Injury Scenarios of Ankle Sprains in the National Football League

External Rotation and Eversion Mechanisms

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Background: Ankle sprains in American football resulting from external rotation and eversion (EE) mechanisms remain a persistent injury that often involves player-to-player contact. Currently, there is little research that describes the frequency or source of this contact in American football and what scenarios are responsible for these injuries across different player positions.

Purpose: To identify injury scenarios of ankle sprains that result from EE mechanisms in the National Football League (NFL).

Study Design: Descriptive epidemiology study.

Methods: Ankle sprains reported during NFL games over 4 consecutive seasons (2017-2020) were identified through a query of the NFL Electronic Medical Record by an independent epidemiological company based on a set of clinical impression codes. Injuries with available video to view the injury enabled the identification of ankle sprains that resulted from EE mechanisms. Standardized terminology was developed to systematically describe and categorize each injury.

Results: A total of 257 ankle sprains resulting from EE mechanisms were identified from a review of 670 ankle sprains and grouped into 8 standardized injury scenarios. Direct contact to the injured player's foot, ankle, or leg from a large external mass, such as an opponent's pelvis, accounted for 79% of reviewed injuries. Direct contact from a large external mass was the most common scenario for all positions except safeties, and 83% of running back injuries were the result of a tackle. Only 15% of injuries reviewed resulted from injury scenarios in which injurious loading was transmitted solely through the cleat-surface interaction. Safeties and cornerbacks were more commonly involved in these nondirect injury scenarios, such as change of direction, where current interventions may prove more effective.

Conclusion: EE ankle sprains were observed to occur from 8 different injury scenarios that varied by player position. Interventions through training, bracing, or changing cleat-surface interaction may not be effective for all injury scenarios. Tackling technique may be a unique intervention for running backs.

Keywords: football (American); ankle ligaments; medical aspects of sports; injury prevention; video review

Ankle sprains remain one of the most common injuries in American football.[16,18,28] In the National Football League (NFL), the ankle is the second most injured joint, behind the knee, with little change in incidence over 4 seasons.[18]

Ankle sprains are commonly classified based on the ligaments damaged and the severity of the injury.[11,29] Typical classifications include lateral, medial, or high ankle sprains, while severity is described by a scale with 3 grades.[12,22,29] Concomitant injuries such as tendon strains, intra-articular injuries, and fibular fractures can also occur from shared injury mechanisms.[16,25] While accurate reporting of anatomic injury patterns is crucial for studies assessing the effectiveness of treatments, ankle sprains can present with a variety of patterns for mechanistically similar loading conditions.[19] Therefore, when analyzing injuries for the purpose of developing prevention strategies, studies that specify inclusion criteria based solely on anatomy may inadvertently exclude injuries that involve separate anatomic structures but occur from shared mechanisms, making assessments of intervention effect difficult to acertain.[23] An alternative approach is to categorize injuries according to their mechanism. For example, a combination of internal rotation and inversion (II) of the ankle and variably including plantarflexion is typically responsible for lateral ankle sprains but can

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also cause additional concomitant injuries.[14,29] Similarly, a combination of external rotation and eversion (EE) of the ankle and variably including dorsiflexion is commonly associated with high and medial ankle sprains.[6,22,29] Segregating ankle sprains into these common mechanistic groups can allow for injury mitigation strategies tailored to the injurious mechanisms as opposed to anatomic regions of injury.

Of the 2 commonly reported injury mechanism groups, ankle sprains that result from EE mechanisms are less common but result in longer recovery times than ankle sprains that result from II mechanisms.[16,18] Ankle sprains that result from an EE mechanism have been reported to result from contact between players, specifically involving a lateral load to the leg.[1,3] However, little documentation exists to describe the source of this lateral load, or the prevalence of player-to-player contact involved. Furthermore, different player positions have different incidence and rates of ankle injuries.[28] Thus, it is not clear if EE ankle sprains for different player positions result from different injury scenarios. Identification of position-specific mechanisms has been previously suggested to help tailor injury prevention efforts to position-specific solutions.[4] Given the current lack of specificity around mechanistic understanding for these ankle injuries, understanding the contact, loading, and positional variations of EE injury scenarios is a necessary first step to designing effective intervention strategies.

To characterize these mechanistic groups, we leveraged in-game video to compile detailed scenarios of injury for analysis. Video analysis is frequently used to obtain insight into the biomechanics of sports injury, with multiple reviewers viewing an injury, generating consensus on injury causation, and devising a plan for injury reduction.[1,13,15] Broadcast footage of NFL games provides multiple views of each play, allowing for viewing of injuries when they occur, and NFL player injuries are documented through a standardized electronic medical record (EMR).[7,15] Therefore, the goal of the current analysis was to perform a video analysis of confirmed EE ankle sprains reported in NFL games to characterize common injury scenarios by player position.

