

Concussion Incidence in Professional Football

Position-Specific Analysis With Use of a Novel Metric

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Background: In the United States alone, millions of athletes participate in sports with potential for head injury each year. Although poorly understood, possible long-term neurological consequences of repetitive sports-related concussions have received increased recognition and attention in recent years. A better understanding of the risk factors for concussion remains a public health priority. Despite the attention focused on mild traumatic brain injury (mTBI) in football, gaps remain in the understanding of the optimal methodology to determine concussion incidence and position-specific risk factors.

Purpose: To calculate the rates of concussion in professional football players using established and novel metrics on a group and position-specific basis.

Study Design: Case-control study; Level of evidence, 3.

Methods: Athletes from the 2012-2013 and 2013-2014 National Football League (NFL) seasons were included in this analysis of publicly available data. Concussion incidence rates were analyzed using established (athlete exposure [AE], game position [GP]) and novel (position play [PP]) metrics cumulatively, by game unit and position type (offensive skill players and linemen, defensive skill players and linemen), and by position.

Results: In 480 games, there were 292 concussions, resulting in 0.61 concussions per game (95% CI, 0.54-0.68), 6.61 concussions per 1000 AEs (95% CI, 5.85-7.37), 1.38 concussions per 100 GPs (95% CI, 1.22-1.54), and 0.17 concussions per 1000 PPs (95% CI, 0.15-0.19). Depending on the method of calculation, the relative order of at-risk positions changed. In addition, using the PP metric, offensive skill players had a significantly greater rate of concussion than offensive linemen, defensive skill players, and defensive linemen ($P < .05$).

Conclusion: For this study period, concussion incidence by position and unit varied depending on which metric was used. Compared with AE and GP, the PP metric found that the relative risk of concussion for offensive skill players was significantly greater than other position types. The strengths and limitations of various concussion incidence metrics need further evaluation.

Clinical Relevance: A better understanding of the relative risks of the different positions/units is needed to help athletes, team personnel, and medical staff make optimal player safety decisions and enhance rules and equipment.

Keywords: concussion; mTBI; National Football League; athlete exposures; game positions; position plays; risk assessment; concussion incidence

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In the United States, sports-related concussions (SRCs) occur between 1.6 and 3.8 million times per year, making them the leading cause of mild traumatic brain injury (mTBI).⁸ All 50 state governments as well as the District of Columbia have passed laws with the goal of minimizing the incidence and potential long-term consequences of SRCs.¹⁵ Football is among the leading causes of SRC and has been a focal point of SRC analysis and intervention.³ Since the 1994 establishment of the National Football League (NFL) Committee on Traumatic Brain Injury, changes in rules, equipment, and sideline assessment have focused on reducing the incidence of SRCs.² However, there are still significant gaps in knowledge relating to the incidence of football concussions as well as the relative risks of the different positions.

Even after regulation changes and increased media scrutiny, succinct NFL concussion incidence rates have not been reported by position since the 2007 season.^{2,3} The lack of available literature suggests the need for an evaluation of current concussion incidence in football to validate the accuracy of past reporting and the efficacy of recent rule changes. NFL players serve as a useful study cohort because of the availability of public data sources.

Concussion incidence has been previously described in the literature utilizing multiple methods of calculation. Prior reports have calculated concussion incidence rates either by the athlete exposure (AE) metric or the game position (GP) metric. The AE metric provides an overall risk assessment per session of athlete participation and has been used in multiple reports of football-related concussion incidence.^{6,7,11} It can misrepresent the risk of SRC for a given athlete or position because it is calculated using the number of players on an active roster (46) and assumes that all players, regardless of playing time, are equally exposed to injury over the course of a given game. Furthermore, when calculating concussion rate by position using AE, there is the possibility of misrepresenting positional incidence; the AE metric assumes that a team will have the same number of players at a given position on its active roster. Therefore, AEs are most useful in team-based analyses of concussion incidence unless used prospectively with exact roster data.

