

Video Analysis of Concussion Exposures in a National Collegiate Athletic Association Division I Football Team

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Background: Research into improving player safety of sport-related concussion (SRC) in American football has been an ongoing endeavor. In an attempt to better understand the incidence of SRCs in American football, research has focused on the characteristics of SRC during gameplay. Determining SRC specifics and assessing them quantitatively can help identify high-risk scenarios and predict exposure risk.

Purpose: To identify and assess the incidence of SRCs in a National Collegiate Athletic Association football team by comparing field location, player positions, collision partners, and player cues.

Study Design: Descriptive epidemiology study.

Methods: We used physician sideline reports of diagnosed concussions from a Division I football team from September 2010 to December 2018. Game videos were analyzed to identify the field location where the SRC occurred, collision partner, and player behavior postconcussion. The incidence of in-game SRCs by position was also assessed. We used the “words of estimative probability” model to categorize each concussion as *certain*, *almost certain*, *probable*, or *even* on the basis of our confidence in identifying them using game film.

Results: This study examined 44 SRCs that occurred over 9 seasons. The SRC incidence was significantly higher in the middle defense (5–20 yards from the line of scrimmage) compared with all other field locations (relative risk, 2.46; 95% CI, 1.14–5.29; $P < .05$). In-game collision partners were most commonly defensive backs. The most common player cue was a hand to helmet/face mask. The positions with the highest SRC incidence by athlete-exposure, game position, and position play belonged to the defensive backs, wide receivers, and running backs.

Conclusion: The middle defense had a significantly higher incidence of SRCs than all other field locations. We pose a new method to categorize concussions during video analysis by using words of estimative probability. Knowledge of SRC gameplay characteristics can potentially guide the medical staff and medical observer to better identify them.

Keywords: sport-related concussion; football position; collision partner; medical observer; field location

Sport-related concussion (SRC) has been a primary focus for sports medicine providers, administrators, players, and the public over the past decade.^{17,20,21,28,30,43} Concern for player safety in the sport of American football remains high.^{1,3,9,16,20,25,36,41} As awareness for SRC has intensified, the incidence of SRC has risen.^{18,19} After the National Collegiate Athletic Association (NCAA) instituted the 2010 Concussion Management Policy, there was a 58% increase in reported concussions when the 2009 season data were compared with the 2010 season data in a single sample of Division I football programs.²⁶

Several studies^{22,32,37} have focused on the incidence of SRC by player position, recognizing different higher risk

positions. Such positions include defensive back (DB) and wide receiver (WR). Special team (ST) play is also high risk, with the kick returner having the highest incidence of concussion based on some studies.^{7,37} Position-specific concussion numbers can be misleading because certain positions are represented more frequently in gameplay, which can lead to more total concussion numbers because of a higher number of exposure opportunities. To illustrate a truer incidence of SRC position analysis, studies have used various metrics to calculate exposure risk, in which each formula calculates a slightly different exposure risk for each position.³²

With the advent of in-game video analysis, investigators are able to characterize SRCs in greater detail.^{11,12,27,29} These details include player cues, helmet impacts, and field position at the time of the concussion.^{8,27,38} A greater knowledge of the details of in-game SRCs can better prepare the sideline medical staff to identify concussions in real time.

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Investigation into methods to improve player safety is ongoing and has included modification of equipment, rule changes, and wearable monitoring technology.¹¹ An additional tactic to improve player safety has been to implement extra medical personnel, known as the medical spotter, “eye in the sky,” or medical observer (MO). The National Football League (NFL) first implemented an MO in a 2012 wild card playoff game in response to a missed SRC that occurred earlier in the season.² Following the lead of the NFL, many NCAA Division I conferences introduced the MO role in the ensuing years.^{4-6,14,23,24,40} The MO’s priority is to observe in-game concussions with the goal of identifying SRCs potentially not seen by the sideline medical staff. Prompt sideline evaluation and removal of those players from the game can prevent more catastrophic injury. As an expert in identifying in-game concussion, the MO must have an understanding of the nuances of SRC. With instant replay at their fingertips and the various situational details such as player positions, cue, or location, the MO is best able to utilize these specifics to identify in-game SRC.

As the bulk of descriptive data of football game SRCs grows, it remains unclear how this knowledge can be utilized to improve player safety. Sideline medical personnel and MOs have a difficult task to identify SRCs as they occur. Synthesis of this knowledge can potentially help predict SRCs and better recognize them as they happen on the field.

The purpose of this study was to identify and assess the incidence of SRCs in a single NCAA football team by comparing field location, player positions, collision partners, and player cues. We hypothesized that specific player positions and collision partners will correlate with certain field locations.

