

Effect of Concussions on the Performance of Running Backs and Wide Receivers in the National Football League

Toufic R. Jildeh,^{*†} MD, Kelechi R. Okoroha,[†] MD, Kevin A. Taylor,[†] MD, Patrick Buckley,[‡] BS, Samir Mehta,[§] MD, Nima Mehran,^{||} MD, and Vasilios Moutzouros,[†] MD

Investigation performed at Henry Ford Health System, Detroit, Michigan, USA

Background: Concussion injuries are common in professional football players; however, their effect on player performance remains unclear.

Purpose: To quantify the effect of concussions on the performance of running backs and wide receivers in professional football players.

Study Design: Cohort study; Level of evidence, 3.

Methods: Concussion data from the National Football League were collected for a period of 4 seasons (2012-2015) for running backs and wide receivers. Age, experience, position, time to return to play, yearly total yards, and touchdowns were recorded. A power rating (total yards divided by 10 plus touchdowns multiplied by 6) was calculated for each player's injury season as well as for the 3 seasons before and after their respective injury. A control group of running backs and wide receivers without an identified concussion injury who competed in the 2012 season was assembled for comparison. Player performance up to 3 seasons before and after the injury season was examined to assess acute and longitudinal changes in player performance.

Results: A total of 38 eligible running backs and wide receivers sustained a concussion during the study period. Thirty-four (89%) players were able to return to competition in the same season, missing an average of 1.5 ± 0.9 games; the remaining 4 players returned in the subsequent season. Power ratings for concussed players were similar to those of controls throughout the study period. Concussed players did not suffer an individual performance decline upon returning within the same season. Furthermore, no significant difference in change of power rating was observed in concussed players in the acute (± 1 year from injury; -1.2 ± 4.8 vs -1.1 ± 3.9 , $P = .199$) or chronic (± 3 years from injury; -3.6 ± 8.0 vs -3.0 ± 4.5 , $P = .219$) setting compared with controls. All concussed players successfully returned to competition in either the index or next season.

Conclusion: A high rate of National Football League running backs and wide receivers are able to return to play after a concussion injury. These players were found to perform at a similar level in both the acute and long-term period after concussion.

Keywords: concussion; outcome; NFL; football; performance

Concussions within American football players are a common injury. Given the recent correlation between mild traumatic brain injury and negative long-term neurological effects, understanding the consequences of sport-induced mild traumatic brain injury has become a topic of great interest in public health.^{7,11,28} Research has shown that concussions have been associated with both short- and long-term cognitive problems, such as dizziness, headache, anxiety, depression, and suicide.^{4,27} Despite multiple initiatives and rule changes to curtail concussion rates, recent studies have shown that the incidence of concussions in National Football League (NFL) players has increased; however, this may be a consequence of refined surveillance methods.¹⁵

Prior studies have investigated return-to-play (RTP) rates and performance after various musculoskeletal injuries in NFL players and have shown significant decline after injury; this is especially true in skilled position players after lower extremity ligament and tendon ruptures, including injuries to the anterior cruciate ligament, Achilles tendon, or knee extensor mechanism.^{2,3,16,25,29} However, with respect to concussion injuries, these details are not fully understood despite their relatively common occurrence.

The purpose of this study was to investigate the effect of concussion on the performance of running backs and wide receivers in the NFL with respect to RTP and player productivity. Running backs and wide receivers were targeted given their high rate of concussion and readily quantifiable performance metrics. We hypothesized that athletes would RTP at a high rate; however, they would face appreciable decline in performance after concussion based on objective offensive statistics.

METHODS

All concussions sustained by professional athletes in the NFL during a 4-year period (2012-2015) were collected from publicly available injury reports, player profiles, and game summaries using methods similar to those in previous studies.^{8,9,13,17,18,23} The NFL mandates that teams quickly and accurately disseminate injury information to the league office, their opponents, local and national media, and the league's broadcast partners. Players were included in the study if their primary position was wide receiver or running back and they were formally diagnosed with at least 1 concussion by a team physician while on an active NFL roster. Demographic variables surrounding the injury were also recorded including age, body mass index, NFL experience, and date of injury. Sources for injury data included team injury reports and websites, personal websites, press releases, and statistical websites. None of the authors were affiliated with the NFL or NFL teams.

