Style of Play and Rate of Concussions in the National Football League

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Background: The majority of studies on concussion in the National Football League (NFL) focus on testing, evaluation, and outcomes. Meanwhile, there is a paucity of research on how a team's style of play influences the risk of concussion.

Hypothesis: Style of play, such as offensive and defensive strategies, is associated with the rate of concussions in the NFL.

Study Design: Descriptive epidemiology study.

Methods: The current study retrospectively analyzed data from the 2012 to 2014 NFL regular seasons. Reported numbers of concussions were stratified by each team and each position and were compared based on style of play, including offensive scheme (West Coast offense, Air Coryell offense, or other offensive schemes) and defensive alignment (3-4 or 4-3), attempts statistics, per-drive statistics, and offensive and defensive productions, along with strength of schedule (SoS) and team quality measured by simple rating system (SRS). Data analyses included descriptive statistics, 1-way analysis of variance, correlation analysis, and regression analysis.

Results: There were 437 documented concussions during the 2012 to 2014 NFL regular seasons, with a mean 4.6 concussions per season per team. In general, players most involved in pass plays reported more concussions. The number of concussions sustained by offensive players was significantly higher among the teams adopting the West Coast offense (mean, 3.0) than among those utilizing the Air Coryell offense (mean, 1.6; $P = .006$) or those with non–West Coast offenses combined (mean, 1.9; $P = .004$). The multiple regression analysis revealed that the West Coast offense or not, SoS, and SRS explained 25.3% of the variance in the number of concussions by offensive players. After accounting for SRS, the West Coast offense was found to be a significant predictor of the number of concussions ($P = .007$), while there was a tendency for SoS to be inversely associated with the number of concussions ($P = .105$). None of the variables for attempts statistics, per-drive statistics, and offensive production were significantly associated with the number of concussions in the regression analysis.

Conclusion: In the NFL, players most involved in pass plays appear to be at increased risk for concussions. The West Coast offense may be associated with a greater risk of concussion. Furthermore, teams with easier schedules may have more players sustaining concussions.

Keywords: concussion; style of play; National Football League (NFL); West Coast offense; epidemiology; risk factor; statistics

Concussion, classified as a mild traumatic brain injury (mTBI),[5] is one of the major injury concerns in the National Football League (NFL) today.[37] In the NFL, a strike by another player's helmet is a primary cause of concussions, followed by impact from other body regions of the striking player as well as impact with the ground.[26] mTBI can lead to a number of adverse health consequences ranging from transient mild symptoms (eg, headache, dizziness, and incoordination) to persistent disabling problems (eg, anxiety, depression, and dementia).[12] Chronic traumatic encephalopathy, a neurological condition caused by repeated concussive and subconcussive blows to the brain, has been documented among retired NFL players.[19-21] It was reported that in the 2002 to 2007 NFL seasons, there were 0.38 documented concussions per game.[3] Recently,

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a tentative US$765 million settlement over concussion-related brain injuries has been reached between the NFL and 18,000 retired NFL players.[15] Hence, risk identification, prevention, accurate diagnosis, and effective treatments for concussion are urgent topics that need to be addressed in the NFL as well as in the field of sports medicine in general.

Current research on concussion in the NFL focuses on signs and symptoms, biomechanics, treatments, evaluations, neuropsychological testing, and outcomes of concussion.[25,27] Recent studies also have looked at risk factors of individual NFL players, such as history of concussions, demographic and performance data, particular playing situations, and recovery.[3,4,7,11] Meanwhile, to the best of our knowledge, there is no existing study on how a team's style of play influences the risk of concussions in the NFL. For example, some NFL teams may choose more pass plays than run plays for their offense, while others may be characterized as a running team. Different offensive and defensive strategies are utilized in the NFL, such as the West Coast or Air Coryell offense and the 3-4 or 4-3 defensive alignment.[30,31] For example, the West Coast offense emphasizes a short passing game, whereas long, downfield throws are utilized more in the Air Coryell offense.[1,10] The 4-3 defensive alignment puts 4 linemen at the line of scrimmage and 3 linebackers behind it, putting more pressure on the quarterback.[1] On the other hand, there are 3 linemen and 4 linebackers positioned in the 3-4 defensive alignment, providing greater flexibility to defend both pass and run plays.[1] We were interested in knowing how different offensive and defensive strategies might be associated with the risk of concussions for NFL players. The aim of this study was to investigate the association between style of play and the rate of concussion in the NFL.