METHODS

Identification and Inclusion of Injuries

Missed-time ankle sprains sustained by NFL players were reviewed over 4 NFL seasons: 2017, 2018, 2019, 2020. Injuries were identified through a query of a league-wide EMR[7] conducted by an independent epidemiological company, IQVIA. The NFL EMR was a result of collective bargaining between the NFL and the National Football League Players Association (NFLPA); it serves as a workplace injury recording system. NFL players sign authorization forms to allow the data provided to this system to be used in furtherance of approved research by the NFL and the NFLPA. Approval for this study was obtained through the NFL-NFLPA collective bargaining agreement and the Player Scientific and Medical Research Approval Process,[17] and an external institutional review board organized through the Mount Sinai Health System was retained to provide oversight of the approved study.

Ankle sprains identified from the EMR were included based on clinical impression codes[7]: "High Ankle Sprain/Syndesmotic," "High Ankle Sprain/Anterior Tibiofibular," "High Ankle Sprain/Posterior Tibiofibular," "Medial Ankle Sprain/Deltoid," "Lateral Ankle Sprain/Anterior Talofibular," "Lateral Ankle Sprain/Calcaneofibular," "Lateral Ankle Sprain/Posterior Talofibular," and "Lateral Ankle Sprain/Ligament Unknown."

Each injury is linked to a unique game and play. The specific play in which each injury was sustained was confirmed based on review of video. Ankle sprains for which an injury play could not be identified (33%) were excluded from analysis.

Video Sources

For each injury play, available video footage was obtained from 4 distinct video sources: (1) "all-22" footage, which included wide-angle end zone and sideline views; (2) network broadcast footage, which included all footage aired during the televised broadcast of the game; (3) NFL Films footage, which is frequently shot for the purposes of documentaries; and (4) network "melt reel" footage, which is video shot by the network but not included in the televised feed of the game. Each injury play was reviewed using all available video. A web application was created to consolidate available video footage and associate it with each unique injury play as well as other relevant review information such as player position, jersey number, and team. Original video frame rates and resolutions were preserved to allow frame-by-frame inspection.

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TABLE 1
Standardized Video Review Parameters

Parameter	Description
Injury play: play type[a]	Field goal/extra point, pass, rush, punt returned, punt not returned, kickoff returned, kickoff not returned
Injured player position[a,b]	Cornerback, defensive line, kicker, linebacker, offensive line, quarterback, running back, safety, tight end, wide receiver
Injured aspect[a]	Left ankle, right ankle
Injury mechanism[c]	External rotation and/or eversion, internal rotation and/or inversion, other direct, indirect, noncontact
Player-to-player contact[c]	Direct, indirect, noncontact
Directly contacting body region[c]	No contact, helmet, arm/hand, shoulder, torso, pelvis, thigh, leg/foot
Loading type[c]	No external mass, small external mass, large external mass
Injury scenario[c]	Roll-up, impact, crossed leg, misstep, accordion, overload, landing, change of direction

[a]Parameter defined by the National Football League.
[b]Player position is nominal and does not indicate that the player was necessarily performing tasks typically associated with that position. For example, a cornerback may play on special teams.
[c]Parameter was coded by reviewers in the initial and secondary reviews.

Determination of Injury Mechanism and Standard Parameters

Of the 994 ankle sprains observed during the study window, 670 were video reviewed by 2 experienced biomechanical engineers (C.M.O., E.M.S.) who conducted independent reviews and documented injury mechanism. If the injury mechanism could not be observed from the available video sources, the injury was excluded from further analysis. Of the 383 cases in which the injury mechanism could be observed, approximately one-third (n = 128) were randomly selected for a blinded matched-case comparison of injury mechanism. The results of the 2 reviewers were compared and disagreements were adjudicated by group review and consensus decision from a committee of 4 experienced biomechanical engineers (C.M.O., E.M.S., K.B.A., D.J.L.). Standardized parameters were defined from the initial review (Table 1). Definitions and visual examples were developed to aid reviewers in the secondary review (Appendix A, available in the online version of this article).

Injury Scenarios for EE Ankle Sprains

The initial review was used to group ankle sprains based on their injury mechanism and to define standardized parameters to document the injury. Subsequently, a secondary video review for all confirmed EE ankle sprains was performed by 2 experienced biomechanical engineers (C.M.O., E.M.S.) who completed independent reviews and documented the standardized parameters for each injury. Of the 257 ankle sprains identified for the EE group, a further one-third (n = 84) were randomly selected and used for a blinded matched-case comparison of the standardized parameters. The results of the 2 reviewers were compared and disagreements were settled by consensus decision from a committee of 4 experienced biomechanical engineers (C.M.O., E.M.S., K.B.A., D.J.L.).