METHODS

SRC Incidence

This retrospective, descriptive epidemiological study used sideline reports of diagnosed concussions from an NCAA Division I football team during the 2010 to 2018 football seasons to calculate the SRC incidence. Institutional review board approval was obtained for this study. Primary care sports medicine fellowship-trained team physicians diagnosed the SRC on the sideline according to their protocol using the Sport Concussion Assessment Tool–5th edition (SCAT5),¹⁵ with components that include a patient-

reported symptom checklist, a focused examination, a standardized cognitive assessment, and the modified Balance Error Scoring System.

Video Review

The film from all games in which an SRC occurred was reviewed play by play to characterize the gameplay scenario for each SRC and the player’s behavior after a concussion. We identified locations on the field where the SRC occurred, player position, collision partner (the player position that made contact with the concussed player), and post-SRC player cues. Player cues are the player’s actions immediately after the collision that caused the concussion. We applied the consensus statement by Davis et al¹² as our basis for these player cues, which included lying motionless, motor incoordination, slowness to get up, and tonic posturing. An additional category, hand to helmet, was added, as we found this to be the most common action after a concussion. Game film included the broadcasted game and coach’s video. The coach’s video is each team’s recording of the game, which includes a wide-angle end zone view and a sideline view. Three different physicians with at least 2 years of experience as a sideline medical provider (A.V.A., P.S., and J.B.K.) reviewed each video. At least 2 of the 3 physicians reviewed each game film for the SRC event.

Field Location

Using video review, the field location where the SRC occurred was documented. We divided the field into 4 zones: line, backfield, middle defense, and deep defense. The *line* measured 5 yards on either side of the line of scrimmage. The *backfield* stretched 5 yards from the line of scrimmage into the backfield. The *middle defense* extended from 5 yards to 20 yards downfield. The *deep defense* started at 20 yards from the line and stretched to the end zone. We chose these measurements for several reasons. The quarterback’s (QB’s) 3-step and 5-step drops are the most common and usually take the QB no farther than 6 yards from the line of scrimmage. The offensive linemen usually travel no further than 3 yards from the line of scrimmage or they are considered ineligible receivers. Intermediate passing plays occur within 15 to 20 yards of the line of scrimmage. Furthermore, 5-yard delineations made it easier to record while reviewing video.

We calculated the relative risk of SRC in each field location by first determining the total number of plays that ended in each zone over the study period using the website Profootballfocus.com.³⁴ We then compared the total number of plays in each zone with the zone in which the concussion occurred.

¹¹References 7, 10, 20, 22, 26, 31, 33, 35, 42.

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Ethical approval for this study was obtained from the University of Virginia Institutional Review Board for Health Sciences Research (study No. 19421).

Position Incidence

The current study used athlete-exposure (AE), game position (GP), and position play (PP) metrics. An AE was defined as the average number of players per position per game multiplied by the number of games, which equaled the number of AEs per position. We then calculated the number of concussions per 1000 AEs. GP was defined as the total number of concussions divided by the standard number of players on the offensive and defensive starting group multiplied by the number of games played. We calculated the SRC rate for every 100 games played. PP was also defined using the standard number of players on the starting sides multiplied by games played and the average number of snaps played over the 9 study seasons.³² We determined the SRC rate to be the number of SRCs per 1000 PPs. The statistics to calculate the exposure incidence were obtained from Sports-Reference.com.¹³ We condensed the positions of cornerback and safety into DB; we also grouped ST as 1 position group and made no distinction between the different positions within ST.

Words of Estimative Probability

We discovered that despite often knowing the quarter the concussion occurred, we were unable to determine the exact collision with certainty. As a result, we used the “words of estimative probability” model to categorize each concussion on the basis of our confidence in viewing them on video as *certain*, *almost certain*, *probable*, or *even*. These probability terms are based on previous research established by Sherman Kent.^{39,44} We defined *certain* as situations in which we knew the exact time the SRC occurred, the player exhibited loss of consciousness, or the player showed other obvious SRC cues such as tonic posturing. We defined *almost certain* as a situation in which the player sustained a hard hit to the helmet and did not return to the game, he incurred no other hits in the game, and we knew the quarter the SRC occurred in the game. We defined *probable* as when the player sustained a hard hit to the helmet, he incurred no other hits in the game, and he continued playing. We defined *even* as when the player either had multiple hard hits in the game or had no significant hits and he continued playing. Based on Kent’s work, *certain* correlated with 100% certainty, *almost certain* correlated with 95% certainty, *probable* correlated with 80% certainty, and *even* correlated with 50%.^{39,44} For the in-game SRC characteristics of field location, collision partner, and player cues, we utilized the SRCs categorized as *certain* and *almost certain*. This correlates with the acceptable levels of uncertainty of preventing a type 1 error.