METHODS

The present study retrospectively analyzed data from 32 NFL teams during the 2012 to 2014 NFL regular seasons (3 years; including preseasons but excluding playoffs). Specifically, data on concussion in the NFL were obtained from the Public Broadcasting Service (PBS) FRONTLINE Concussion Watch (http://www.pbs.org/wgbh/pages/frontline/sports/concussion-watch/about-concussion-watch/),[22-24] and variables for styles of play, along with performance measures, by the NFL teams described below were obtained from Pro-Football-Reference.com[28,29,32] and NFL.com.[16-18] Numbers of concussions reported during these 3 seasons were stratified by each team and each position. Variables for a team's style of play included: offensive scheme (West Coast offense, Air Coryell offense, or other offensive schemes) and defensive alignment (3-4 or 4-3) identified, taking into account coaches' preferred offensive strategies.[36] The West Coast offense is philosophically defined as utilizing short passing games with crossing routes, whereas attacking vertically through seams is a distinct feature of the Air Coryell offense.[1,10] Other variables of interest in relation to the number of concussions included attempts statistics, per-drive statistics, and productions from passing and rushing offense and from passing and rushing defense. Pass attempts per game (Pass-Att) and rush attempts per game (Rush-Att) were used for attempts statistics. Per-drive statistics included mean number of plays per drive (plays/drive), net yards per drive (yds/drive), and mean time in minutes per drive (time/drive). Offensive productions were quantified by expected points contributed by passing offense (EXP-Pass-Offense) and by rushing offense (EXP-Rush-Offense). Similarly, defensive productions were quantified by expected points contributed by passing defense (EXP-Pass-Defense) and by rushing defense (EXP-Rush-Defense). Expected points are the estimate or likelihood of scoring or "being the next scorer"[2] at the start of a given play, taking into account down and field position[33] or "the expected value of the next score to the team" depending on the game situation.[35] Positive expected points indicate the likelihood of your team scoring next, while the likelihood of your opponent scoring is indicated by negative expected points.[2] Expected points can be used to assess the contributions of each team's squad to the scoring margin of the game.[35] Cumulative totals of expected points for each team in a single season are available on Pro-Football-Reference.com[28,29,32] and were used in this study. We also included strength of schedule (SoS) and team quality measured by simple rating system (SRS) as another set of predictors. SRS is a measure of "team quality relative to average (0.0)," whereas SoS is "average quality of opponent as measured by SRS."[32] SRS is calculated from all game results that are adjusted for by margin of victory and then weighted by the opponent's strength.[14] Despite its inherent limitations,[34] SRS is considered a better measure of a football team.[14] The offensive scheme and defensive alignment of each team were determined as those utilized most frequently by the team during the 3 years. Regarding the other quantitative variables, 3-year averages were used for subsequent data analyses.

Descriptive statistics were calculated for the number of concussions by each team, by position, and by the variables of interest described above. Subsequent analyses involved both univariate and multivariate analyses of the data. As part of univariate analyses, a 1-way analysis of variance (ANOVA) was used to compare numbers of concussions sustained by offensive and defensive players based on different offensive schemes and defensive alignments. In case of significant results from the ANOVA, relationships of numbers of concussions to SoS, SRS, attempts statistics, per-drive statistics, and offensive and defensive productions were examined by Pearson correlation coefficients. Furthermore, a multiple linear regression (MLR) analysis was performed as a multivariate technique to examine the relative importance of each variable to predicting the number of concussions after identifying sets of variables from the results of the correlation analysis.

RESULTS

There were 437 concussions reported during the 2012 to 2014 NFL regular seasons (including preseasons), with a mean 4.6 concussions per season per team (SD, 1.6;

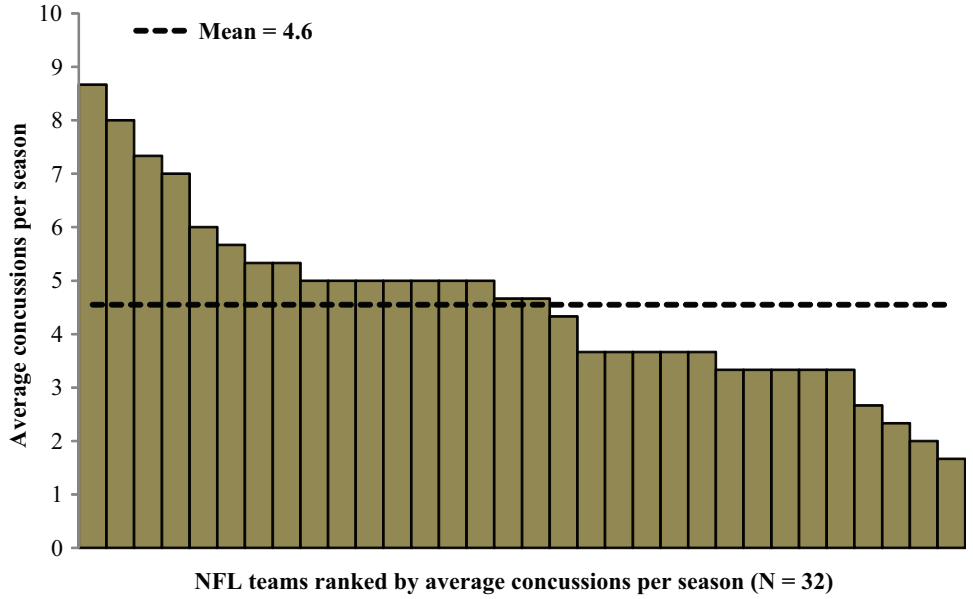

Figure 1. Rate of concussions by each team during the 2012 to 2014 National Football League (NFL) regular seasons.