The GP metric provides a position-specific risk assessment and has been used in papers published by the NFL Committee on Traumatic Brain Injury on the incidence rates of concussion in the NFL.^{2,14} Calculating concussion incidence by GP is dependent on the number of players on the field in a given position, not merely on the active roster. Therefore, concussion incidence for those players who are not a part of the starting line-up may be overestimated. Like the AE, the GP metric assumes a standard, fixed number of players in each position; when utilizing GP on a positional basis, the metric misrepresents concussion risk for players on teams that deviate from the standard position breakdown in on-field sets assumed by the mTBI committee. For example, if a team chooses to utilize 3 wide receivers (WRs) and no tight ends (TEs) in a given play or series (rather than the average 2 WRs and 1 TE), concussion rates for these 2 positions will be under- and overestimated, respectively. The GP and AE metrics calculate concussion incidence rates differently, and therefore, published rates using one measure cannot be statistically compared with those using the other.

We hoped to validate the quality of concussion reporting given the use of multiple metrics in the literature. We also sought to expand on the current understanding of concussion in the NFL by reporting its incidence on a position-by-position basis. A positional analysis will inform the league of their at-risk players and allow optimum enhancement of current game rules. Further, given the potential for misrepresentation in the past literature standards, we developed a novel metric to more accurately describe rates of concussion. This new metric, position play (PP), considers the intragame variability in the positional makeup of on-field units. PP utilizes the exact number of plays in

which a given position participates rather than estimating based on assumptions of traditional positional numbers in offensive or defensive sets. This gives a more refined look at positional head injury risk because each position is evaluated separately according to how much playing time it receives. We hypothesized that past representations of concussion rate by position are inaccurate due to the limitations of the GP and AE metrics discussed. We hoped that by using our novel PP metric, we will be able to publish more comprehensive and accurate rates of concussion in the NFL compared with past literature standards.

These data will serve to assist health care providers across the country as they educate the 7.8 million high school athletes of the risk associated with high-impact sports.¹ Specifically, data determining which positions are at the greatest risk for concussion can be used to modify rules, equipment, and on-field behavior. While this study is about professional football, the head injury burden transcends all impact sports and may be even more prevalent among youth athletes.³ It is our belief that the data presented will be useful to players, parents, sports affiliates, and physicians as they make decisions regarding the health and safety of current and future athletes.

METHODS

Publicly available NFL injury data were utilized to determine which players sustained concussions and head injuries during the 2012-2013 and 2013-2014 seasons. Concussion rates were calculated using the total number of concussions that occurred during regular-season games in weeks 1 through 16 and 3 quantitative measures of risk. Teams that make the playoffs are not required to report injuries that occur in week 17. Therefore, data from this week were omitted from our calculations.

Metric Use

The first of the quantitative measures uses AE to determine risk. Given 46 active players per team per game and 240 games in the first 16 weeks of the season, the number of game exposures for each season is approximately 22,080. Of those 46 players, there are on average 5 wide receivers (WRs), 3 tight ends (TEs), 4 running backs (RBs), 7 offensive linemen (OL), 2 quarterbacks (QBs), 8 defensive linemen (DL), 7 secondary linemen (DBs), 7 linebackers (LBs), and 3 special teams players (STs) (1 punter, 1 kicker, and 1 long snapper).⁹

The second metric (GP) utilizes the total number of concussions divided by the standard number of players in a starting lineup position multiplied by the number of games in the study period.^{2,14} For example, the 1-year GP for TEs would be calculated by dividing the total number of TE concussions by 1 (the number of TEs in a standard offensive unit) times the number of games in the study period.

Our unique method (PP) utilizes the number of plays in which a given position participates, defined by play count, to calculate concussion incidence. Therefore, positions that participate in play more frequently can be appropriately

weighted. Calculations for concussion rate were performed to determine total concussion incidence rates and concussion incidence rates by position over 2 seasons in the NFL.

