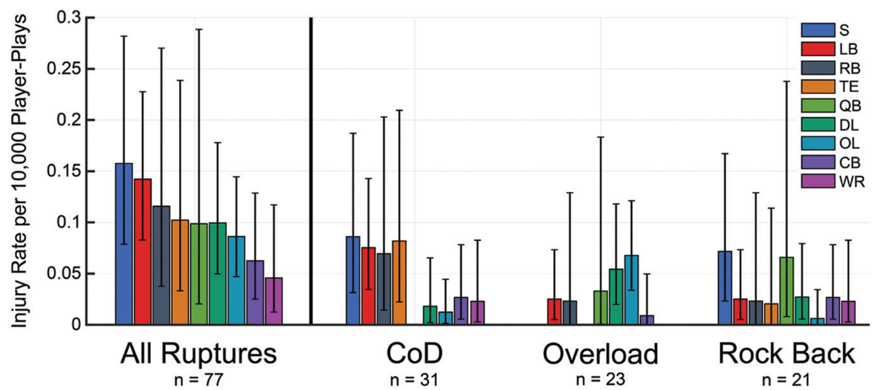

Figure 3. Injury rate by player position displayed per 10,000 player-plays with 95% confidence intervals. Injury rates are shown for all Achilles tendon ruptures (n = 77) and for the 3 main injury scenarios: change of direction (CoD; n = 31), overload (n = 23), and rock back (n = 21). Player position groups are safety (S), linebacker (LB), running back (RB), tight end (TE), quarterback (QB), defensive lineman (DL), offensive lineman (OL), cornerback (CB), and wide receiver (WR).

injuries, comprising 74% of these ruptures (Table 2 and Figure 3).

Play Type. Over two-thirds of the ATRs occurred on pass plays (Table 2), resulting in an injury rate of 0.14 injuries per 10,000 player-plays. This rate was significantly higher than that of rush plays (0.08 injuries per 10,000 player-plays; IRR, 0.57 [95% CI, 0.33-0.96]; P = .034) and special teams plays (0.08 injuries per 10,000 player-plays; IRR, 0.22 [95% CI, 0.06-0.60]; P = .001) (Appendix Table A3 [available online]).

Season Type. Most ATRs occurred during regular-season games (81%) (Table 2), but the injury rate was similar across preseason, regular-season, and postseason games ($P > .8$), with both the preseason and regular season having a rate of 0.10 injuries per 10,000 player-plays (Appendix Table A4 [available online]). Additionally, there were no significant differences in the injury rate by game quarter (full incidence and rate results in Appendix Tables A1 and A5 [available online]).

Age and Experience in NFL. The mean age of players who sustained an ATR was 27.5 years and was similar across the 3 primary injury scenarios (Table 2). This was comparable to the mean age of all NFL players who participated in a game from 2018 to 2024, which was approximately 26 years. To examine player experience, the data were grouped using a threshold of 3 years playing in the NFL. This is the median experience of players in the NFL and has been used as a threshold for previous analyses.[39] Players with >3 years of experience accounted for 57% of ATRs (Table 2), with a rate of 0.12 injuries per 10,000 player-plays (Appendix Table A6 [available online]). This was a significantly higher injury rate compared to players with ≤3 years of experience (0.07 injuries per 10,000 player-plays), with an IRR of 1.66 (95% CI, 1.03-2.69; P = .036) (Appendix Table A6).

Player Tracking Data

The median player speed at the time of injury across all ATRs was 2.5 m/s, or 33% of maximum positional speed once normalized (Figure 4). The subset of injuries that were change of direction had a median speed of 3.7 m/s at injury, and overload injuries had a median speed of 2.7 m/s. Injuries classified as rock back had the slowest player speeds at injury (median, 1.2 m/s). Half of all ATRs occurred in Z1 (walking) and Z2 (jogging) (Figure 4B). All 7 ATRs that occurred with players moving at speeds in Z4 or Z5 were change of direction injuries. Notably, rock back injuries occurred almost exclusively at player speeds in Z1 and Z2, with a median of 15% of maximum positional speed (Figure 4B).

Overall, ATRs occurred in players moving in various directions, with no single primary direction of motion at injury (Figure 5). However, when stratified by injury scenario, distinct patterns emerged. For change of direction injuries, most players were moving forward, often with some lateral motion. Nearly 40% occurred with forward/lateral motion (45° in Figure 5). In contrast, overload injuries more frequently involved lateral or backward player motion compared to the other scenarios (Figure 5). Rock back injuries predominantly occurred with forward motion at the time of injury. Almost half (48%) of the rock back injuries involved players moving directly forward (0° in Figure 5). Reviewers consistently observed that at the time of injury, the injured leg was extended behind the athlete, often with the upper body rotating anteriorly relative to the center of mass (Figure 1). This trunk rotation during the injurious step resulted in their shoulders moving forward at the time of injury, as reflected in Figure 5 by the prevalence of forward motion, particularly in rock back injuries.