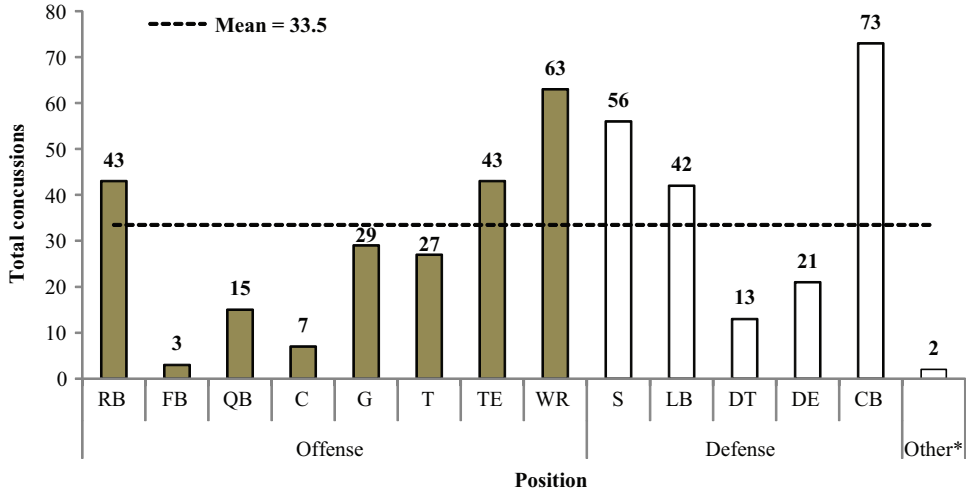

Figure 2. Total number of concussions by each position during the 2012 to 2014 NFL regular seasons. *1 long snapper and 1 undefined role. C, center; CB, cornerback; DE, defensive end; DT, defensive tackle; FB, fullback; G, offensive guard; LB, linebacker; NFL, National Football League; QB, quarterback; RB, running back; S, safety; T, offensive tackle; TE, tight end; WR, wide receiver.

maximum, 8.7; minimum, 1.7) (Figure 1). The 3 greatest numbers of concussions per season per team were 8.7, 8.0, and 7.3, whereas 1.7, 2.0, and 2.3 were the 3 fewest numbers of concussions reported per season per team.

Figure 2 compares total numbers of concussions by position during the 2012 to 2014 NFL regular seasons. Among the offensive players, wide receivers (WRs) recorded the greatest number of concussions (n = 63) during the 3 years. Running backs (RBs) and tight ends (TEs) each reported 43 concussions during the same years. Other offensive players reported to sustain concussions included fullbacks (FBs), quarterbacks (QBs), centers (Cs), offensive guards (Gs), and offensive tackles (Ts). For the defensive players, cornerbacks (CBs) reported the greatest number of concussions (n = 73), followed by safeties (Ss; n = 56) and linebackers (LBs; n = 42). Other defensive players with reported concussions were defensive tackles (DTs) and defensive ends (DEs).The mean (±SD) number of concussions across all positions during the 3 years was 33.5 ± 22.7. Players most involved in passing games, such as WRs, TEs, CBs, and Ss, had greater numbers of reported concussions (235 concussions during 66,640 total pass attempts; 3.5 concussions per 1000 passing plays) compared with RBs and LBs, who are mainly involved in running games (85 concussions total during 52,569 total rush attempts; 1.6 concussions per 1000 running plays). During the 2012

TABLE 1
Summary Statistics of All Teams During the 2012-2014 National Football League Regular Seasons[a]

Variable	Mean ± SD
SoS	0.0 ± 1.1
SRS	0.0 ± 5.1
Pass-Att	35.0 ± 3.4
Rush-Att	27.0 ± 2.6
Mean plays/drive	5.7 ± 0.2
Yards/drive	29.7 ± 2.9
Mean time/drive, min	2.6 ± 0.2
EXP-Pass-Offense	57.1 ± 71.7
EXP-Rush-Offense	–23.0 ± 19.3
EXP-Pass-Defense	–57.1 ± 38.9
EXP-Rush-Defense	23.0 ± 20.2

[a]EXP-Pass-Defense, expected points contributed by passing defense; EXP-Rush-Defense, expected points contributed by rushing defense; EXP-Pass-Offense, expected points contributed by passing offense; EXP-Rush-Offense, expected points contributed by rushing offense; Pass-Att, pass attempts per game; Rush-Att, rush attempts per game; SoS, strength of schedule; SRS, simple rating system.

to 2014 NFL seasons, the teams, on average, attempted more passes than rushes per game (Pass-Att, 35.0 vs Rush-Att, 27.0) and relied more on pass plays than run plays for scoring (EXP-Pass-Offense, 57.1 vs EXP-Rush-Offense, –23.0) (Table 1).