Statistical Analysis

To quantify possible positional bias associated with limiting the analyses to only injuries that could be viewed, the player positions from 994 reported game ankle sprains and the subset of 383 in which the injury mechanism could be viewed were compared using a chi-square goodness-of-fit test.[10] Additionally, the blind matched-case comparison described above was performed to assess reviewer agreement through percent agreement and Cohen kappa for injury mechanism and the defined standardized parameters.[21]

RESULTS

Overall Distributions

Over the 4 NFL seasons reviewed, 994 game ankle sprains were reported. Of these, 670 (67%) had a play associated and were considered for initial review. The reviewers could observe the mechanism of injury for 383 (39%) ankle sprains, and these were included in the secondary review. To check representation of player positions in the reviewed sample, a chi-square goodness-of-fit test was performed for the injured player positions between the ankle sprains with an identified injury mechanism (n = 383) and all reported game ankle sprains (n = 994). There was no statistical difference ($P = .99$) between the player position distributions of the 2 groups, indicating that the cases included in the secondary review were representative of the overall injury sample in distribution of player positions.

Three categories for injury mechanism were defined to bin ankle sprains in the secondary review: EE (n = 257; 67%), II (n = 113; 30%), and other (n = 13; 3%). EE was defined as an ankle sprain caused by either ankle external rotation, eversion, or a combination of both. II was defined as an ankle sprain caused by either ankle internal rotation, inversion, or a combination of both. Other was defined

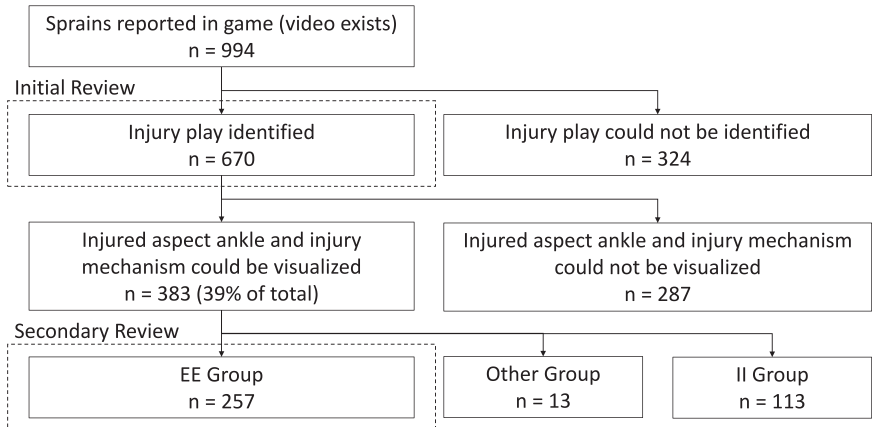

Figure 1. Proportion of ankle sprains that occurred in the National Football League during the 2017-2020 season games and those included in the review.

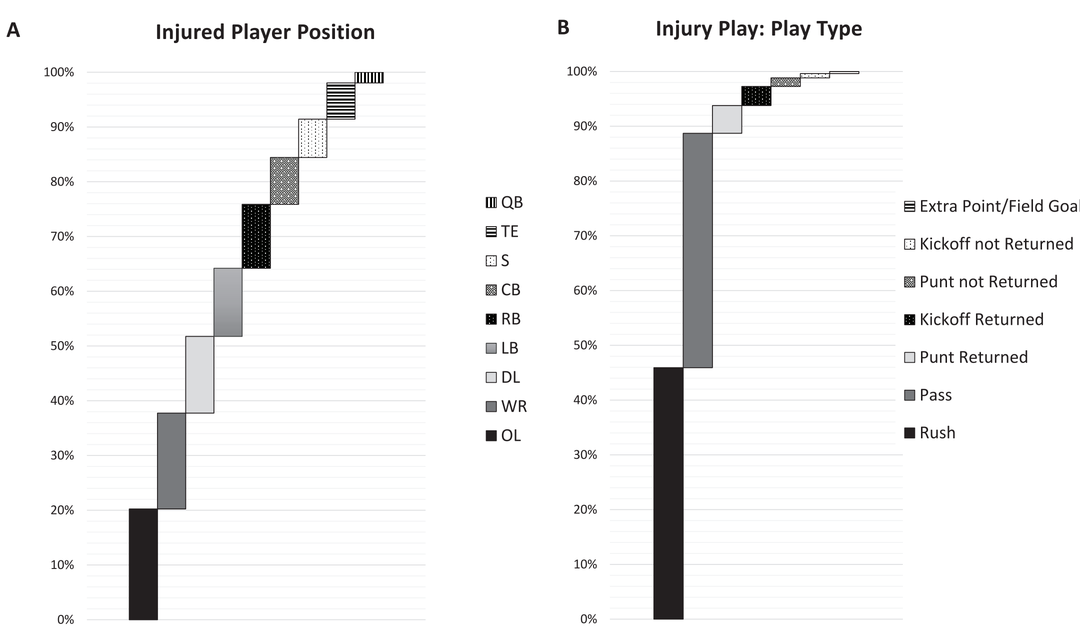

Figure 2. Parameters reported by the National Football League (n = 257). (A) Distribution of injured player position for the confirmed external rotation and eversion ankle sprains reviewed. (B) Distribution of injury play type for the confirmed EE ankle sprains reviewed. CB, cornerback; DL, defensive lineman; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; S, safety; TE, tight end; WR, wide receiver.

for ankle sprains caused by a combination of motions from both EE and II. Of the 383 ankle sprains included in the secondary review, 257 (67%) resulted from an EE injury mechanism (Figure 1).