Concussion Data

Concussion data were collected from information presented on the Public Broadcasting Service (PBS) Frontline Concussion Watch web resource (<http://www.pbs.org/wgbh/pages/frontline/concussion-watch/>).⁴ Concussion Watch presents all league-confirmed head injuries from the 2012-2013 and 2013-2014 NFL seasons and information on which player sustained the injury, his position and team, and the time in the season the injury occurred. The injuries reported by PBS Frontline are clinically suspected concussions at the time of impact that ultimately meet the NFL's criteria for a confirmed concussion. All injuries, whether referred to as "concussion" or "head injury" in the Frontline database, were included in our analysis; numerous "head injuries" were ultimately diagnosed as concussions. This form of reporting was preferred because the risk of either injury type results from similar on-field behaviors.

Concussion Rate by Position

An analysis of concussion rates by position was conducted using the aforementioned 9 position groupings. The group "offensive line" consists of the field positions guard, offensive tackle, and center. The group "offensive skill" consists of QB, WR, TE, RB, and fullback (FB). As per the literature, defensive ends and defensive tackles were grouped to create the "defensive line" (DL) and cornerbacks and safeties were grouped to create the "defensive back" (DB) group.¹⁴ The group "defensive skill" includes the defensive back group and linebackers. Concussion rates for each of the 9 position groups were calculated using the 3 different metrics and have been reported with 95% confidence intervals. Nonoverlapping intervals are considered to be significantly different, with an $\alpha = .05$.

Snap Counts

Snap count data from the 2012-2013 and 2013-2014 seasons were obtained from Football Outsiders (<http://www.footballoutsiders.com>), an online resource that aggregates NFL statistics obtained from the NFL's official media website.^{12,13} A player's snap count is equal to the number of plays in which that athlete participated. These snap counts were aggregated for a given position and utilized in the PP calculation.

RESULTS

Total Concussion Incidences

In the 2012-2013 and 2013-2014 NFL regular seasons (weeks 1-16), there were a total of 292 reported concussions. These concussions occurred over 480 games, 44,160 AEs, 21,120 GPs, and 1,718,813 PPs. For context, there are a

TABLE 1
Overall and Position-Specific Concussion Rates per 1000 AEs for the 2012-2013 and 2013-2014 NFL Seasons^a

| Position | Total AEs | No. of Concussions | Concussions per 1000 AEs (95% CI) |
|----------------|---------------------|--------------------|-----------------------------------|
| Defensive back | 6720 | 79 | 11.76 (9.16-14.35) |
| Tight end | 2880 | 32 | 11.11 (7.26-14.96) |
| Wide receiver | 4800 | 47 | 9.79 (6.99-12.59) |
| Running back | 3840 | 29 | 7.55 (4.80-10.30) |
| Quarterback | 1920 | 13 | 6.77 (3.09-10.45) |
| Offensive line | 6720 | 41 | 6.10 (4.23-7.97) |
| Linebacker | 6720 | 24 | 3.57 (2.14-5.00) |
| Fullback | 960 | 3 | 3.13 (0.25-7.52) |
| Defensive line | 7680 | 24 | 3.13 (1.87-4.38) |
| Total | 44,160 ^b | 292 | 6.61 (5.85-7.37) |

^aAEs, athletic exposures; NFL, National Football League.

^bThis number includes 3 additional special teams players for which position-specific data were not available.

mean 128 snap counts per game. Thus, there were a total of 0.61 concussions per game (95% CI, 0.54-0.68), 6.61 concussions per 1000 AEs (95% CI, 5.85-7.37), 1.38 concussions per 100 GPs (95% CI, 1.22-1.54), and 0.17 concussions per 1000 PPs (95% CI, 0.15-0.19).

Athlete Exposures

Table 1 shows the concussion incidence rates for various position groupings by AE. Descriptively, DBs (11.76/1000 AEs) and TEs (11.11/1000 AEs) had the highest concussion incidence rates. The DL (3.13/1000 AEs) and FBs (3.13/1000 AEs) had the lowest concussion incidence rate of the 9 groupings.

Game Position

Table 2 shows the concussion incidence rates for position groupings by GP. Descriptively, TEs (3.33/100 GPs) and RBs (3.02/100 GPs) had the highest concussion incidence rates. The DL (0.63/100 GPs) and FBs (0.31/100 GPs) had the lowest concussion incidence rate.