Numbers of concussions by offensive and defensive players based on offensive scheme and defensive alignment are shown in Figures 3 and 4. According to the 1-way ANOVA, there was a significant difference in the number of concussions by offensive players per season among the 3 different offensive schemes ($P = .007$). The post hoc tests with the Tukey honestly significant difference test revealed that the number of concussions was significantly higher ($P = .006$) (Figure 3A) among teams adopting the West Coast offense (n = 15; mean ± SD, 3.0 ± 1.0) than those utilizing the Air Coryell offense (n = 8; mean ± SD, 1.6 ± 0.8). Categorizing the teams into 2 offensive schemes, either the West Coast offense or non–West Coast offense, resulted in a significantly greater number of concussions ($P = .004$) (Figure 3B) for teams playing West Coast offense than for those with non–West Coast offensive schemes (n = 17; mean ± SD, 1.9 ± 0.9). Meanwhile, there was no significant difference in the numbers of concussions by defensive alignment ($P > .05$) (Figure 4) between teams with the 3-4 defensive alignment (n = 14; mean ± SD, 2.0 ± 0.7) and those with the 4-3 defensive alignment (n = 18; mean ± SD, 2.2 ± 1.5). Because the univariate analysis revealed the significant association of the number of concussions by offensive players to the offensive scheme but not by defensive players to the defensive alignment, the subsequent analyses below focused on examining the number of concussions by offensive players.

Table 2 shows the relationships of the number of concussions by offensive players to SoS, SRS, attempts statistics, per-drive statistics, and offensive productions. There were negative correlations with small-to-medium effect sizes

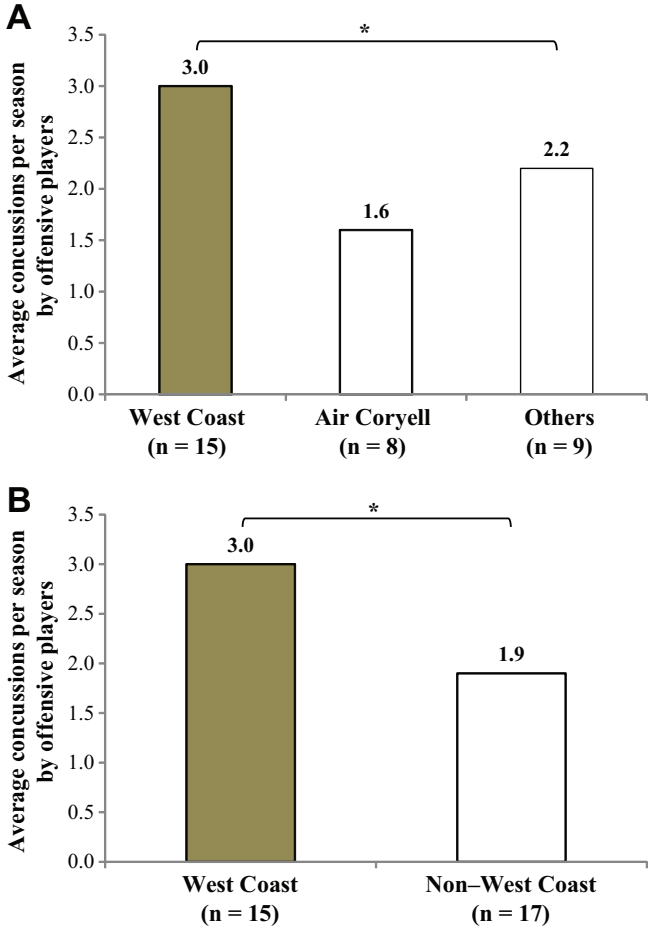

Figure 3. Rate of concussions by offensive players based during the 2012 to 2014 National Football League regular seasons based on (A) offensive scheme and (B) utilization of West Coast offense. Offensive players include running backs, fullbacks, quarterbacks, centers, offensive guards, offensive tackles, tight ends, and wide receivers. *Significant difference ($P < .05$).