Injured Player Position and Play Type

Of the 257 reviewed EE ankle sprains, 135 were left-sided and 122 were right-sided. Offensive linemen had the most sprains (n = 52; 20%), followed by wide receivers with 45 (18%) and defensive linemen with 36 (14%) (Figure 2A). Rush plays were the most common play type observed, accounting for 118 (46%) of the plays (Figure 2A). This was slightly higher than the 110 (43%) EE ankle sprains that occurred on pass plays.

Player-to-Player Contact, Directly Contacting Body Region, and Loading Type

The presence of player-to-player contact, directly contacting body region, and loading type were coded by reviewers for the 257 EE ankle sprains in the secondary video review. Three categories of player-to-player contact were defined:

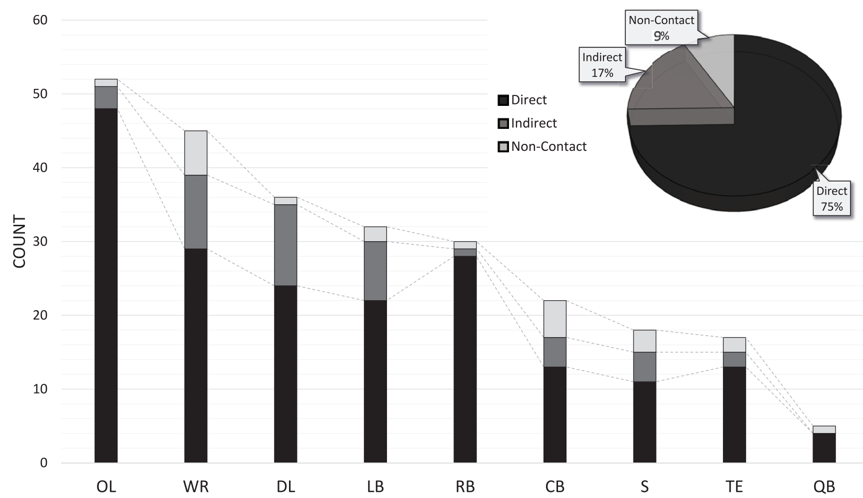

Figure 3. Distribution of player-to-player contact by player position for the confirmed external rotation and eversion ankle sprains reviewed (n = 257). Percentages may not add to 100% due to rounding. CB, cornerback; DL, defensive lineman; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; S, safety; TE, tight end; WR, wide receiver.

direct contact (n = 192; 75%), indirect contact (n = 43; 17%), and noncontact (n = 22; 9%). Direct contact was coded when the injured ankle, ipsilateral foot, or ipsilateral leg was contacted by another player at the time the injury mechanism was observed. Indirect contact was coded when the injured player was contacted by another player at a location other than the injured ankle, ipsilateral foot, or leg at the time the injury mechanism was observed. Noncontact was coded when the injured player was not in contact with any other player at the time the injury mechanism was observed. Direct contact with another player was observed for a majority of injuries for all player position groups (Figure 3). Cleat contact with the field was present in all reviewed ankle sprains.

Eight regions of directly contacting body region were defined: pelvis (n = 76; 30%), torso (n = 67; 26%), thigh (n = 42; 16%), no contact (n = 38; 15%), shoulder (n = 17; 7%), leg/foot (n = 17; 7%), arm/hand (n = 0; 0%), and helmet (n = 0; 0%). Directly contacting body region was defined as the body region with the largest mass that directly contacted the injured player at the time the injury mechanism was observed. The source of the directly contacting body region was most commonly from another player, but instances in which a player's own body contacted the injured body region were also observed (eg, when a player's hip directly contacted their ipsilateral foot, causing injury) (Appendix A, available online). If no body region of any player was directly contacting the injured aspect at the time the injury mechanism was observed, then the directly contacting body region was coded as "no contact." The pelvis was the most common directly contacting body region for wide receivers, defensive linemen, and cornerbacks. The torso was the most common directly contacting body region for offensive linemen, linebackers, and running backs (Figure 4).

The body region that caused the direct contact was consolidated into 3 bins to describe the loading type: large external mass (n = 202; 79%), no external mass (n = 38; 15%), and small external mass (n = 17; 7%). Large external mass was coded when the injury mechanism was the result of both forces transferred through the cleat-surface interaction and external forces applied to the injured aspect by either a helmet, shoulder, torso, pelvis, or thigh. Small external mass was coded when the injury mechanism was the result of both forces transferred through the cleat-surface interaction and external forces applied to the injured aspect by either the leg, foot, arm, or hand. No external mass was coded when the injury mechanism was the result of forces transferred solely through the cleat-surface interaction. Large external mass was the most common loading type for all player positions (Figure 5).

