Effects of Game Characteristics and Player Positions on Concussion Incidence and Severity in Professional Football

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Background: Increasing efforts have been made to reduce the incidence and severity of concussion in high-contact sports. Despite these efforts, a relative lack of knowledge is available regarding modulating factors affecting concussion injury.

Purpose: To analyze the potential influence of game characteristics and outcomes on concussion incidence and severity in professional football.

Study Design: Descriptive epidemiology study.

Methods: PBS *Frontline* Concussion Watch was used to collect concussion injury data from regular-season games of 32 National Football League (NFL) teams from 2012 to 2015. Game characteristic variables such as rushing and passing attempts, turnovers, and margin of victory were collected from ESPN. Analysis included descriptive statistics, analysis of variance, *t* tests, and correlation tests.

Results: Away teams demonstrated a significantly greater concussion incidence per game than home teams. Losing teams had a significantly greater concussion incidence per game than winning teams. Being both the away team and the losing team appeared to have an additive effect. The home-versus-away and win-versus-loss effects were significant for offensive but not defensive positions. Within individual positions, significantly greater concussion incidence was associated with tight ends, running backs, wide receivers, and cornerbacks. When running versus passing positions were compared, passing positions (wide receiver, tight end, cornerback, safety) had significantly greater concussion incidence. A total of 626 games were missed as a result of reported concussions. Away teams had significantly more games missed due to concussion when they lost. Play time did not significantly differ before or after concussion injury. Other game characteristic variables did not significantly affect concussion frequency or intensity.

Conclusion: Position, game location, and game outcome affect concussion incidence for professional football players. In a subset of analyses, the number of games missed aligned with concussion incidence, but this appeared to be an imperfect measure. These findings highlight new factors that may modulate concussion incidence and merit further study on how they may influence concussion evaluation.

Keywords: concussion; epidemiology; American football; home versus away; games missed

Public and scientific awareness of sports-related concussions has increased.[22] Concussions are induced by traumatic biomechanical forces, such as blows to the head, neck, or body, which are then transmitted to the head.[1] Concussions frequently occur in the National Football League (NFL), and it is possible that "style of play" or game characteristic factors could be implicated in modulating concussion incidence and severity.[6] In 2015, Teramoto et al[21] reported that players most involved in passing plays had more concussions during the 2012 to 2014 NFL regular seasons and that offensive schemes devoted to passing versus running plays also had a direct effect on concussion incidence. Teams using the "West Coast offense" scheme, which involves more passing, demonstrated higher rates of concussion than teams using other offensive schemes during those 3 regular seasons. In addition, when analyzing team schedules, Teramoto et al[20] noted a trend whereby the teams deemed to have a lower strength schedule and team quality measured by the simple rating system. Further analysis of team schedules demonstrated no significant association

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between concussion incidence and days of rest, game location, or timing of the bye week (NFL teams each have 1 bye week during the regular season in which they do not play a game) by the team or the opponent. Teramoto et al[21] found no significant evidence that fewer days of rest (3 days of rest due to having played on a Thursday) or playing overseas was linked with an increased risk of concussion.

Our study sought to analyze the potential influence of game characteristics and outcomes on concussion incidence and severity during 2012 through 2015 NFL regular seasons. We hypothesized that metrics including game location, game outcome, and player position may modulate risk of concussion injury.

METHODS

Data Collection

This retrospective study examined the 2012 to 2015 NFL regular seasons (weeks 1 to 16 for 4 years, excluding preseason games and playoffs). Official concussion injury report data were collected from Public Broadcasting Service (PBS) *Frontline* Concussion Watch (http://www.pbs.org/wgbh/pages/frontline/concussion-watch/). Rushing and passing variables for each NFL game were obtained from ESPN.com.

Definitions

Offense, defense, running, and passing position categorization and number of players per position on the field were based on data from Teramoto et al[21] (Table 1):

- Running positions: running back, linebacker
- Passing positions: wide receiver, tight end, cornerback, safety
- Games missed: the total number of regular season games a player missed due to a concussion injury, excluding the game in which he was concussed
- Margin of victory: points scored by winning team minus points scored by losing team
- Concussion causing a player to miss the final game of the regular season (*E* concussion): calculated as [(*week of concussion*) + (*number of games missed*)] $\geq$ 17

Statistical Analysis

In addition to descriptive statistics, analysis of variance, Welch *t* tests, and correlation tests were used. Statistical analyses were performed with GraphPad Prism 6. An alpha level less than .05 was considered significant for all tests. Mean values are presented with standard error of the mean (SEM).