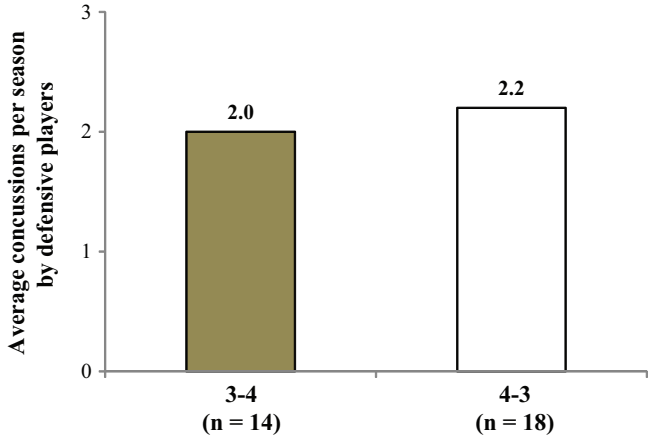

Figure 4. Rate of concussions by defensive players based on defensive alignment during the 2012 to 2014 National Football League regular seasons. Defensive players include safeties, linebackers, defensive tackles, defensive ends, and cornerbacks.

TABLE 2
Correlation Matrix of Number of Concussions by Offensive Players to SoS, SRS, Attempts Statistics, Per-Drive Statistics, and Offensive and Defensive Productions During the 2012-2014 National Football League Regular Seasons[a]

	Concussions/ Season	SoS	SRS	Pass-Att	Rush-Att	Mean Plays/Drive	Mean Yards/Drive	Mean Time/Drive	EXP-Pass-Offense	EXP-Rush-Offense
Concussions/season	1.000	–0.298	–0.189	–0.033	0.112	–0.136	–0.206	–0.343	–0.183	0.186
SoS		1.000	0.075	–0.371	–0.009	–0.231	–0.233	0.061	–0.233	–0.023
SRS			1.000	–0.059	0.509	0.601	0.666	0.520	0.781	0.316
Pass-Att				1.000	–0.576	0.345	0.324	–0.200	0.354	–0.438
Rush-Att					1.000	0.188	0.180	0.229	0.168	0.549
Mean plays/drive						1.000	0.881	0.669	0.831	0.309
Mean yards/drive							1.000	0.608	0.933	0.374
Mean time/drive, min								1.000	0.547	0.328
EXP-Pass-Offense									1.000	0.197
EXP-Rush-Offense										1.000

[a]Offensive players include running backs, fullbacks, quarterbacks, centers, offensive guards, offensive tackles, tight ends, and wide receivers. EXP-Pass-Offense, expected points contributed by passing offense; EXP-Rush-Offense, expected points contributed by rushing offense; Pass-Att, pass attempts per game; Rush-Att, rush attempts per game; SoS, strength of schedule; SRS, simple rating system.

between the number of concussions per season and SoS (r = –0.298), SRS (r = –0.189), plays/drive (r = –0.136), yds/drive (r = –0.206), time/drive (r = –0.343), and EXP-Pass-Offense (r = –0.183). Positive correlations with a small effect size were observed between the number of concussions per season and Rush-Att (r = 0.112) and EXP-Rush-Offense (r = 0.186). It should be noted that the correlation analysis reported here was used to explore potential relationships and was not to provide hypothesis-driven inquiries; therefore, P values are not provided in the table.

Based on the analyses above, 4 regression models were developed using the MLR analysis to predict the number of concussions sustained by offensive players. The combinations of the predictors were as follows: (1) West Coast offense or not, SoS, and SRS; (2) West Coast offense or not, SoS, SRS, and attempts statistics; (3) West Coast offense or not, SoS, and per-drive statistics; (4) West Coast offense or not, SoS, and offensive productions. There were high correlations between SRS and some of the variables for per-drive statistics or those for offensive and defensive productions (multicollinearity). Since a lack of multicollinearity among predictors is one of the assumptions for an MLR analysis to avoid issues with matrix singularity, SRS was not included in regression models 3 and 4. The results of the MLR analysis are shown in Tables 3 to 6. Regression model 1 (West Coast offense or not, SoS, and SRS) explained 25.3% of the variance in the number of concussions (Table 3). After accounting for SRS, the West Coast offense was found to be a significant predictor for the number of concussions (P = .007), while there was a tendency for SoS to be inversely associated with the number of concussions (P = .105). Regression models 2, 3, and 4 indicated that if offensive scheme and SoS were taken into account, none of the variables in the attempts statistics, per-drive statistics, or offensive and defensive productions were significant for predicting the number of concussions (Tables 4-6). Meanwhile, the contributions of the West Coast offense or not and SoS in these regression models were similar to those in the regression model 1.