DISCUSSION

Injury Scenario Breakdown

Change of direction was the most common ATR scenario in NFL games, accounting for 40% of all ruptures. These injuries typically occurred when players planted their injured

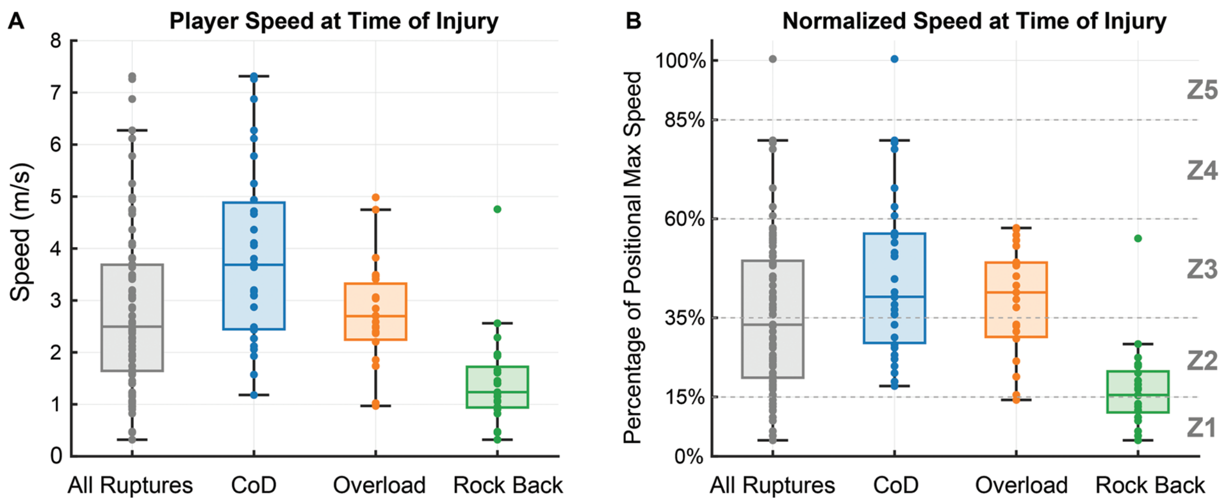

Figure 4. (A) Player speed at the time of injury. (B) Player speed at the time of injury normalized to each player's maximum positional speed[44] with percentage-based zones as follows: Z1, walking (<15%); Z2, jogging (≥15-<35%); Z3, striding (≥35-<60%); Z4, running (≥60-<85%); and Z5, sprinting (≥85%). Data are grouped to show results for all (n = 77) ruptures in gray, change of direction (CoD; n = 31) ruptures in blue, overload (n = 23) ruptures in orange, and rock back (n = 21) ruptures in green.

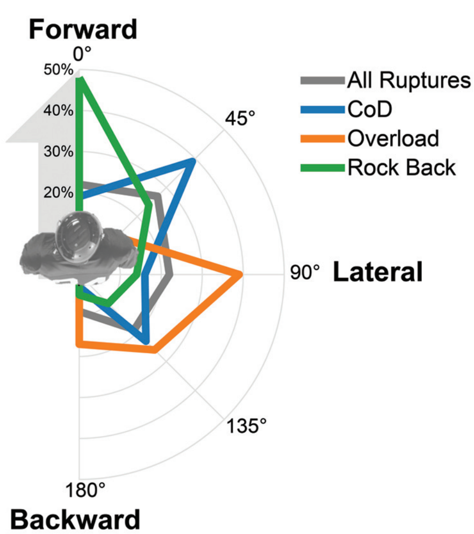

Figure 5. Direction of player motion at the time of injury. Direction of motion was rounded to the nearest 45° and grouped from 0° to 180°. Line magnitude is the percentage of injuries for that direction of motion within each group. The 4 groups presented are as follows: all (n = 77) ruptures in gray, change of direction (CoD; n = 31) ruptures in blue, overload (n = 23) ruptures in orange, and rock back (n = 21) ruptures in green. Player orientation (the direction in which the player was facing) is represented as 0°.

limb to cut or change direction in response to live play, with the intent of creating or closing space (Table 1 and Figure 1). Most were noncontact (Table 2) and involved lateral motion (Figure 5). Although the median speed at injury was highest for this scenario (3.7 m/s), most injury speeds still fell within the low to moderate player intensity zones (Figure 4). Similar to the overall ATR cohort, most change of direction injuries occurred on defense (Table 2 and Figure 2), with safeties, linebackers, running backs, and tight ends exhibiting the highest injury rates (Figure 3).