TABLE 1
Summary of NFL Player Positions[a]

Position	No. on Field
Offense	
Center	1
Fullback	1
Guard	2
Long snapper	1
Quarterback	1
Running back	1
Tight end	1
Offensive tackle	2
Wide receiver	1
Defense	
Cornerback	2
Defensive end	2
Defensive tackle	2
Linebacker	3
Safety	2

[a]NFL, National Football League.

RESULTS

Concussion

A total of 558 concussions were reported during the 960 regular-season games from 2012 to 2015. The number of concussions per game was significantly higher during the second half of the regular season ($P = .0004$), losing teams had higher mean concussions per game ($P = .0166$), and away teams had higher mean concussions per game ($P = .0108$). In addition, no significant difference was found between a player's average playing time per game before a concussion versus upon return after recovery (Figure 1).

Number of Games Missed

A total of 626 games were missed due to the 558 concussions, averaging 1.1 games missed per concussion. The number of games missed from concussions had a decreasing trend as the season progressed, but this was not statistically significant. This trend may have been due to a

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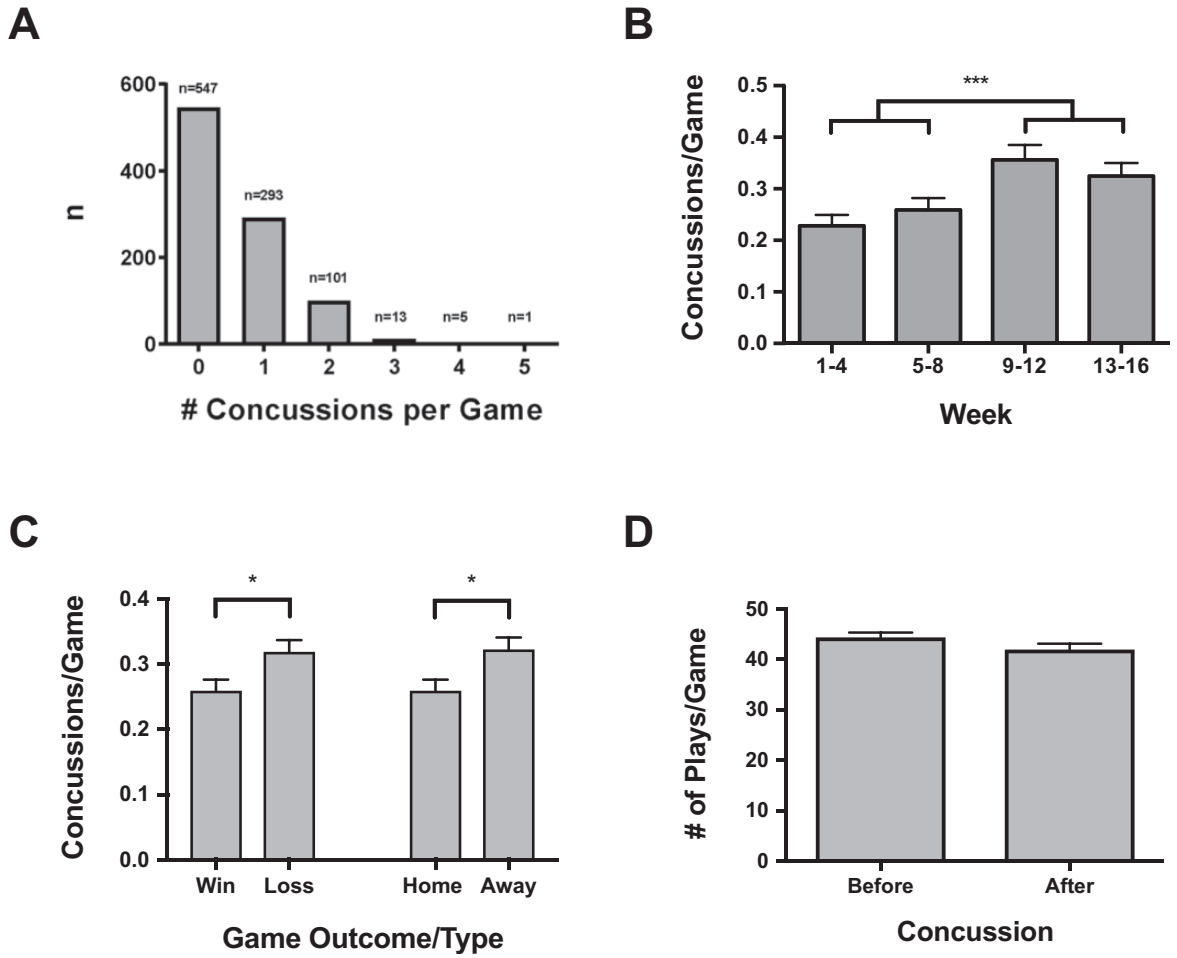