Injury Scenario

The standardized parameters of player-to-player contact, directly contacting body region, and loading type, along with repeated situational patterns observed by reviewers, were consolidated into 8 injury scenarios: roll-up (n = 112; 44%), impact (n = 63; 25%), accordion (n = 27; 11%), change of direction (n = 26; 10%), crossed leg (n = 14; 5%), overload (n = 6; 2%), landing (n = 6; 2%), and misstep (n = 3; 1%) (Figure 6). Roll-up was coded when another player directly contacted the injured player through an unintended action, typically resulting from being pushed or falling. The directly contacting body region was always a large external mass resulting in an additional external load to the injured aspect. Impact was coded when another player directly contacted the injured player through what was deemed an intended action, typically resulting from tackling. The directly contacting body region was always a large external mass resulting in an additional external load to the injured aspect. Accordion was coded when another player indirectly contacted the injured player,

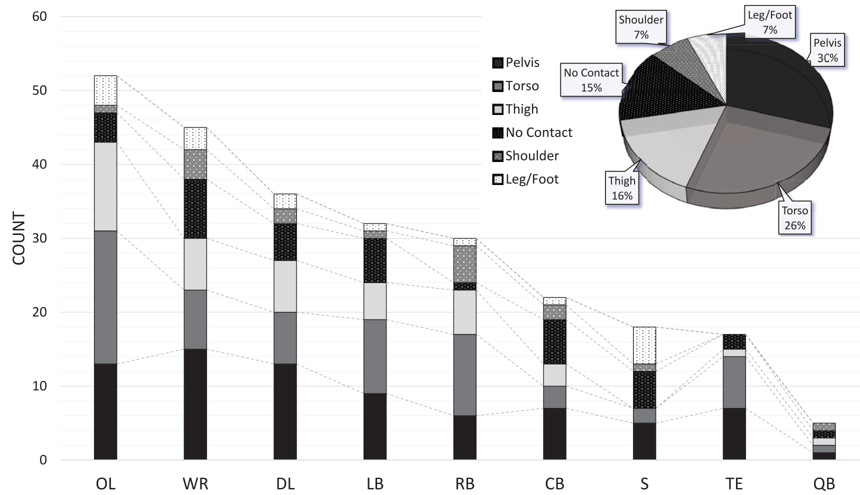

Figure 4. Distribution of directly contacting body region by player position for the confirmed external rotation and eversion ankle sprains reviewed (n = 257). Percentages may not add to 100% due to rounding. CB, cornerback; DL, defensive lineman; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; S, safety; TE, tight end; WR, wide receiver.

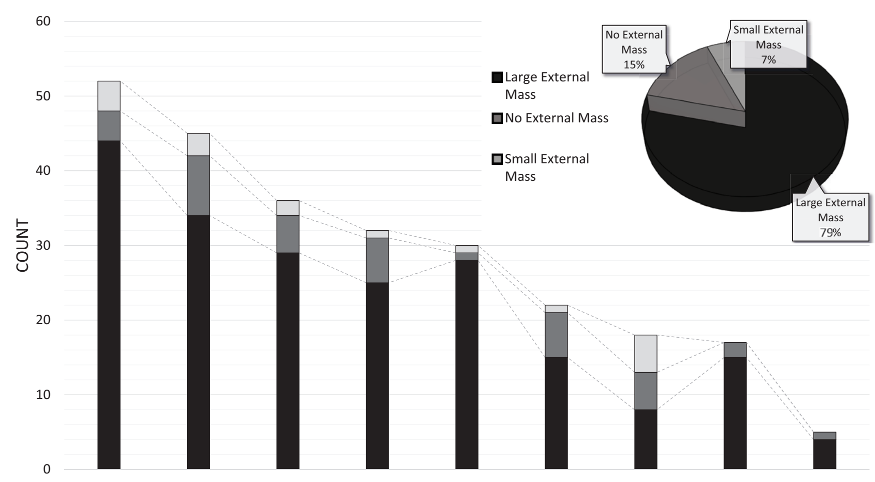

Figure 5. Distribution of loading type by player position for the confirmed external rotation and eversion ankle sprains reviewed (n = 257). Percentages may not add to 100% due to rounding. CB, cornerback; DL, defensive lineman; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; S, safety; TE, tight end; WR, wide receiver.