TABLE 3
Regression Model 1: Analysis of West Coast Offense or Not, Strength of Schedule, and Simple Rating System on Number of Concussions by Offensive Players During the 2012-2014 National Football League Regular Seasons[a]

Predictor	B (SE)	β	t	P	r^2	sr^2
West Coast offense	0.985 (0.335)	0.466	2.937	.007	0.248	0.208
SoS	–0.259 (0.155)	–0.261	–1.677	.105	0.089	0.068
SRS	–0.017 (0.033)	–0.079	–0.501	.621	0.036	0.006

[a]Offensive players include running backs, fullbacks, quarterbacks, centers, offensive guards, offensive tackles, tight ends, and wide receivers. Dependent variable = number of concussions; $F(3, 28) = 4.492$; $P = .011$; $R^2 = 0.325$; adjusted $R^2 = 0.253$. B, regression coefficient; SE, standard error; SoS, strength of schedule; SRS, simple rating system.

TABLE 4
Regression Model 2: Analysis of West Coast Offense or Not, Strength of Schedule, Simple Rating Scale, and Attempts Statistics on Number of Concussions by Offensive Players During the 2012-2014 National Football League Regular Seasons[a]

Predictor	B (SE)	β	t	P	r^2	sr^2
West Coast offense	1.018 (0.393)	0.481	2.590	.016	0.248	0.171
SoS	–0.187 (0.189)	–0.189	–0.989	.332	0.089	0.025
SRS	–0.033 (0.044)	–0.156	–0.735	.469	0.036	0.014
Pass-Att	0.055 (0.080)	0.174	0.689	.497	0.001	0.012
Rush-Att	0.070 (0.110)	0.167	0.631	.533	0.013	0.010

[a]Offensive players include running backs, fullbacks, quarterbacks, centers, offensive guards, offensive tackles, tight ends, and wide receivers. Dependent variable = number of concussions; $F(5, 26) = 2.662$; $P = .045$; $R^2 = 0.339$; adjusted $R^2 = 0.211$. B, regression coefficient; Pass-Att, pass attempts per game; Rush-Att, rush attempts per game; SE, standard error; SoS, strength of schedule; SRS, simple rating system.

TABLE 5
Regression Model 3: Analysis of West Coast Offense or Not, Strength of Schedule, and Per-Drive Statistics on Number of Concussions by Offensive Players During the 2012-2014 National Football League Regular Seasons[a]

Predictor	B (SE)	β	*t*	*P*	r^2	sr^2
West Coast offense	1.112 (0.327)	0.526	3.398	.002	0.248	0.237
SoS	–0.173 (0.157)	–0.174	–1.101	.281	0.089	0.025
Plays/drive	2.400 (1.439)	0.556	1.668	.107	0.018	0.057
Yards/drive	–0.108 (0.112)	–0.295	–0.965	.343	0.042	0.019
Time/drive, min	–3.023 (1.282)	–0.489	–2.359	.026	0.118	0.114

[a]Offensive players include running backs, fullbacks, quarterbacks, centers, offensive guards, offensive tackles, tight ends, and wide receivers. Dependent variable = number of concussions; $F(5, 26) = 4.555$; $P = .004$; $R^2 = 0.467$; adjusted $R^2 = 0.364$. B, regression coefficient; SE, standard error; SoS, strength of schedule.

TABLE 6
Regression Model 4: Analysis of West Coast Offense or Not, Strength of Schedule (SoS), and Offensive and Defensive Productions on Number of Concussions by Offensive Players During the 2012-2014 National Football League Regular Seasons[a]

Predictor	B (SE)	β	*t*	*P*	r^2	sr^2
West Coast offense	0.926 (0.435)	0.438	2.128	.043	0.248	0.114
SoS	–0.288 (0.165)	–0.291	–1.746	.092	0.089	0.076
EXP-Pass-Offense	–0.001 (0.003)	–0.093	–0.476	.638	0.033	0.006
EXP-Rush-Offense	0.001 (0.011)	0.016	0.083	.934	0.035	<0.001

[a]Offensive players include running backs, fullbacks, quarterbacks, centers, offensive guards, offensive tackles, tight ends, and wide receivers. Dependent variable = number of concussions; $F(4, 27) = 3.250$; $P = .027$; $R^2 = 0.325$; adjusted $R^2 = 0.225$. B, regression coefficient; EXP-Pass-Offense, expected points contributed by passing offense; EXP-Rush-Offense, expected points contributed by rushing offense; SE, standard error.

Last, since the West Coast offense or not was significant in every regression model, the differences in the variables by this category were further examined. The analysis showed that the teams adopting the West Coast offense had significantly lower productions from passing offense (29.5 vs 81.5 for EXP-Pass-Offense; $P = .038$) and significantly greater productions from rushing offense (–14.7 vs –30.4 for EXP-Rush-Offense; $P = .019$) than those not using the West Coast offense (Table 7). Teams with a West Coast offense had significantly more success on scoring by run plays than by pass plays compared with those with non–West Coast offensive schemes. Pass-Att was significantly lower for the teams with West Coast offense than those with non–West Coast offensive schemes (33.6 vs 36.3; $P = .026$) despite its relatively small difference, while Rush-Att was not significantly different between these 2 groups ($P > .05$).