Figure 1. Concussion incidence and style of play overview. (A) Number of games with differing concussion incidence. (B) Mean concussion incidence during different weeks in the NFL season (***$P = .0004$). (C) Mean concussion incidence during different game outcomes and types (win/loss, *$P = .0166$; home/away, *$P = .0108$). (D) Mean number of plays per game before and after sustaining a concussion. Error bars represent SEM.

clipping effect, as players with concussion injuries at the end of the season inherently miss fewer potential games. When concussions causing players to miss the last game of the regular season were removed (E correction), the number of games missed from concussion significantly decreased ($P = .0002$). The number of games missed per E concussion significantly decreased as the season progressed ($P < .0001$). The number of E concussions increased as the season progressed (Figure 2).

Home vs Away

Of the 558 concussions, 248 occurred in home team players and 310 in away team players (44.4% and 55.6%, respectively). Of the 626 games missed, 248 were missed by home team players and 378 by away team players (39.6% and 60.4%, respectively). Similarly, away teams had a significantly greater number of concussions per game compared with home teams ($P = .0108$). This effect remained when the home team won ($P = .0011$), but the significance in home versus away concussions was absent when the away team won. In addition, when games were separated into division and nondivision games, home teams had significantly fewer concussions than away teams during division games ($P = .0417$) but not during nondivision games (Figure 3A).

Analyses of the number of games missed showed similar trends. When the home team won, the away team had a significantly higher number of games missed per concussion compared with the home team ($P = .0392$). Although not statistically significant, away teams had trends toward higher numbers of games missed than home teams for both overall and division games. As with the concussion incidence results, no significant differences were seen in number of games missed for home versus away teams during away team victories and nondivision games (Figure 3B).

Offense vs Defense

Of the 558 total concussions, 285 occurred in offensive positions (51.1%), resulting in 360 games missed (57.5%),