SPSS Version 24.0 (IBM SPSS Statistics for Windows; IBM Corp) was used to analyze the data for descriptive statistics.

RESULTS

In the 111 games from September 2010 to December 2018, there were 44 SRCs. There was 1 SRC for which we had no video; for this case, we did not determine field location,

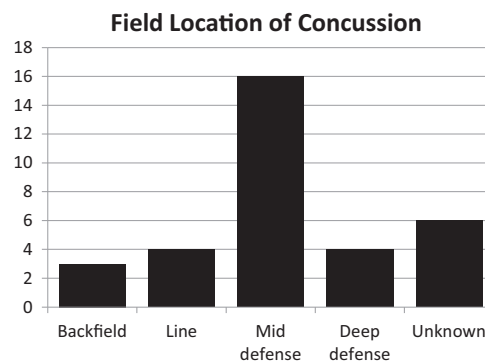


Figure 1. Number of concussions by field location as categorized by video analysis review. The different field locations were defined as follows: line, 5 yards on either side of the line of scrimmage; backfield, 5 yards or greater from the line into the backfield; middle defense, 5 yards from line to approximately 20 yards downfield; deep defense, 20 yards from the line to the end zone.

collision partner, player cue, or terms of estimative probability. There were a total of 15,562 offensive and defensive plays in games from 2010 to 2018.

Field Location

The percentage of plays that occurred in the backfield was 5%, line 52%, middle defense 37%, and deep defense 6%. The most common area for SRCs to occur in-game was the middle defense (Figure 1). SRC incidence in the middle defense was significantly higher when compared with all other field locations (relative risk, 2.46; 95% CI, 1.14-5.29; $P < .05$). Concussion incidence was not significant when the other 3 field zones—backfield, line, and deep defense—were each compared with total plays.

Position Groups

The incidence of SRC per 1000 AEs was highest among running backs (RBs), followed by DBs and WRs (Table 1). The incidence per 100 GPs was highest among RBs, then WRs, followed by DBs (Table 2). The SRC highest incidence among PP was DBs, WRs, and RBs (Table 2). Although the lowest incidence among the position groups was less consistent, the offensive line (OL) and defensive line (DL) had the 2 lowest incidences in 2 of the 3 metrics (GP, AE).

Collision Partner

In-game collision partners were most commonly the DBs. The position groups the DBs concussed most frequently were WRs and RBs. The RBs were the second most common collision partner. RBs were most likely to concuss DBs. The position groups least likely to cause a concussion were the OLs, QBs, and WRs (Figure 2). The “unknowns” were SRCs we defined as either probable, even, or had no video and as

TABLE 1
Athlete-Exposure Position Analysis^a

Position	SRC	Players/ Position ^b	Games	Total AE	SRC/1000 AE (95% CI)
RB	7	10	111	1110	6.30 (2.83-12.34)
DB	9	15	111	1665	5.41 (2.68-9.84)
WR	6	10	111	1110	5.41 (2.26-11.11)
TE	1	3	111	333	3.00 (0.32-13.95)
LB	2	8	111	888	2.25 (0.47-7.21)
QB	1	4	111	444	2.25 (0.02-10.48)
DL	3	13	111	1443	2.08 (0.59-5.54)
OL	3	16	111	1776	1.69 (0.48-4.5)

^aAE, athlete-exposure; DB, defensive back; DL, defensive line; LB, linebacker; OL, offensive line; QB, quarterback; RB, running back; SRC, sport-related concussion; TE, tight end; WR, wide receiver.

^bAverage number of players per position on the roster for game.

a result we could not determine collision partner with confidence.

Player Cues

Through analysis of the video, we found the most common player cue of an SRC to be a hand to helmet/tugging on helmet. We also commonly found no discernable cue. We observed 4 players lying motionless, which typically means they lost consciousness. The player cues observed over the study period are listed in Table 3.

Terms of Estimative Probability

Of the 44 identified concussions, there were 24 in-game SRCs that were categorized as *certain*. We determined that 14 were *almost certain* and 3 were *probable*. There were 2 SRCs classified as *even* and 1 for which estimative probability could not be determined (Table 4).