Any player who was able to return to regular season NFL competition for a least 1 play met RTP criteria. Players did not meet RTP criteria if they returned to a preseason game or another professional football league (eg, Canadian Football League or Arena Football League), as this was not the same level of competition. The number of games missed and time to RTP were calculated from initial injury date to the date of the first game played. Players whose concussion was sustained in the last or penultimate game of their season were excluded from RTP analysis as they uniformly returned the following season. Any athlete who sustained a concussion in the past was excluded from the control group.

An age-, body mass index-, and NFL experience-matched control group consisting of all running backs and wide receivers that did not sustain a documented concussion in their career and completed the 2012 NFL season was assembled. Athletes were not included in the control group if they sustained an injury during the 2012 season. This control group was used to compare performance before and after concussion. Our methods for selecting a control cohort were similar to those reported in previous literature.^{8,9,13,17,18,23} The index year in the concussion group was defined as the season in which concussion occurred, and the index year for the control group was defined as the 2012 season. Acute changes were measured by comparing changes in player performance pre- and postinjury within the index season. The 3 seasons

before and after the index season were also examined to appropriately assess longitudinal changes in player performance. Performance was analyzed for each player using offensive metrics including games played, total yards (receiving or rushing), and touchdowns. From these variables, the offensive power rating was calculated for each athlete. The offensive power rating was previously described and proven reliable and validated for use as an outcome instrument in the orthopaedic literature.^{5,19,22} It is used to quantify athlete contribution to a team's offense. It is calculated using the following formula: power rating = (total yards/10) + (6 × touchdowns).

If players were not eligible to participate in an NFL game in the season before injury, the power rating was recorded as a null value. Players were excluded if their total power rating over the course of 7 seasons was less than 200 to eliminate the effect of players with low production over the study interval. The use of power rating has been shown in previous studies⁵ to be reliable and valid as an effective method of quantifying player performance.

Statistical Analysis

All continuous data were reported as mean ± SD, while categorical data were reported as counts and column percentages. For continuous variables, univariate 2-group comparisons were performed using independent 2-sample *t* tests if the variable was normally distributed, and using Wilcoxon signed-rank tests if the variable was nonnormally distributed. For categorical variables, univariate 2-group comparisons were performed using chi-square and Fisher exact tests. To see if the power rating per season differed between control and concussed groups, 2 repeated measures analyses for the cohorts of wide receivers and running backs were performed separately and controlled for age and experience; statistical significance was set at $P < .05$. All analyses were performed using SAS 9.4 (SAS Institute Inc).

RESULTS

One hundred eighteen NFL players sustained concussions during the 2012 to 2015 seasons. Thirty-eight running backs and wide receivers with a total power rating >200

*Address correspondence to Toufic R. Jildeh, MD, Department of Orthopaedic Surgery, Henry Ford Health System, 2799 W Grand Blvd, Detroit, MI 48202, USA (email: touficjildeh@gmail.com).

[†]Department of Orthopaedic Surgery, Henry Ford Health System, Detroit, Michigan, USA.

[‡]Wayne State University School of Medicine, Detroit, Michigan, USA.

[§]Department of Orthopaedic Surgery, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania, USA.

^{||}Southern California Permanente Medical Group, Department of Orthopedics, Kaiser Permanente Los Angeles Medical Center, Los Angeles, California, USA.

Presented at the annual meeting of the AOSSM, Boston, Massachusetts, July 2019.