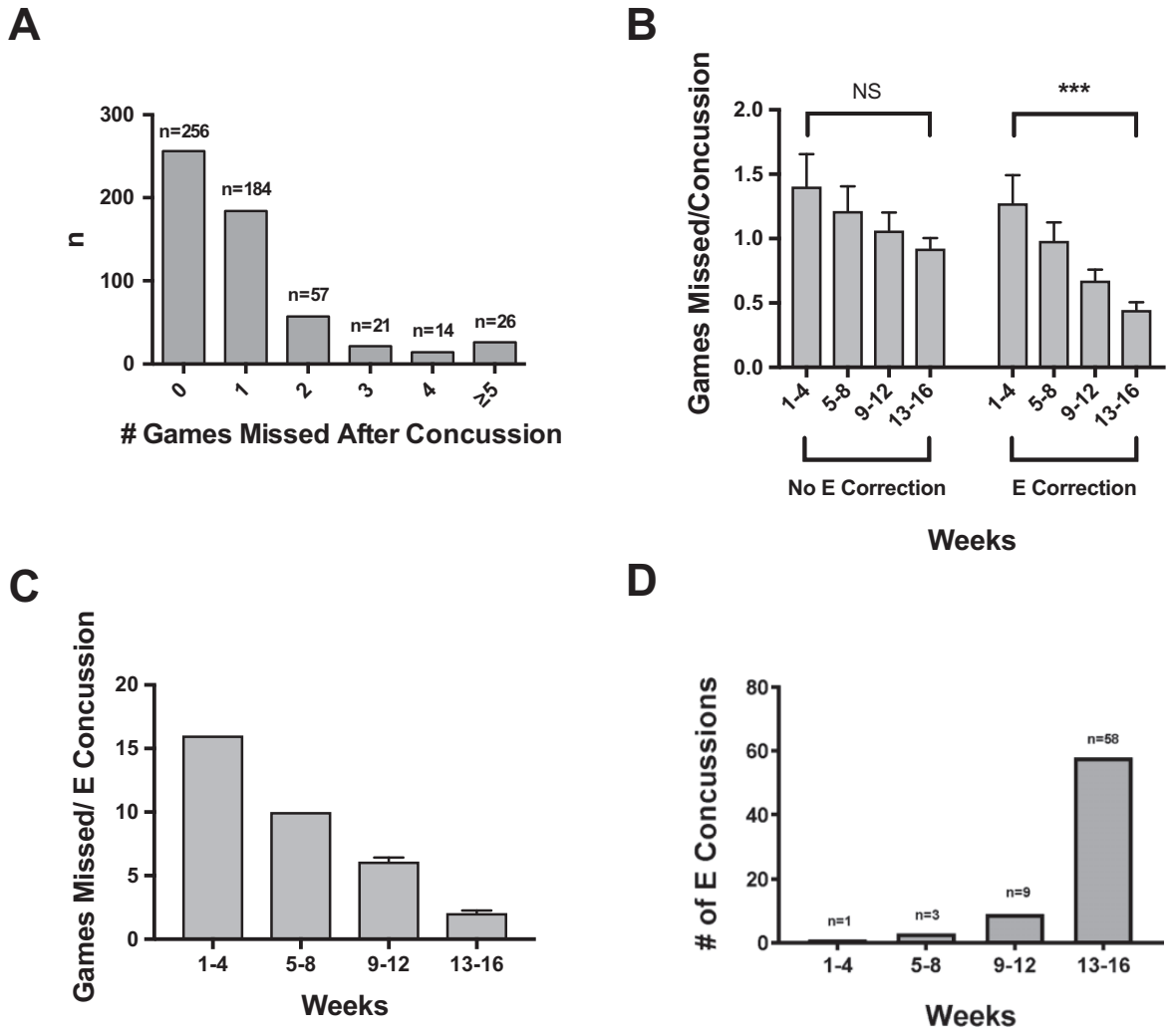

Figure 2. Games missed due to concussion as a marker of concussion intensity. (A) Differing numbers of games missed after sustaining a concussion. (B) Mean games missed due to concussion during different weeks in the National Football League season. Data are split into 2 groups: all data as well as data excluding *E* concussions (concussions causing players to miss the last game of the regular season) (NS, $P = .1919$; ***$P = .0002$). (C) Mean games missed due to *E* concussions during different weeks in the regular season. (D) Number of *E* concussions during different weeks in the regular season. Error bars represent standard error of the mean. NS, not significant.

and 273 concussions occurred in defensive positions (48.9%), resulting in 266 games missed (42.5%). Overall, no significant difference was found in concussion incidence between offensive and defensive players. However, offensive players had a higher concussion incidence during away games ($P = .0025$) as well as during losses ($P < .0001$) (Figure 4A). Home-versus-away and win-versus-loss variables had no significant effects on defensive players.

Analyses of games missed showed a trend toward offensive players missing more games than defensive players ($P = .0732$). Offensive players had a higher number of games missed during away games and losses, although neither of these comparisons were significant. Defensive comparisons were also not significant, but defensive players had a slightly higher number of games missed during losses (Figure 4B).

The mean number of concussions normalized based on the number of players per position on the field was 24.5 from the 2012 to 2015 regular NFL seasons. Running backs, wide receivers, tight ends, cornerbacks, and defensive ends were above the mean (Figure 5). Within offensive positions, tight ends and running backs had significantly more concussions compared with all other offensive positions except each other and wide receivers ($P < .05$). In addition, wide receivers had significantly more concussions than fullbacks and long snappers ($P < .05$) (Figure 6A). Within defensive positions, cornerbacks had significantly more concussions compared with all other defensive positions ($P < .05$) (Figure 6B). No significant differences