DISCUSSION

With player safety at the forefront for all involved with football, knowledge of the nuances of in-game SRC can better prepare medical providers in identifying them. We reported on 9 years of SRCs in a single NCAA Division I football team, reviewing, play by play, all 43 games in which the SRCs occurred. In order to optimize player safety, the sideline medical staff and the MO need to be active participants scanning the field for concussions during gameplay. To date, there have been no data to suggest where the medical staff should focus its attention. This study helps provide a more succinct picture of the field of play on the football field in terms of high-risk concussion exposures.

Our data suggest field location to be an important factor in SRCs. The middle defense ranging from the 5-yard line to the 20-yard line appears to be a high-risk field zone ($P < .05$ compared with all other field locations) and

the location on the field with the highest risk for an SRC to occur.

Previous data investigating SRC incidence by AE, GP, and PP support and are consistent with the results in this study.^{8,22,27,32,37} Some of the differences in AE data between NCAA and NFL studies can be attributed to the total roster number constraints on NFL teams compared with NCAA teams. Our results are also consistent with a 2018 study showing a higher incidence of concussions among the DB and WR positions.²⁷ The DBs and WRs operate in the open field and can generate more forceful hits. The open field also exposes players to be blindsided. Our data indicated that the linemen (OL and DL) have a lower SRC incidence during gameplay. The study results showed the ST to be the position of high incidence on the field. While ST was not the focus of this study and we did not delineate positions among the ST, the results confirm ST as a high-risk event during game play. Rule changes in ST play, including changing the starting position of the kickoffs and touchbacks as well as allowing for a fair catch within the 25-yard line, have promoted a decrease in SRC incidence.^{33,42} Although this study spanned many of those major rule changes, we did not investigate differences before versus after such changes. Future research could look into this topic closer for college football. Regardless of the rule changes, the reality of 10 players sprinting down the field at full speed with the intent of tackling 1 player creates a high-risk event, and so ST should remain a focus for medical personnel.

The collision partner, described by Lessley et al²⁷ in NFL players, is a new data point to better characterize the player interactions on the field at the time of an SRC. Our data showed the DB to be the most common collision partner. The DB accounted for 20 of the 44 concussions when we combined SRC position and collision partner, resulting in the DB position being involved in almost half of all concussions that occurred in games over the study time period. The DB appears to be a nidus for SRC during gameplay.

When field location, player position, and collision partner are combined, a recurring theme occurs and a narrative can be written to describe the field of play in terms of concussions. The field location with the highest risk is the middle defense. The high-risk positions, DB, WR, and RB, commonly operate within the middle defense. This composite of the evidence reveals high-risk zones and positions, which, in turn, create a map of high-risk concussive exposures on the football field. As the medical staff and MO scan the field, the speed of play makes it difficult to catch all collisions occurring, often simultaneously, on the field. As an active observer for concussions, awareness of these high-risk concussive exposures can potentially better prepare the sideline medical team and MO to recognize SRC events in real time. Additionally, this knowledge can lead to implementation of player education on tackling and game scenarios, equipment modifications, and rule changes.

With the advent of video analysis, investigators have made it a priority to evaluate and develop standards for video signs of concussion.¹² Certain video signs are more definitive for a diagnosis of an SRC, such as being

TABLE 2
Position Incidence Analysis Using Game Position and Player Position Metrics^a

Position	Total SRC	Games ^b	Players Per Position	GP Incidence		PP Incidence		
				Total GPs	SRC Per 100 Games Played (95% CI)	Plays Per Position Per Game ^c	Total PPs	SRC Per 1000 PPs (95% CI)
RB	7	111	2	222	3.15 (1.42-6.09)	72.6	8058.6	0.87 (0.39-1.70)
WR	6	111	2	222	2.70 (1.14-5.49)	72.6	8058.6	0.74 (0.31-1.53)
DB	9	111	4	444	2.03 (1.01-3.67)	67.6	7503.6	1.20 (0.59-2.19)
ST	12	111	11	1221	0.98 (0.54-1.66)	14.7	17,941.0	0.67 (0.37-1.13)
LB	2	111	2	222	0.90 (0.19-2.86)	67.6	7503.6	0.27 (0.06-0.85)
QB	1	111	1	111	0.90 (0.10-4.13)	72.6	8058.6	0.12 (0.01-0.58)
TE	1	111	1	111	0.90 (0.10-4.13)	72.6	8058.6	0.12 (0.01-0.58)
DL	3	111	5	555	0.54 (0.15-1.44)	67.6	7503.6	0.40 (0.11-1.07)
OL	3	111	5	555	0.54 (0.15-1.44)	72.6	8058.6	0.37 (0.10-0.99)

^aDB, defensive back; DL, defensive line; GP, game position; LB, linebacker; OL, offensive line; PP, player position; QB, quarterback; RB, running back; SRC, sport-related concussion; ST, special teams; TE, tight end; WR, wide receiver.