often upper body to upper body contact, resulting in the injured player collapsing onto their own foot. The directly contacting body region was typically the pelvis of the injured player, resulting in an additional external load to the injured aspect. Change of direction was coded when the injured player changed direction, faked a cut, or decelerated in response to another player or the football with the intention of creating or closing space. There was no directly contacting body region and all loading was sustained through the cleat-surface interaction, although there may be indirect contact, such as pushing or handfighting. Crossed leg was coded when the injured player was directly contacted by another player who was typically backpedaling or running. The directly contacted body region was a small external mass, typically a leg, resulting in an additional external load to the injured aspect. Overload was coded when another player indirectly contacted the injured player, often upper body to upper body, such as seen in blocking or tackling. In this scenario, the contacting player grabbed and maintained contact with the injured player during the injury. There was no directly contacting body region, indicating all loading was sustained through the cleat-surface interaction. Landing was coded when the injured player was injured while landing after a jump or dive. Typically, the injured player was indirectly contacted by another player while vying for the football in the air and then sustained injury during landing. There was no directly contacting body region; thus, all

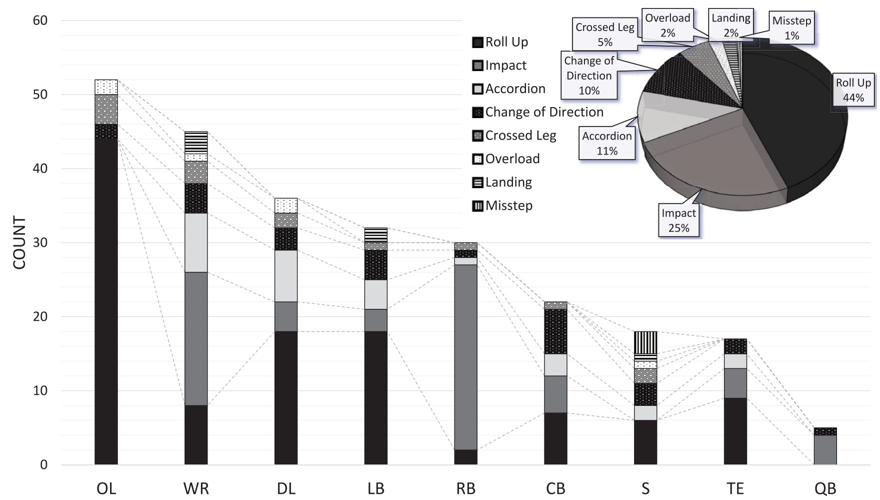

Figure 6. Distribution of injury scenario by player position for the confirmed external rotation and eversion ankle sprains reviewed. CB, cornerback; DL, defensive lineman; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; S, safety; TE, tight end; WR, wide receiver.

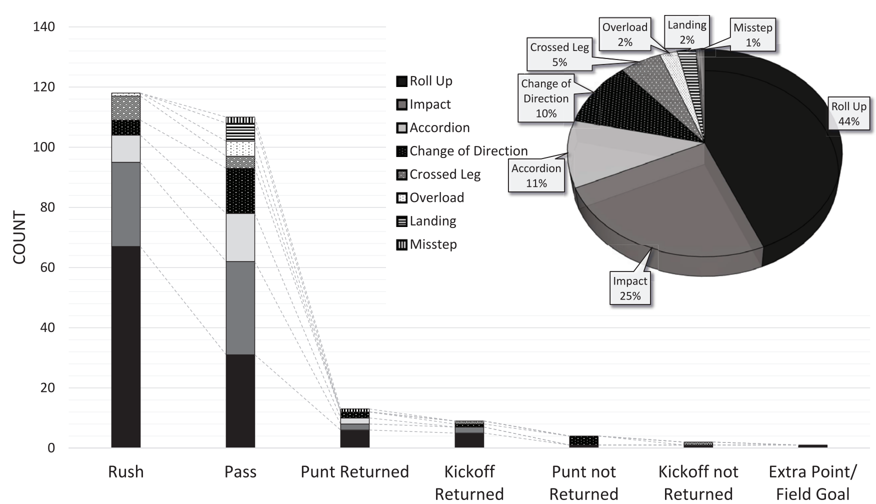

Figure 7. Distribution of injury scenario by play type for the confirmed external rotation and eversion ankle sprains reviewed.

loading was sustained through the cleat-surface interaction. Misstep was coded when another player directly contacted the injured player through an unintended action, by either stepping on the cleat of another player or having their 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. Roll-up scenarios were most common for the positions of offensive linemen, defensive linemen, linebackers, cornerbacks, safeties, and tight ends. Impact scenarios were most common for wide receivers, running backs, and quarterbacks (Figure 6).

Like the variations seen among player positions, play types also showed differences in their distributions of injury scenarios (Figure 7). Most rush plays involved roll-up scenarios, while pass plays exhibited equivalent roll-up and impact scenarios. Pass plays displayed more variation in their injury scenarios than rush plays and had a larger percentage (n = 26; 24%) of injuries not resulting from an external mass than other play types.

Blinded Matched-Case Comparisons

A blinded matched-case comparison (n = 128) revealed that for the initial review, reviewers agreed on the injury mechanism 100% of the time ($\kappa = 1$). Blinded matched-case comparisons (n = 84) of the standardized parameters for EE ankle sprains revealed that for the secondary review, reviewers agreed on the parameter of player-to-player contact 98% of the time ($\kappa = 0.94$), directly contacting body region 88% of the time ($\kappa = 0.84$), loading type 94% of the time ($\kappa = 0.86$), and injury scenario 95% of the time ($\kappa = 0.94$).