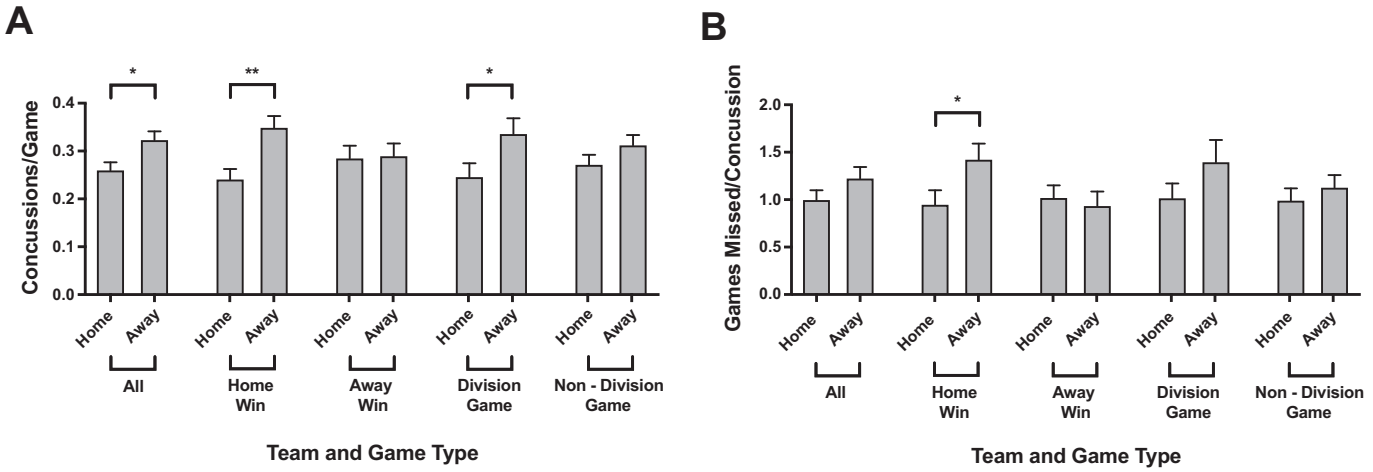

Figure 3. Effect of playing at home on concussion incidence and severity. (A) Mean concussion incidence for different game outcomes and types (all, $^{*}P = .0108$; home win, $^{**}P = .0011$; division game, $^{*}P = .0417$). (B) Mean games missed due to concussion for different game outcomes and types ($^{*}P = .0392$). Error bars represent standard error of the mean.

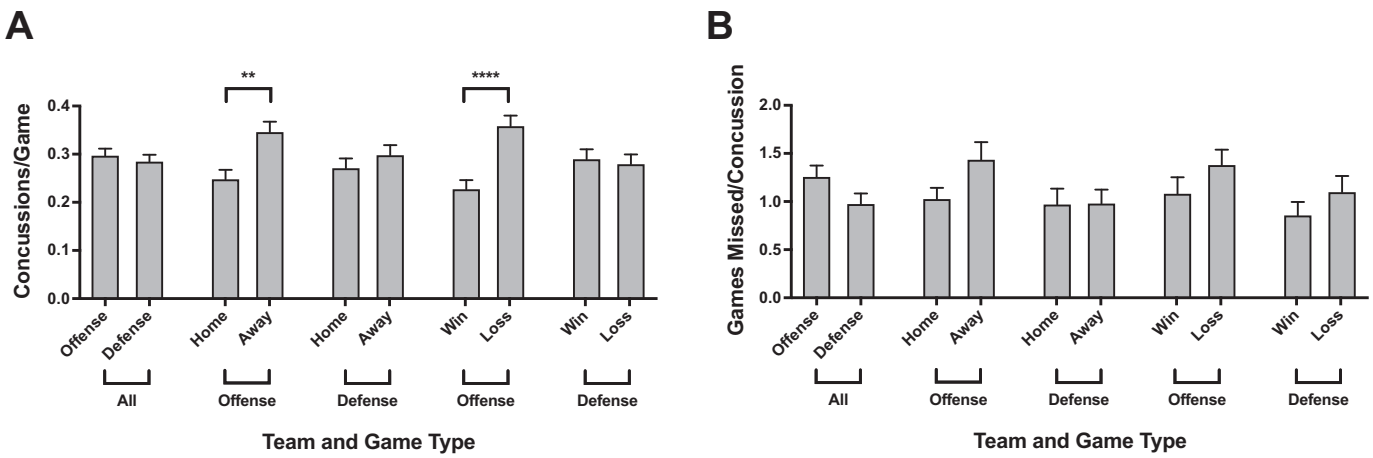

Figure 4. Effect of offensive and defensive playing on concussion incidence and severity. (A) Mean concussion incidence for offensive and defensive players within different game outcomes and types ($^{**}P = .0025$; $^{****}P < .0001$). (B) Mean games missed due to concussion for offensive and defensive players within different game outcomes and types. Error bars represent standard error of the mean.

were found among offense positions or defense positions for games missed (Figure 6, C and D). When running versus passing positions were compared, passing positions had significantly more concussions ($P = .0009$).

Game Characteristics

The number of passing attempts in games with concussions was significantly higher than in games without concussions (mean attempts, 36.09 vs 35.04, respectively; $P = .0218$). However, this difference was not clinically significant. No significant differences were found in the number of points scored, margin of victory, rushing yards, passing yards, turnovers, or rushing attempts when concussion-free and concussion games were compared.

DISCUSSION

Our study demonstrated that game outcome, game type, and player position may affect concussion incidence in NFL teams. Away teams and losing teams experienced significantly increased concussion incidence, and offensive players but not defensive players were significantly affected by home-versus-away and win-versus-loss variables. Within individual positions, significantly higher concussion incidence was associated with tight ends, running backs, wide receivers, and cornerbacks. Passing positions had a significantly higher concussion incidence than running positions. When concussion severity was measured, similar trends were noted, and away teams had significantly more games missed due to concussion when they lost.