The overload injury scenario accounted for 30% of ATRs and was most commonly observed among offensive and defensive linemen engaged in blocking at the line of scrimmage (Table 2). A few overload injuries involved players being tackled, although without direct contact to their injured lower limb. Indirect contact with another player often disrupted the injured athlete's body positioning, which contributed the him extension of the injured leg far behind the athlete's center of mass in an attempt to resist or redirect the force from the opposing player (Figure 1). Offensive and defensive linemen predictably had the highest rate of overload injuries (Figure 3). Overload is a mechanism of injury that has been observed for other football injuries[6,38] but is rare or absent in analyses of ATRs in other sports.[11,20,26,42] This is likely due to the absence of tackling and sustained blocking situations that are common in football but not present in sports such as basketball and soccer.

The ATRs classified as rock back emerged as a particularly unique and interesting group of injuries, accounting for 27% of the ruptures in the NFL from 2018 to 2024. Overall, rock back injuries were 100% noncontact and typically occurred with volitional motion at very low overall movement speeds. When examining these injuries in more detail, 3 highly specific football situations emerged that further describe most (18/21) of the rock back injuries. First, 6 ATRs in this cohort occurred within 0.6 seconds of ball snap. These injuries occurred on the player's very first step of the play as the athlete attempted to accelerate forward off or toward the line of scrimmage. This is where the label of rock back for this group of injuries originated, as this term refers to a movement strategy in which a player "rocks back" to load his back leg as a strategy to accelerate forward from standing. Next, 7 injuries specifically occurred to defensive secondary players (cornerbacks and safeties) who were backpedaling and then ruptured their Achilles tendon when transitioning out of their backpedal to accelerate forward. Lastly, 5 injuries occurred to players in the backfield (behind the line of scrimmage) after the ball had moved away. These players all seemed to be "resetting" after the play had moved away by performing a small hop and extending one leg behind them to begin moving downfield. Compared to the other injury scenarios, player motion during rock back injuries could be considered a movement strategy rather than a reaction. Often, athletes were attempting to propel themselves forward from a stationary or semistationary position by pushing off their injured limb, which was extended far behind them (Figure 1). The median speed for rock back injuries was 1.2 m/s, which is a typical walking speed. Consistent with this finding, all but one of these injuries occurred within the normalized speed zones of Z1 and Z2 (Figure 4). At least 1 rock back injury was observed for all position groups (Table 2 and Figure 3), but the injury rate was higher for defensive players overall compared to offensive players (Figure 2).

Comparison to Other Sports

Our results align with prior video-based investigations of ATRs in other sports, such as basketball and soccer, which have also found that these injuries rarely result from direct contact to the affected limb.[11,20,26,42,49] In these sports, athletes most often rupture their Achilles tendon during noncontact events and have a characteristic movement pattern preceding the injury that involves a backward step that extends their leg far behind their center of mass.[20,26,42] Notably, the rock back injury scenario identified in this study is a prevalent injury mechanism of ATRs in other sports. In professional basketball, this same movement pattern has been termed a "false step" or "takeoff/acceleration" scenario and accounts for over two-thirds of ATRs.[23,26,42] In professional soccer, 35% to 42% of ATRs have been attributed to similar scenarios labeled by researchers as "stepping back," "starting," or "forward acceleration from standing."[12,20] This consistency in injury scenarios and mechanism across sports suggests that specific movement patterns, along with intrinsic biomechanical factors, likely play a central role in Achilles tendon injury risk for elite athletes.