One or more of the authors has declared the following potential conflict of interest or source of funding: T.R.J. has received educational support and hospitality payments from DePuy Synthes. V.M. has received educational and research support and hospitality payments from Smith & Nephew and Stryker; and education and hospitality payments from Arthrex and Pinnacle. N.M. has received education payments from Arthrex and Smith & Nephew; and a grant from Linvatec. S.M. has received consulting fees from Smith & Nephew, Synthes USA, Medical Device Business Services, Acumed, Globus Medical, Miami Device Solutions, Flower Orthopedics, Bioventus, KCI USA, Stryker Corp, Zimmer Biomet, DePuy Orthopaedics, and Olympus Biotech; compensation for services other than consulting from Smith & Nephew, Synthes GmbH, Pacira Pharmaceuticals, Bioventus, Zimmer Biomet, and GE Healthcare; royalties from Miami Device Solutions and Flower Orthopedics; and hospitality payments from Biedermann Medtech. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

TABLE 1
Study and Control Group Characteristics^a

	Concussed Players (n = 38)	Controls (n = 139)	P Value
Mean age, y	26.8 ± 2.8	26.3 ± 3.1	.325
Mean BMI, kg/m ²	28.4 ± 2.5	28.4 ± 2.1	.949
Mean NFL experience, seasons	3.7 ± 2.8	3.7 ± 3.1	.923
Position distribution, no. of running backs/wide receivers	15/23	52/87	.816
Mean total exposures (games) in 3 seasons before index year	29.9 ± 15.0	28.0 ± 16.7	.523

^aUnless otherwise stated, data are presented as mean ± SD. Only players with a total power rating (sum of all 7 seasons) >200 points were included in the player analysis. BMI, body mass index; NFL, National Football League.

TABLE 2
Study and Control Group Player Performance Statistics^a

	Concussed Players (n = 38)	Controls (n = 139)	P Value
Games played per season			
Index year -3	13.7 ± 3.2	14.1 ± 3.2	.277
Index year -2	14.1 ± 3.5	13.5 ± 3.7	.515
Index year -1	13.7 ± 2.8	13.5 ± 3.5	.848
Index year	12.7 ± 3.0	13.7 ± 3.6	<.001
Index year +1	13.7 ± 3.3	12.8 ± 4.0	.400
Index year +2	12.9 ± 3.6	12.6 ± 4.5	.758
Index year +3	11.9 ± 4.5	12.5 ± 4.2	.812
Power rating per season			
Index year -3	123.8 ± 73.1	126.7 ± 57.6	.844
Index year -2	118.6 ± 75.7	114.7 ± 71.5	.806
Index year -1	121.2 ± 67.7	112.4 ± 64.3	.498
Index year	104.9 ± 64.1	102.0 ± 61.5	.866
Index year +1	108.5 ± 67.7	94.4 ± 59.6	.239
Index year +2	90.5 ± 64.3	91.5 ± 57.3	.938
Index year +3	84.8 ± 46.5	79.5 ± 50.2	.685
Power rating per game played			
Index year -3	8.8 ± 4.3	9.0 ± 3.8	.841
Index year -2	16.6 ± 13.0	14.2 ± 12.8	.394
Index year -1	8.9 ± 4.7	8.3 ± 4.0	.474
Index year +1	8.0 ± 5.7	7.1 ± 3.8	.378
Index year +2	12.6 ± 10.9	13.3 ± 13.2	.796
Index year +3	6.8 ± 3.0	5.9 ± 3.1	.280
1-year delta (95% CI)	-1.2 ± 4.8 (-3.0, 0.64)	-1.1 ± 3.9 (-1.9, -0.3)	.199
2-year delta (95% CI)	-2.1 ± 8.1 (-4.95, 0.69)	-1.4 ± 7.4 (-2.95, 0.09)	.064
3-year delta (95% CI)	-3.6 ± 8.0 (-9.7, 2.6)	-3.0 ± 4.5 (-4.7, -1.4)	.219

^aUnless otherwise stated, data are presented as mean ± SD. Bold values indicate statistical significance. Only players with a total power rating (sum of all 7 seasons) >200 points were included in the player analysis.

points who sustained concussions were identified and included for analysis. A matched control population of 139 running backs and wide receivers with total power ratings of >200 points who completed the 2012 season without an identified concussion was constructed for comparison. There were no statistical differences in age, position, NFL experience, or total number of games played during the 3 seasons before injury (*P* > .05) (Table 1).