Position Plays

Table 3 shows the concussion incidence rates for the 9 position groupings by PP. Descriptively, RBs (0.37/1000 PPs) and TEs (0.32/1000 PPs) had the highest concussion incidence rates. LBs had the lowest concussion incidence rate (0.09/1000 PPs).

Analysis by Unit

Figures 1 through 3 show the concussion rates and 95% CIs for all players, and offensive skill, offensive line, defensive skill, and defensive line groupings by AE, GP, and PPs, respectively. When calculating by AE, defensive skill players had the greatest concussion rate. When calculating by GP, the offensive skill group had a greater rate of

TABLE 2
Overall and Position-Specific Concussion Rates per 100 GPs for the 2012-2013 and 2013-2014 NFL Seasons^a

| Position | Total GPs | No. of Concussions | Concussions per 100 GPs (95% CI) |
|----------------|-----------|--------------------|----------------------------------|
| Tight end | 960 | 32 | 3.33 (2.18-4.49) |
| Running back | 960 | 29 | 3.02 (1.92-4.12) |
| Wide receiver | 1920 | 47 | 2.45 (1.75-3.15) |
| Defensive back | 3840 | 79 | 2.06 (1.60-2.51) |
| Quarterback | 960 | 13 | 1.35 (0.62-2.09) |
| Offensive line | 4800 | 41 | 0.85 (0.59-1.12) |
| Linebacker | 2880 | 24 | 0.83 (0.50-1.17) |
| Defensive line | 3840 | 24 | 0.63 (0.37-0.88) |
| Fullback | 960 | 3 | 0.31 (0.025-0.75) |
| Total | 21,120 | 292 | 1.38 (1.22-1.54) |

^aGPs, game positions; NFL, National Football League.

TABLE 3
Overall and Position-Specific Concussion Rates per 1000 PPs for the 2012-2013 and 2013-2014 NFL Seasons^a

| Position | Total PPs | No. of Concussions | Concussions per 1000 PPs (95% CI) |
|----------------|-----------|--------------------|-----------------------------------|
| Running back | 79,011 | 29 | 0.37 (0.23-0.50) |
| Tight end | 98,489 | 32 | 0.32 (0.21-0.44) |
| Wide receiver | 173,139 | 47 | 0.27 (0.19-0.35) |
| Defensive back | 387,487 | 79 | 0.20 (0.16-0.25) |
| Quarterback | 64,597 | 13 | 0.20 (0.09-0.31) |
| Fullback | 23,791 | 3 | 0.13 (0.01-0.3) |
| Offensive line | 351,350 | 41 | 0.12 (0.08-0.15) |
| Defensive line | 247,141 | 24 | 0.097 (0.06-0.14) |
| Linebacker | 266,681 | 24 | 0.090 (0.05-0.13) |
| Total | 1,718,813 | 292 | 0.17 (0.15-0.19) |

^aNFL, National Football League; PPs, position plays.

concussion than all other groups. This finding reached significance when calculating by PP only.

DISCUSSION

The calculated overall and positional incidence values using GP were considerably higher in our study than those of Casson et al.² For the 1996 through 2001 seasons, QBs had the highest concussion incidence rate (1.62/100 GPs). From 2002 through 2007, QBs had the second highest incidence (1.20/100 GPs).² In the 2012-2013 and 2013-2014 seasons, QBs had a concussion incidence rate of 1.35/100 GPs. Moreover, TEs were found to have the highest concussion incidence rate from 2002 through 2007 (1.45/100 GPs; 95% CI, 1.10-1.86), up from the 1996 through 2001 NFL seasons (0.94/100 GPs; 95% CI, 0.63-1.25).² TEs were also the highest risk position in our GP analysis (3.33/100 GPs; 95% CI, 2.18-4.49). The concussion rate for TEs increased significantly from the 2002 through 2007 seasons to the 2012-2013 and 2013-2014 seasons. The increases in our calculated rates per 100 GPs may be a result of recent efforts