^bTotal games played from 2010 to 2018.

^cAverage number of plays per game for either offensive or defensive position for the 9 seasons studied.

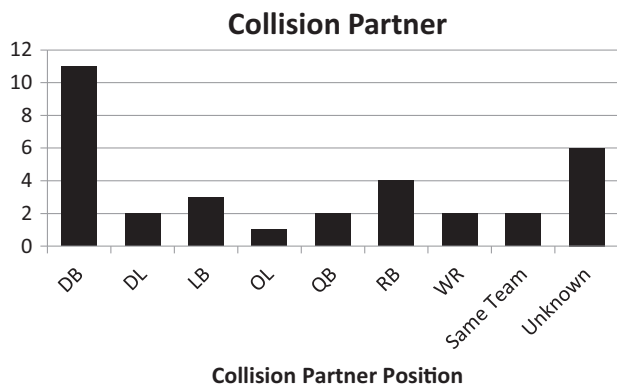


Figure 2. The player position who inflicted the sport-related concussion (SRC). The defensive back (DB) was the most frequent instigator of SRCs and the running back (RB) was the second most common. DL, defensive line; LB, linebacker; OL, offensive line; QB, quarterback; WR, wide receiver.

TABLE 3
Player Cues

	No. Identified
Hand to helmet/tugs helmet	13
Lying motionless	4
Motor incoordination	5
No cue	10
Slow to get up	5
Tonic posturing ^a	1
Unknown ^b	6
Total over the study period	44

^aDefined as involuntary sustained tonic extension or flexion of 1 or more limbs.

^bIncluded 3 SRCs classified as probable, 2 SRCs classified as even, and 1 SRC that had no video. SRC, sport-related concussion.

TABLE 4
Video Analysis of SRC Probability^a

Estimative Probability	No. of SRC
Certain	24
Almost certain	14
Probable	3
Even	2
Unknown	1
Total over the study period	44

^aBased on Kent.^{39,44} Certain, 100%; almost certain, 95%; probable, 80%; even, 50%; unknown, no video. SRC, sport-related concussion.

unresponsive or exhibiting tonic posturing. Missing such player cues would be detrimental. A primary reason the MO role was created was because those cues had been missed. However, other player cues are nonspecific, such as adjusting the face mask or getting up slowly. Making a return-to-play decision based on a nonspecific player cue is difficult. Additionally, many of the SRCs in this study had no identifiable video sign. More research is needed in this area of SRCs. It is likely that the obvious player cues will continue to provide strong evidence for an SRC. The nonspecific signs may provide additional clinical details but lack the necessary specificity to be a sole diagnostic tool.

While reviewing video, one conclusion we made was how difficult it was to identify some of the SRCs. This was despite knowing the quarter the concussion occurred and reviewing the video from multiple angles. This led us to utilize terms of estimative probabilities. We defined 38 of the 43 in-game SRCs as certain to almost certain and 2 concussions we could not confirm. This demonstrates that not all concussions will be identifiable. To expect the sideline medical team or MO with replay video to recognize all concussions is unrealistic. Some will go unidentified because of the nature of the sport and player candidness.

This study had some limitations. We examined 1 NCAA football team, and our results may not accurately describe different conferences or divisions in the NCAA or the NFL. Our total concussion numbers, while comparable with some published studies,²² were lower than others, and we could not make conclusions of risk based on position analysis. However, our results were in line with many of the previous studies looking on position incidence.^{8,22,27,32,37} Additionally, over the 9-year study period, the team we studied had 2 different coaching groups with different offensive and defensive schemes, which could have affected the results. Further research is needed to determine the positive predictive value of player cues, as some cues are likely to have a greater probability of indicating an SRC than others. To better describe the video review for SRCs, we used words of estimative probability. This is a new tool to use while studying video for SRCs, and more research is needed to further delineate their value.

CONCLUSION

The results of this study build on the growing knowledge of SRC position incidence and add to the novel metric of collision partners. DBs and WRs had the highest incidence of SRCs on the field, with DBs also being the most common position to deliver a hit that resulted in an SRC. Some player cues are obvious and others are nonspecific to SCR. Further research is needed to help differentiate those that are specific to SRC in football. We pose a new method to categorize concussions in video analysis studies by using terms of estimative probability. The results of this study can potentially help the medical staff and/or designated MOs to better identify in-game SRCs and, consequently, improve player safety.

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