DISCUSSION

A video review of 257 EE ankle sprains was completed to identify common injury scenarios in NFL football. Offensive linemen accounted for the greatest number of sprains, followed by wide receivers. While this finding suggests offensive linemen sustain the greatest number of EE ankle sprains, they likely do not have the highest injury rate (ie, injuries per play). This is because the number of plays participated in by each position group has a wide disparity, with wide receivers accruing half the number of game plays as offensive linemen. This difference in exposure accounts for wide receivers experiencing a higher injury rate per play than offensive linemen.[18] Therefore, it is important to stress that this study is descriptive of how EE ankle sprains occur within each position but may not be suited to describing the relative injury rate between each position.

Direct player-to-player contact was the most reviewed feature for every position and was present in 75% of reviewed injuries. This finding supports previous findings that EE ankle sprains occur due to player-to-player contact.[1,3] The player positions with the highest percentages of direct contact were offensive linemen and running backs, with 92% and 93%, respectively. The player positions with the lowest percentages of direct contact were cornerbacks and safeties, with 59% and 61%, respectively. Not only was direct contact abundant, but the body region responsible for the direct contact was most frequently the pelvis. Combined, direct contact that resulted from a pelvis or torso accounted for 55% of the injuries reviewed. Two loading types were defined that coarsely describe the magnitude of forces applied when the injury occurred. It was observed that either through another player or through the injured player themselves, a large external mass contacted and loaded the injured aspect in 79% of the injuries reviewed. Only 7% involved a small external mass, typically applied by another player's leg. The magnitude of load transmitted through the external directly contacting mass relative to the forces transmitted through the cleat-surface interaction was not quantified in this study. For the remaining 15% of reviewed ankle sprains, forces were transmitted solely through the cleat-surface interaction. Depending on the position, involvement in these large external mass cases varied. Offensive player injuries consisted of 84% large external mass cases, while defensive player injuries only consisted of 71% large external mass cases. This variation in how energetic different positional group injuries are may partially explain variations observed in return-to-play time for different positions.[5]

Running back injuries were notable in that 93% involved a large external mass. This finding is hypothesized to be due to the unique positional demands that result in being constantly exposed to situations in which they are tackled or in contact with larger players in positions such as linemen and linebackers. In contrast, cornerbacks and safeties have positional demands that place them in less populated and more open locations on the field. This characterization is supported by observations from this study that cornerbacks and safeties had lower proportions of EE ankle sprains involving large external masses. Interestingly, safeties were the only position observed to have fewer than half (44%) of their EE ankle sprains involve a large external mass. Instead, their EE ankle sprains more frequently occurred in the open field and were the result of forces transmitted through the cleat-surface interaction, or from additional forces applied by a small external mass typically caused by direct contact with another player's legs. Cornerbacks and safeties had comparable proportions of EE ankle sprains that resulted solely from forces transmitted through the cleat-surface interaction at 27% and 28%, respectively.

Eight injury scenarios were defined to characterize the actions that lead to EE ankle sprains. Of these, roll-up and impact scenarios were most prevalent. These reflected situations in which a large external mass applied load directly to the injured player's leg, ankle, or foot. Across player positions, roll-up was the most frequent injury scenario for offensive linemen, defensive linemen, linebackers, cornerbacks, safeties, and tight ends. Because of their proximity to the line of scrimmage, it was often observed that an adjacent player would fall or be pushed near other players, and the unintended action resulted in them landing on the lateral aspect of the injured player's ankle, resulting in an EE mechanism. In contrast, impacts were the most frequent injury scenario for wide receivers, running backs, and quarterbacks. These injuries were frequently observed during the act of being tackled while having possession of the ball, where the impact was the unintended consequence of the tackling player falling onto the lateral aspect of the injured player's ankle during a tackle.

The results of the current study underscore the challenges for interventions aimed at limiting the frequency or severity of EE ankle sprains. For the 79% of injury scenarios that involved a large external mass, it is not realistic that changes in training alone could prepare a player for these situations given the magnitude of force that could be generated. It may be possible to update either rules or education around these scenarios involving large external masses to limit their occurrence. For example, running backs were injured from impact scenarios 83% of the time. Future work may focus on the tackles leading to these impact scenarios to identify alternative tackling techniques that reduce the exposure of large external masses directly contacting the ankles of running backs while providing efficacy for tackling. Of current interventions, bracing or structural support of the ankle is the most obvious path given the scenarios that most commonly cause EE ankle sprains. While lace-up ankle braces have shown effectiveness in limiting all types of ankle sprains in football at the high school level,[20] the EE injury mechanism has been described as resulting from a greater amount of force than other types of ankle sprains, and the scenarios presented in the current study support this assertion.[3] Because 79% of the reviewed EE ankle sprains involved direct contact from a large external mass, proposed ankle braces should be assessed for their ability to resist realistic magnitudes of forces reflective of the scenarios and magnitude of loading characterized in this study.