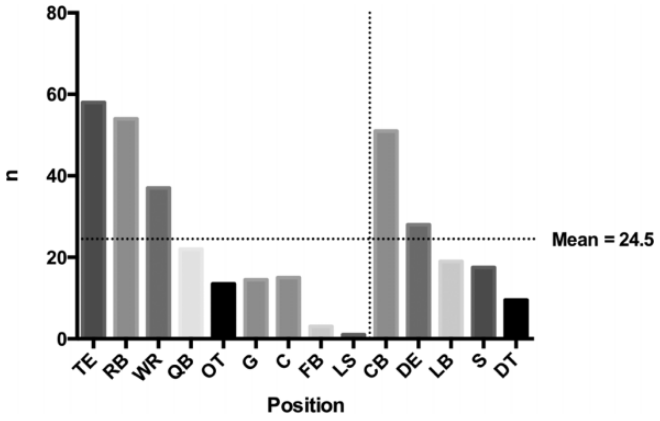

Figure 5. Overview of concussion incidence in offensive and defensive positions. The vertical dotted line separates offensive positions from defensive positions. C, center; CB, cornerback; DE, defensive end; DT, defensive tackle; FB, fullback; G, guard; LB, linebacker; LS, long snapper; OT, offensive tackle; QB, quarterback; RB, running back; S, safety; TE, tight end; WR, wide receiver.

Previous research studies have demonstrated an overall advantage and increase in win percentage for home teams compared with the away teams, but it is unclear exactly which factors cause this advantage. Some hypothesized influences include crowds, referees, and testosterone, which can cause a home team advantage toward winning.[2,12,13,19] However, few studies have looked into game location effects on concussion incidence (home vs away). Teramoto et al[20] reported in 2017 that away teams had more total concussions than home teams, and both days of rest and timing of the bye week had no significant effects on concussion incidence. Yet, it remains unclear whether game characteristics contribute to the overall home-versus-away disparity.

In our study, losing teams had a significantly higher concussion incidence compared with winning teams. It is unclear whether teams have less of a chance to win if they are short a starting player due to concussion. However, this finding could also be influenced by home teams having a home-field advantage over away teams, contributing to decreased concussion incidence for the home team and increased concussion incidence for the away team.[13,20,21] For both home and away teams, increased mean concussion incidence was associated with losing, and decreased mean concussion incidence was associated with winning. Moreover, the disparity in concussion incidence between home and away games was exacerbated when home teams won and away teams lost. In contrast, this disparity disappeared when away teams won, which may be due to the home-versus-away effect counteracting the win-versus-loss effect. A similar relationship was seen regarding division games. Games against other teams in the same division are considered more important when teams are attempting to make the playoffs because a win for a given team also counts as a loss for a division rival. Thus, players may play harder and experience more severe impacts during division games, leading to higher concussion rates. When concussions during division games were analyzed, the home advantage and away disadvantage were seen again.

In addition to concussion incidence, concussion severity may be influenced by game variables. One way to judge the severity of a concussion is neuropsychological testing.[4,5,8,9,11] Previous neuropsychological testing of high school and college athletes has shown that deficits in cognitive performance may persist past 14 days.[10] Another indirect and novel way to judge concussion severity may be the number of games missed after a concussion; more games missed could indicate longer recovery times due to higher concussion severity. Despite this connection, the number of games missed due to concussion was not as strongly correlated with the various factors studied. Our study showed that concussion incidence increases significantly as the season progresses, peaking in weeks 9 to 12 of the regular season (see Figure 1B). This result may be due to lower temperatures and dew points during games later in the season. Our finding agrees with a previous study reporting that decreased temperature and dew point during games were correlated with increased concussion incidence (S.F.Haider et al, unpublished data, 2018). However, the number of games missed did not change significantly as the season progressed (see Figure 2B). This could indicate that while concussion incidence is affected by temporal and environmental factors, concussion severity and number of games missed are not. This could also be due to a clipping effect, as players may have missed more games due to concussion if the regular season was longer.

To study the clipping effect, the concussions that resulted in the player missing the last game of the season (n = 71 of 558) were designated as *E* concussions. Removal of the *E* concussions led to a larger and significant decrease in number of games missed as the season progressed. This is likely because *E* concussions keep players off the field until the end of the season and usually lead to a larger number of games missed per concussion. Removing the *E* concussions decreased the mean number of games missed. The decrease became larger as the season progressed because players concussed later in the season inherently have a lower number of potential games missed; 58 of the 71 *E* concussions occurred in the last quarter of the season (see Figure 2, B-D). Thus, because of the finite number of games per season, the number of games missed has limitations when used as a marker of concussion intensity. Analyzing the severity of a concussion by the number of games missed may only be accurate for concussions occurring early in the season or concussions causing few games to be missed. Last, the lack of correlation between concussion incidence and games missed may also be due to the unpredictability of games being missed, as more severe concussions with higher numbers of games missed are more uncommon and are a result of random, unfortunate circumstances.