TABLE 7
Summary Statistics by West Coast Offense Versus Non–West Coast Offense During the 2012-2014 National Football League Regular Seasons[a]

Variable	West Coast Offense	Non–West Coast Offense
Mean SoS	–0.1 (1.0)	0.1 (1.2)
Mean SRS	–1.0 (6.0)	0.9 (4.2)
Pass-Att[b]	33.6 (3.4)	36.3 (3.0)
Rush-Att	27.7 (2.9)	26.4 (2.2)
Plays/drive	5.6 (0.2)	5.7 (0.3)
Yards/drive	28.8 (2.5)	30.4 (3.1)
Time/drive, min	2.6 (0.2)	2.6 (0.2)
EXP-Pass-Offense[b]	29.5 (64.7)	81.5 (70.4)
EXP-Rush-Offense[b]	–14.7 (18.3)	–30.4 (17.4)

[a]EXP-Pass-Offense, expected points contributed by passing offense; EXP-Rush-Offense, expected points contributed by rushing offense; Pass-Att, pass attempts per game; Rush-Att, rush attempts per game; SoS, strength of schedule; SRS, simple rating system.
[b]Significant between-group difference ($P < .05$).

DISCUSSION

The results of the data analyses showed that players most involved in pass plays generally reported more concussions during the 2012 to 2014 NFL regular seasons. The NFL teams playing with the West Coast offense had higher rates of concussions than did those playing with other offensive schemes during these 3 years. In addition, there was a trend that the teams with lower scores on SoS (ie, easier schedules) reported more concussions. Some of the variables for attempts statistics, per-drive statistics, and offensive and defensive productions had small- to medium-sized correlations with the number of concussions. After the effects of offensive scheme and SoS were removed, however, none of these variables were significantly associated with number of concussions. The teams with the West Coast offense were more likely to produce scores from running the football than from passing it during the 2012 to 2014 regular seasons, though these teams did not necessarily have more rush attempts than their counterparts.

In general, players most involved in passing games, such as WRs, TEs, CBs, and Ss, had more documented concussions during the 2012 to 2014 NFL regular seasons. This finding is at least partly because the NFL teams attempted more passes than rushes by an average of 8 plays per game during these 3 seasons. Another explanation could be that a passing game is associated with a greater risk for concussion, as shown by a greater rate of concussions sustained by players mainly involved in passing plays (WRs, TEs, CBs, and Ss; 3.5 concussions per 1000 passing plays) compared with those mainly involved in running plays (RBs and LBs; 1.6 concussions per 1000 running plays). It may be that pass plays place athletes at risk for greater speed open-field impacts compared with most running plays. According to Martini and colleagues,[13] high school football players whose teams favored pass plays (ie, pass-first offense) sustained greater magnitudes of subconcussive

head impacts than did players in teams with run-first offense. The researchers speculate that athletes in pass plays spread across the playing field more, and thus are able to reach greater running velocities prior to contact, increasing head impact magnitude.[13] This implies that passing plays tend to put offensive players in more vulnerable positions. Regardless of the potential explanations, it is important to be aware that football players in certain positions may have a greater risk of sustaining concussions than those in other positions.

It was of particular interest to discover that the West Coast offense, compared with other offensive schemes, was associated with greater rates of concussion in the NFL during the 2012 to 2014 regular seasons. One specific feature of the West Coast offense is to utilize more lateral movements during passing routes, whereas the Air Coryell offense, for example, tends to move the ball vertically up the field.[10] Therefore, it may be that receivers and tackling players who are moving laterally across the field are at increased risk for concussion. Another characteristic of the teams using the West Coast offense during the 2012 to 2014 regular seasons was that they produced more points by running the football than by passing it. The study of high school football players by Martini et al[13] found that run-first offense was associated with more "frequent" subconcussive head impacts, although, as mentioned above, the "magnitudes" of subconcussive head impacts were greater for players on teams with pass-first offense. Hence, there may be a common underlying factor associated with the increased risk of concussion in run-first offense as well as in the West Coast offense. It should be pointed out that the mean number of Rush-Att was not significantly different between the teams with the West Coast offense and those with other offensive schemes. One speculation is that it is not the percentage of running plays that puts a team at risk for concussion but rather the nature of the crossing passing routes that teams with run-first offense or West Coast offense are more likely to use compared with passing teams that tend to use long, down-field passing routes to a greater degree than short, crossing routes. During vertical passing routes, the receiver and the defender are often running in parallel with one another, and therefore, their relative speeds are less. During cross-field routes, however, the receiver and the defender(s) are more likely to be running at an angle relative to one another, or even directly toward one another, which could result in greater impact forces. Additionally, during vertical passing routes, the receiver is more likely to have potential tacklers in their line of vision, while receivers in cross-field routes, may be less likely to see tacklers coming from various angles as they catch and then try to run up field with the ball. Therefore, it may be that quick transitions from running a crossing route and receiving the football to rushing in a vertical direction may be associated with a greater risk of concussion.