Comparison to Other Injuries

Compared to other high-impact injuries in football, such as ACL tears, hamstring strains, and concussions, ATRs stand out because of the lack of player contact and the relatively low translational speeds at which they occur. Similar to ATRs, ACL tears are high-burden lower extremity injuries in the NFL in which most injuries are not a result of direct player-to-player contact.[6] Change of direction is the most common injury scenario for ACL tears in the NFL, and these injuries typically occur at high player speeds and intense decelerations. An analysis of 100 change of direction ACL tears in NFL games by O'Cain et al[37] found a median player speed of 5.3 m/s at the moment of injury, which is substantially higher than the median speeds in this study: 2.5 m/s across all ATRs and 3.7 m/s for the ruptures categorized as change of direction (Figure 4A). High player speeds are also associated with other injuries: hamstring strains frequently occur during sprinting,[36] and concussions are often associated with high-speed impacts.[4,35] In contrast to these other frequently investigated injuries, ATRs tend to occur at relatively low whole-body movement speeds (Figure 4). Additionally, unlike ACL tears and concussions, which historically are more common on special teams plays because of high-speed, open-field situations,[32,35,39] ATRs have a lower injury rate on these plays (Figure 2 and Appendix Table A3). These distinctions suggest that intervention strategies focused on reducing high-speed collisions that are relevant for lowering certain other football injuries may have limited relevance for mitigating ATRs. Alternatively, injury-specific approaches should be explored to address this unique injury mechanism.

Practical Applications and Interventions

The low translational player speeds and predominantly noncontact nature of ATRs indicate that the high tendon loads leading to failure are likely driven by player body positioning and local joint mechanics rather than external loads or high-velocity running. From qualitative observation during video analysis, the injured leg was loaded with the ankle in a dorsiflexed position for all injury events. Typically, this leg was positioned behind the athlete's center of mass with an extended knee and hip, and the trunk was positioned anterior to the center of mass (Figure 1). When this limb is loaded, the calf muscles eccentrically contract to create a supportive internal plantarflexion moment. This contraction, combined with a high degree of ankle dorsiflexion, likely places the Achilles tendon under high tension as it stretches to store elastic energy. The typically observed single-leg loading, extremely posterior foot position, and trunk rotation all contribute to the high forces that are applied to the tendon in this stretched position. The single-leg stance concentrates the athlete's loading to only the injured limb, while the significant distance between the injured ankle and the athlete's center of mass creates a large moment arm for the resulting plantarflexion moment acting around the joint. These combined factors make this push-off position biomechanically demanding for the Achilles tendon and may create a "perfect storm" of tendon loading that leads to rupture, even for what may be perceived as a relatively low-intensity movement overall.[12] While these interpretations are based on qualitative analysis of observed movement patterns rather than direct measurements of joint kinematics or ground reaction forces, the proposed biomechanical mechanism is consistent with fundamental principles and previously described mechanisms for ATRs.[9,11,12,23,26,42]

These findings highlight the potential for injury mitigation strategies that target underlying player movement patterns. Coaches may be able to train athletes to have effective movement strategies to still perform at the highest level but avoid risky mechanics that generate high Achilles tendon loads. For example, coaches could emphasize retaining a degree of knee or hip flexion during backward steps, which would reduce how far the athlete's back foot is placed behind their body. In particular, defensive back coaches could work with safeties and cornerbacks to encourage this technique when they are breaking out of their backpedal, which is a common football scenario for ATRs. Additionally, coaches could encourage players to distribute force more evenly between limbs when pushing off from a set stance, which would reduce high forces on the Achilles tendon in their back leg and potentially help reduce ruptures that occur immediately after ball snap. These coaching and training approaches may not only be particularly effective in mitigating rock back injuries, which occurred at remarkably low speeds and with volitional player movement, but could also help prevent change of direction ruptures, which share similar mechanics and were also predominantly noncontact.

Underlying tendon health is also a critical factor when assessing the risk of ATRs. It is possible that some players may have had preexisting tendon degeneration that reduced the load tolerance of their Achilles tendon. Although ATRs often occur without prior symptoms or warning signs, athletes who have had chronic Achilles tendinopathy or a prior ATR are known to be at an increased risk of injury.[2,19,48] This analysis did not evaluate detailed athlete injury history. An in-depth investigation of prior injuries and their potential associations with ATRs would be valuable in establishing a more complete understanding of risk factors. This analysis did, however, examine athlete age and experience in the NFL. While the mean age of players who experienced an ATR was 27.5 years (Table 2), players with >3 years of experience in the NFL had an increased risk of injury compared to those with ≤3 years (Appendix Table A3). Prior studies have demonstrated that Achilles tendon stiffness and elasticity decline with age, potentially compromising the tendon's ability to tolerate high forces.[10,13,19] This suggests that veteran players and players with prior calf and Achilles tendon injuries should be monitored for targeted intervention strategies that aim to improve tendon health and mechanics. While there is limited research investigating evidence-based interventions to reduce ATR risk, existing studies have shown that targeted resistance training approaches can improve Achilles tendon properties,[13] which may offer protective benefits against ruptures. Interestingly, there is evidence that imaging modalities, such as ultrasound, can detect preclinical tendon abnormalities that are predictive of injury risk.[8] It is worthwhile to consider screening athletes for underlying tendon abnormalities, but it may be logistically challenging to implement league-wide because of the required intensive clinician time and large roster sizes in the NFL.