Although no link was found between concussion incidence and number of games missed based on timing during the season, a link was found between these parameters in home versus away as well as offense versus defense variables. Away teams had a higher number of games missed

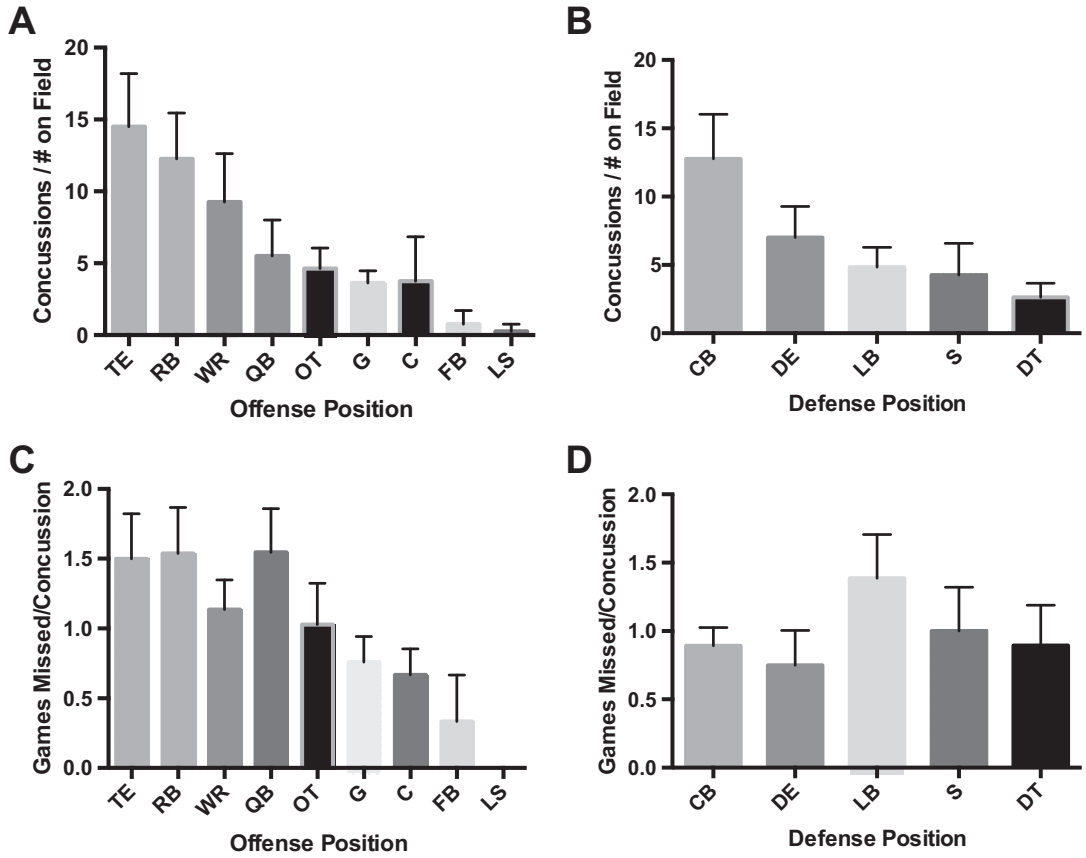

Figure 6. Concussion incidence by offensive and defensive position. Mean concussion incidence normalized by the number of players per position on the field for (A) offensive positions and (B) defensive positions. Mean games missed due to concussion for (C) offensive positions and (D) defensive positions. Error bars represent standard error of the mean. C, center; CB, cornerback; DE, defensive end; DT, defensive tackle; FB, fullback; G, guard; LB, linebacker; LS, long snapper; OT, offensive tackle; QB, quarterback; RB, running back; S, safety; TE, tight end; WR, wide receiver.

for aggregate data, and this effect was increased when the home team won as well as when teams were in the same division; however, only the comparison between home and away teams during a home win was significant (Figure 3B). The mirroring between the results for concussion incidence and number of games missed could be interpreted as away teams having both more frequent and more severe injuries, which are exacerbated by, or contribute to, losing to the home team or playing in higher stakes division games.[7]

For offense-versus-defense analysis, a weaker link was found between concussion incidence and number of games missed. Overall, no significant difference was noted in concussion incidence between offensive and defensive players. Home-versus-away and win-versus-loss effects on concussion incidence significantly affected offensive, but not defensive, position players (Figure 4A). Although not a statistically significant finding, offensive players experienced more games missed from concussion than defensive players despite having roughly equal numbers of concussion (Figure 4B). This discrepancy may indicate that offensive players are affected more by game characteristics than defensive players when sustaining a concussion injury. Offensive players may also be more vulnerable to severe concussion injury, leading to longer recovery time.