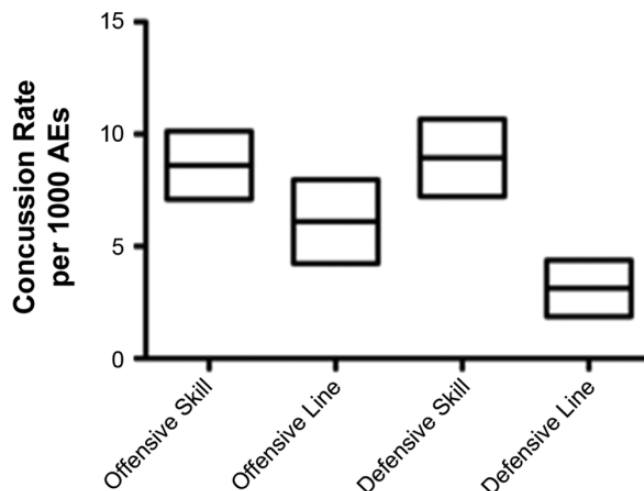


Figure 1. Concussion rates by position groupings and overall for the 2012-2013 and 2013-2014 National Football League seasons per 1000 athlete exposures (AEs). Boxes represent 95% CIs.

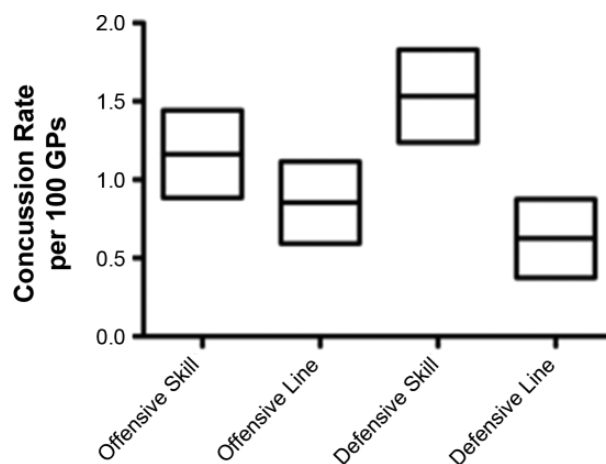


Figure 2. Concussion rates by position groupings and overall for the 2012-2013 and 2013-2014 National Football League seasons per 100 game positions (GPs). Boxes represent 95% CIs.

to improve concussion recognition and reporting by instituting a standardized concussion reporting protocol.

Depending on the metric, the at-risk players change relative order. For example, RBs are the fourth most vulnerable when reporting in AEs (7.55/1000 AEs) but became the most vulnerable position when calculating using PPs (0.37/1000 PPs). Alternatively, the defensive secondary is the most vulnerable position in AEs (11.76/1000 AEs) but the fourth most vulnerable in PPs (0.20/1000 PPs). Furthermore, a comparison of the 3 different metrics gives varying accounts of defensive and offensive concussion risk when players are grouped by position type (skill vs linemen). Only the PP metric revealed that offensive skill players have a significantly greater risk of concussion. These

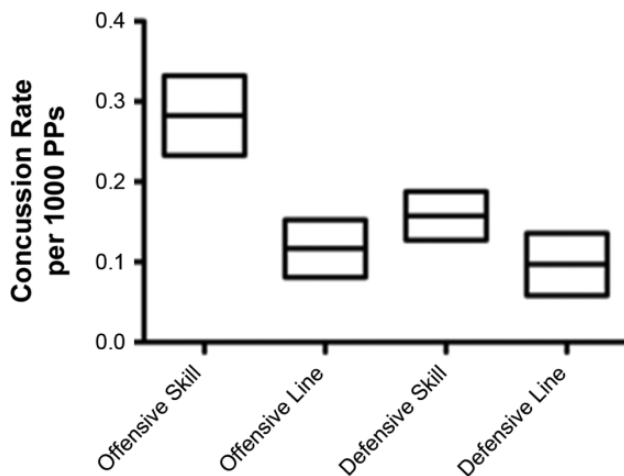


Figure 3. Concussion rates by position groupings and overall for the 2012-2013 and 2013-2014 National Football League seasons per 1000 position plays (PPs). Boxes represent 95% CIs.

data are lost when these values are calculated by AE and GP. The various incidence rates calculated in our report indicate that there exists the possibility of a general misrepresentation of concussion incidence rates depending on the method of computation. Without the use of the PP metric, appropriate individuals would be unaware that offensive skill players, rather than defensive skill players, are at the greatest risk for concussion.