There was no difference in the injury rate between preseason, regular season, and postseason games (Appendix Table A4), and similarly, there was no detectable difference in the injury rate across game quarters (Appendix Table A5). These findings indicate that ruptures occurred at a consistent frequency throughout the NFL's competitive calendar and the duration of a game. This consistency contradicts previous analyses based on publicly available datasets, which report higher early-season injury rates for ATRs in the NFL.[24,43] These discrepancies likely stem from differences in the study period, inclusion criteria, and completeness of the data sources. Investigations by Ready et al[43] and Krill et al[24] analyzed the 2009 to 2016 seasons, which precede the 2018 to 2024 seasons examined in this study. Ready et al[43] included practice-related injuries in their cohort, which likely contributed to their higher reported preseason injury percentages. While Krill et al[24] identified higher injury rates in the first half of the regular season across a sample of 44 ruptures, their analysis did not specifically evaluate the preseason. Additionally, these investigations relied on publicly obtained data, which are prone to inaccuracies due to underreporting of the true injury incidence and a bias toward high-profile players.[21,22]

The consistent distribution of ATRs across the season is another notable distinction from ACL tears and overall lower extremity injury patterns in the NFL in which preseason games are reported to have a higher rate of injuries compared to regular season games.[31,39] It is important to note that our study characterized injuries that occurred during NFL game play, and ATRs that occur in practice may have a different distribution across season types and other variables. Nevertheless, this analysis suggests that the in-game injury risk remains relatively consistent throughout the season, emphasizing the need for year-round prevention strategies.

Limitations and Future Work

This study did not quantify joint angles at the time of injury and instead reported characteristic body position attributes observed during video analysis. This approach was taken because visual estimations of joint angles are often inaccurate[36] and challenging for some injury instances based on available video views. Additionally, the player tracking data used in this study were sampled at 10 Hz. This sampling frequency may limit the ability to capture extremely rapid movement changes around the injury event, such as brief peaks in velocity or abrupt changes in orientation occurring over intervals shorter than 100 milliseconds. Despite this limitation, this study provides comprehensive player tracking data and represents the most advanced and complete dataset currently available for quantifying player movements in live NFL competitions. Future research leveraging computer vision–based motion capture with higher frequency data from emerging technology could be utilized to provide more accurate biomechanical assessments of player motion surrounding the time of injury.

While all ATRs included in this analysis were acute injuries reported as ruptures, this study did not report the specific rupture type or examine any preexisting symptoms or abnormalities that may have influenced the injury event. Also, clinical treatment and outcome data were not included in this analysis, but future research exploring the relationship between injury mechanisms, epidemiological factors, and player outcomes would be valuable.

Although these findings do not demonstrate a clear association between temporal variables and the injury risk at the population level, the player movement–driven and soft tissue nature of ATRs highlights individual workload and exposure as an interesting area for future research. Future work could investigate whether individual athlete participation and workload metrics influence the injury risk across the duration of a game or an entire season. Evaluating participation data (eg, session frequency, playing time, and play counts) alongside player tracking metrics (eg, cumulative distance and frequency of acceleration events) could provide a more complete understanding of whether specific fatigue patterns or workload spikes are associated with risk of ATR.

Finally, this study exclusively analyzed in-game injuries. Future investigations should extend this work to evaluate practice-related ATRs to determine whether the movement patterns and mechanisms identified here are similarly prevalent in non-game settings and whether similar injury prevention strategies are applicable in those contexts.

CONCLUSION

This study presents a systematic video analysis of every ATR sustained during an NFL game from 2018 to 2024, capturing the complete cohort of 77 injuries over these 7 seasons. By integrating a robust video analysis with game and play information, epidemiological factors, and player tracking data, the results offer a comprehensive characterization of the injury mechanisms and situational contexts of these injuries. ATRs in the NFL were primarily noncontact and indirect contact injuries that occurred within 3 injury scenarios: change of direction, overload, and rock back. Players on defense and those with >3 years of NFL experience had an increased injury rate. The low translational speeds and noncontact nature of ATRs indicate that the high tendon loads leading to failure are likely driven by player body positioning and push-off mechanics. This suggests that targeting high-risk player movement patterns could be an effective injury prevention strategy, especially for rock back injury scenarios in which player motion is more of a planned movement strategy rather than a reaction.

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