Further analysis of individual player positions showed that tight ends, running backs, wide receivers, and cornerbacks in particular had higher concussion rates, and passing positions had a higher concussion rate than running positions (Figure 6). This finding indicates that the nature of passing positions may be more conducive to concussion incidence compared with running positions. Pellman et al[18] similarly reported in 2004 that the relative risk of concussions per game was highest for tight ends and wide receivers, positions typically heavily involved in the passing style of play, for 1996 to 2001 NFL games. Because of the increased risk of injury at these positions, changes to rules on player safety and in-game penalties designed to protect these positions may allow a meaningful decrease in concussion injury.

Although the data showed that playing at home versus away as well as being on offense versus defense affected concussion incidence and severity, many other factors tested had surprisingly little to no effect. We hypothesized that several factors related to style of play and game

scenarios may contribute to concussion incidence and severity, including points scored, margin of victory, turnover rate, rushing yards, rushing attempts, passing yards, and passing attempts. Points scored, margin of victory, and turnover rate were thought to be indicative of the competitiveness of games, and it was predicted that the more competitive games would have a higher rate of concussion incidence and severity. The lack of significant findings may indicate that players in the NFL consistently play at high levels, as earning a spot on each team is already extremely difficult and competitive. Variables associated with rushing and passing were predicted to have effects as well, since previous studies had indicated that a more offensive style of play affected concussion rate.[21] The lack of significant findings may be due to lack of specificity in the variables tested. Number of plays and yards for rushing and passing may not reflect the true styles of offense, rushing, and passing exhibited by NFL teams.

The findings from our study may be used to identify players at a higher risk of concussion and potentially make rule changes to the game to improve player safety. It is helpful to know that away teams and losing teams have a higher concussion incidence and severity, especially for offensive positions. Careful monitoring of concussion injuries in these groups can help prevent further injury. After returning from a concussion injury, athletes played the same average number of plays per game as they did before the concussion, which may indicate that current NFL return-to-play concussion protocols are to an extent able to accurately evaluate a player's recovery. Nevertheless, neurocognitive testing is necessary, but not sufficient, for team physicians to base their return-to-play decisions.[3,17] Research on how to better evaluate and treat concussions should continue in order to prevent injured players from returning to the field. Another important finding is that positions involved in passing plays have the highest concussion incidence among NFL players. This is understandable given the high-speed plays, high-speed impacts between receiving players and defensive players, and the relative importance of passing plays within the game.[15] Recent rule changes penalizing hits to receivers' head and neck areas when they make catches as well as lowering helmets and using helmets to tackle players are likely helping to decrease these injuries.[14] Additional rule changes discouraging contact to head and neck areas should be considered if these impacts continue to occur in professional football.

Limitations

The data on concussion injuries in the NFL are team-reported. Team-reporting may be biased, as a team's mentality may be to return players to the field as soon as possible and therefore to underestimate concussion severity; players, coaches, and team physicians may feel these pressures during concussion recovery periods. The NFL reported 1000 concussions between the 2012 and 2015 seasons, whereas our study identified 558 concussions during that time.[16] However, the NFL data include concussions during the preseason, bye weeks, week 17, and postseason, resulting in the NFL reporting more concussions than did PBS *Frontline* Concussion Watch. Therefore, the assessment of number of games missed is not completely accurate in cases where a player was concussed, had a bye week, and played in a regular season game the following week, or where a player's team progressed through the playoffs and the player continued to miss games past week 17. Injuries during preseason, week 17, and postseason could potentially influence the number of plays and games missed during the regular season, adding some error to our analysis. However, the NFL data do not specify details about individual concussions. For these reasons, the NFL data were not compared with the PBS *Frontline* data used in this study.

CONCLUSION

The characteristics of games and of player positions have a potential influence on concussion incidence and severity. A reduced incidence of concussion is potentially associated with home team advantage and winning the game. Home games and winning are significantly associated with decreased mean concussion incidence for offensive positions but not defensive positions. A games-missed metric was introduced to characterize concussion intensity, and players on away teams had significantly more games missed due to concussion during losses. The efficacy and limitations of number of games missed need further investigation. Within individual positions, significantly higher concussion incidence was associated with tight ends, running backs, wide receivers, and cornerbacks. When running versus passing positions were compared, passing positions had significantly higher concussion incidence. These findings add to the knowledge of factors that may modify concussion incidence and severity. Understanding which populations are more susceptible will help reduce the rate of concussion in sports through awareness and rule changes. The results of this study merit further study on why these effects occur and how they could play a role in evaluating concussion incidence.

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