Any improved structural support to the ankle would need to be sufficiently stiff to withstand a substantial force, while still allowing a player to meet the demands of their position. Additionally, a brace would need to dissipate force across the ankle and leg in a way that avoids isolated loads to the shaft of the fibula that could cause a fracture.[3,19] An understanding of these scenarios is important when discussing new ankle brace designs. Future work should aim to quantify the loads applied in these injury scenarios, to help guide innovative brace design. Although a minority (7%) of the injury scenarios involved direct contact from a small external mass applied, typically by another player's leg, these scenarios may receive the greatest benefit from current braces, as the role of the brace would only be to support the ankle from small sudden positional changes. Similarly, spatting and taping have been shown to limit the range and rate of ankle inversion in response to sudden stimuli, and we hypothesize that these effects could extend to ankle eversion for scenarios that only involve a small external mass.[24] While these interventions may not be able to mitigate forces generated by large external masses, they may be sufficient to mitigate sudden positional changes of the ankle that result from contact with small external masses. Provided that the ankle brace does not limit the performance of a player, this may be an appropriate intervention for small external mass injury cases.

Lastly, 15% of injuries occurred without any direct contact from an external mass. These scenarios appear to be the best starting point for intervention, as several studies have shown that ankle sprains sustained through indirect or noncontact mechanisms can successfully be decreased through training focused on reaction time, proprioception, bracing of the ankle, or changes to the cleat-field interaction.[2,8,23-27] Additionally, while only 15% of EE ankle sprains did not result from an external mass, all the EE ankle sprains reviewed occurred while the cleat was engaged with the playing surface. This suggests that the cleat-surface interaction contributes at least in part to the forces and torques leading to all EE ankle sprains. Researchers have quantified the mechanical response of the cleat-surface interaction, as it can influence both an athlete's performance and their injury risk. Future research should identify the boundary conditions most relevant to these injuries to better inform cleat-surface testing and intervention.[9] These scenarios were most common for safeties and cornerbacks. Future work should focus on these player positions during change-of-direction scenarios in which no direct contact is present to determine how changes to training, braces, cleats, or playing surfaces can influence injury risk.

The primary limitation of the current study was the inability to review all reported ankle sprains that occurred in the study window. While NFL games allow for comprehensive video coverage, the injured players were frequently not involved in carrying the football and were thus not the focus of the highest-quality broadcast views. For position groups such as linemen, it was often difficult to associate a play with a given injury, resulting in a reduced number of injuries that could be characterized. Nonetheless, our comparison of the player positions between all reported game ankle sprains and the player positions of those reviewed revealed no statistical differences between these 2 positional distributions, providing confidence that the injuries reviewed are representative of the overall injury cohort. Because the ability to view injuries may be associated with the play type (eg, rush plays have more concentrated player formations than kickoff plays) and knowing the play type requires the injury to be associated with a play, the distribution of injuries by play type may not be representative of overall game play. Additionally, viewing the ankle can be especially challenging in wide-angle game footage because player contact can obscure reviewer's view. The ability for this study to obtain game footage from multiple viewpoints, including footage that was not publicly accessible, from vantages around the field provided critical insight where the broadcast game footage was not sufficient. Research focused on the video analysis of ankle injuries in sports should prioritize increasing the sources and quality of time-synced video footage and injury reporting.

CONCLUSION

A detailed review using video footage of ankle sprains that resulted from an EE injury mechanism revealed that within the NFL, direct contact from a large external mass to the injured player's foot, ankle, or leg accounted for 79% of reviewed EE ankle sprains. These EE ankle sprains were dominated by roll-up and impact scenarios. Current equipment interventions will struggle to reduce or redirect the significant external loads typical of these scenarios. Thus, broad reductions in EE ankle sprains that involve direct contact from a large external mass would require innovation to current interventions, such as ankle braces. Overall, 83% of EE ankle sprains sustained by running backs were the result of impact scenarios in which the running back was injured from a tackle. Therefore, changes to tackling techniques to mitigate running back injuries may merit further investigation, as well as understanding the risk to tacklers for different tackling techniques. Overall, 7% of reviewed EE ankle sprains were the result of direct contact from a small external mass. Bracing interventions that can slow or reduce the loads resulting from sudden positional changes may hold promise for reducing injury risk in crossed-leg scenarios. Finally, scenarios such as change of direction, in which the EE ankle sprains resulted from forces transmitted solely through the cleat-surface interaction, accounted for 15% of reviewed EE ankle sprains and were most prevalent for safeties and cornerbacks. These positions are the best place to focus existing interventions, because existing interventions may have the greatest potential to aid injury scenarios in which forces are isolated to just those at the cleat-surface interaction.

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