Another possible factor that may account for the increased number of concussions in teams that more often use the West Coast style of offense is the nature of the athletic talent on these teams. Some researchers suggest that lower skill level is a potential risk factor for concussion, given that high school athletes have greater concussion rates compared with collegiate athletes and that collegiate athletes in National Collegiate Athletic Association Division III athletics have higher concussion rates compared with those in higher divisions.[6,8,9] According to former NFL coach Bill Walsh,[10] the West Coast offense was originally developed to compensate for a lack of athletic ability needed for long, down-field passing plays. Therefore, one speculation is that players on teams adopting the West Coast offense may be at increased risk for concussion because they do not possess the skill sets to avoid hits and be productive in the game. On the other hand, it may be that it is not a lack of talent overall but rather that the specific nature of a team's talent lends itself more to shorter, cross-field passing instead of longer, down-field or vertical passing. Yet, it is possible that skill levels of players may partly explain the association of the West Coast Offense with the greater rate of concussion.

The results of our data analyses also suggested that the NFL teams with easier schedules tended to have more concussions during the 2012 to 2014 regular seasons in this study. A potential explanation for this result could be that the team might take a more aggressive approach toward the game if they knew their opponent were weaker, which would potentially increase the risk of concussions. Zemper[38] argues that aggressive, risk-taking behaviors may be a risk factor for concussion. This particular finding in our study could be another example of how the manner in which a team plays in the game may influence the risk of concussions.

There are limitations associated with the current study. First, the PBS FRONTLINE Concussion Watch, from which the concussion data for this study were obtained, includes players listed in the NFL injury report as either concussion or head injury. Consequently, it is possible that their list of players includes those without actually sustaining concussions, although the majority of injuries listed as head injuries were in fact concussion. Second, identifying a team's style of play is challenging. For example, teams can utilize more than 1 offensive scheme or defensive alignment during the game depending on the game situation (eg, beginning vs end of the game; leading vs trailing) or during the season. We were unable to find information about the percentage of plays corresponding to a specific offensive scheme or defensive alignment for each team. Rather, the characterizations of a team's offensive and defensive strategies in this study represent those that each team most commonly employed during the 2012 to 2014 NFL regular seasons. Injuries to players, coaching philosophy, and coaching changes can influence a team's offensive scheme and defensive alignment in a single season and across seasons. Furthermore, offensive schemes and defensive alignments could potentially be categorized differently or in greater detail than what we did in this study. These factors make it difficult to precisely identify a team's style of play. Third, concussions sustained during kickoffs or punt returns may not be influenced a great deal by a team's offensive and defensive strategies. Fourth, it is likely that there are individual factors, unique to each player, associated with the risk of concussion that were not examined in this study, such as player skill levels and on-field

productions and history of prior concussions. Last, this is an observational retrospective study; hence, we were unable to draw causal inferences of concussions and a team's style of play from our data analyses.

The present study indicates that a team's style of play may influence risk of concussion in the NFL. A team's play selection and offensive scheme, along with SoS, appear to be associated with the rate of concussion. In particular, players most involved in pass plays seem to sustain concussions more frequently, partly due to more pass play selections in the NFL today. Furthermore, teams with West Coast offense may be at increased risk of their players sustaining concussions potentially due to its particular strategy of utilizing cross-field passing routes, to their greater reliance on running games to produce points, and/or to the nature of skill and talent levels of players on their rosters. The teams with easier schedules may have more players sustaining concussions, potentially because they may take a more aggressive approach toward the game.

We believe that our study could shed light on how a team's style of play may influence the rate of concussion in the NFL despite the aforementioned study limitations. To the best of our knowledge, this is the first study of this kind. As the issue of concussion in the NFL is increasingly important today, it is necessary to identify risk factors associated with concussion. Future research could include a longitudinal data analysis to examine how trends of concussions change over the years while identifying a team's style of play in a more detailed manner. It would be important to evaluate skill levels of individual players with a history of concussion and to investigate whether skill level is a potential risk factor for concussion. Furthermore, it would be of particular interest to review tapes of all concussion-producing collisions and to determine the types of routes (eg, crossing vs vertical) and field positions that are associated with a greater risk of concussion.

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