Although team-based concussion rate calculations would reflect similar incidences when using AE, GP, and PP, we believe a standard calculation metric should be adopted that accounts for positional variations on active rosters and individual set pieces. This goal is accomplished when calculating by PP.

The GP and PP analyses may not significantly vary from one another at certain positions such as linemen, where the assumed standard number of players does not change from the actual number of players in an offensive or defensive unit. However, GP is likely to misrepresent concussion rates for skill players like WRs and RBs because there is a high likelihood of deviation from the standard set assumed by the GP metric.

Limitations

Our study is limited by the lack of availability of official data published by the NFL. Prior published studies^{2,14} were commissioned by the NFL with special access to its official data. We therefore had to utilize an independent resource for concussion information. At this point, Frontline has compiled 3 complete years worth of head injury data, which is reliant on team physicians, trainers, and associated officials across the league. The opportunity for unrecognized injuries continues to be a persistent issue because of the lack of uniformity in postconcussive symptoms. Players are often unaware of the presence or severity of the injury and the potential risk of continued play.¹⁰ This lack of recognition may be exacerbated by

fear of team retribution, loss of playing time, and the resolute attitude of professional athletes.⁵ The difficulty in standardizing the clinical constellation defined as “concussion” may be reflected in our reported concussion rates; it is likely that concussions may not be recognized by medical staff or even by players themselves. The data set was further limited due to the lack of required reporting in preseason competition, practices, and games beyond the 16th week of the regular season. Moreover, information on special teams was incomplete because of inconsistencies in reporting. Finally, data were aggregated across the 2012-2013 and 2013-2014 seasons despite differences in game regulations and injury reporting between seasons. Therefore, the numbers we report in this study most likely underestimate the true concussion incidence rates, as it is likely that more concussions are occurring than are represented in our data set.

The PP metric also has some limitations. All snap counts were considered to be a possible head injury exposure despite the fact that some snaps result in a team “taking a knee” or a penalty signaled without contact. Although we are able to capture exposure at a play-by-play level across positions, this information does not differentiate between players who may be playing outside of their official position title. An RB who participates in a special teams unit may confound our results; one position may be more prone to injury than another. Furthermore, teams in the NFL have recently adopted playing styles that utilize “hybrid” positions; although a player may officially be an RB, he may participate in some pass plays and assume the concussion risk of a WR. The hybrid nature of certain positions complicates an absolute analysis of risk. Additionally, these data do not capture differences in head injury risk for starting players compared with substitutes. The utility of the PP metric is limited in leagues where snap counts are not aggregated, though we hope that smaller leagues gather further information about playing time to more completely assess concussion risk.

CONCLUSION

In this study, we analyze the concussion incidence rate for players over the 2012-2013 and 2013-2014 NFL seasons by AE and GP—2 metrics used widely in the literature. We also report a new method of calculating concussion incidence rate that is based on a position’s play count, which we believe to be a more accurate assessment of exposure risk. The incidence of concussion in the NFL appears to have increased across all positions since 2003 when the first analysis was published. This may be a result of changes in game play, injury recognition, or reporting protocol. Unfortunately, comparative analysis is complicated by the lack of a standardized reporting protocol in the literature. Our novel metric, based on position plays, provides a more refined tool for risk assessment in what we hope to become the standard for SRC. This increased focus is necessary so that risk variation across positions can be accurately assessed, rule changes may be executed accordingly, and appropriate education can be provided to the millions who play football across the country.

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