Of the players who sustained concussions from the 2012 to 2015 seasons, 11% (4/38) were unable to return to an NFL game within the same season; however, this was due to injury occurring in either of their last 2 games of their respective season (playoffs included), and they were able to return in the subsequent season. For the remaining

34 players, the average time to RTP was 18.9 ± 7.6 days, missing a mean of 1.5 ± 0.9 games before returning to play. Compared with controls, the concussed players played in significantly fewer games within the index year (13.7 ± 3.6 vs 12.7 ± 3, respectively; *P* < .001) (Table 2). Two athletes sustained multiple concussions. Fourteen players retired during the studied time frame (9 wide receivers and 5 running backs), with 2 retirements (1 wide receiver and 1 running back) directly attributed to the athletes' concussion status; neither of these retirements were among the 4 athletes who did not return in the same season. All concussed players successfully returned to competition in either the index or next season (depending on timing of injury within the season).

TABLE 3
Study and Control Group Player Performance Statistics: Running Backs^a

	Concussed Players (n = 15)	Controls (n = 52)	P Value
Games played per season			
Preinjury -3	14.7 ± 1.6	13.3 ± 3.9	.277
Postinjury +3	12.3 ± 3.9	11.7 ± 4.6	.515
Delta (95% CI)	-3.6 ± 6.8 (-12.0, 4.8)	-1.2 ± 5.2 (-3.7, 1.3)	.965
Power rating per season			
Preinjury -3	136.1 ± 88.0	131.5 ± 66.7	.878
Postinjury +3	100.9 ± 42.7	72.6 ± 54.7	.180
Delta (95% CI)	-97.5 ± 111.2 (-235.5, 40.6)	-34.0 ± 59.9 (-62.9, -5.0)	.255
Power rating per game played			
Index year -3	9.1 ± 5.2	9.8 ± 4.4	.728
Index year -2	8.1 ± 4.4	9.2 ± 4.6	.534
Index year -1	9.0 ± 5.4	8.8 ± 4.6	.864
Index year +1	8.7 ± 5.0	7.5 ± 3.9	.369
Index year +2	7.1 ± 4.1	6.8 ± 3.7	.621
Index year +3	8.4 ± 2.7	5.7 ± 3.5	.048
1-year delta (95% CI)	-0.45 ± 5.0 (-1.0, 3.1)	-0.78 ± 4.8 (-2.35, 0.79)	.780
2-year delta (95% CI)	-0.78 ± 4.7 (-5.7, 4.14)	-2.7 ± 7.1 (-5.8, 0.39)	.084
3-year delta (95% CI)	-5.9 ± 6.9 (-14.5, 2.6)	-2.6 ± 4.0 (-4.5, -0.7)	.355

^aUnless otherwise stated, data are presented as mean ± SD. Bold values indicate statistical significance. Only players with a total power rating (sum of all 7 seasons) >200 points were included in the player analysis.

TABLE 4
Study and Control Group Player Performance Statistics: Wide Receivers^a

	Concussed Players (n = 23)	Controls (n = 87)	P Value
Games played per season			
Preinjury -3	13.3 ± 3.6	14.6 ± 2.6	.071
Postinjury +3	11.7 ± 5.2	13.0 ± 3.9	.676
Delta (95% CI)	-0.75 ± 2.2 (-4.3, 2.8)	-0.14 ± 8.0 (-4.8, 4.5)	.873
Power rating per season			
Preinjury -3	118.4 ± 68.1	123.7 ± 51.7	.745
Postinjury +3	70.5 ± 47.3	83.2 ± 47.0	.459
Delta (95% CI)	-22.3 ± 142.0 (-248.2, 203.6)	-31.4 ± 82.5 (-81.2, 18.5)	.610
Power rating per game played			
Index year -3	8.7 ± 4.0	8.6 ± 3.3	.878
Index year -2	8.1 ± 4.6	7.4 ± 3.8	.521
Index year -1	8.7 ± 4.5	8.0 ± 3.7	.435
Index year +1	7.8 ± 6.4	6.9 ± 3.8	.546
Index year +2	6.2 ± 4.5	7.1 ± 2.9	.425
Index year +3	5.4 ± 2.5	6.1 ± 2.9	.516
1-year delta (95% CI)	-1.2 ± 4.8 (-3.6, 1.09)	-1.3 ± 3.3 (-2.1, -0.45)	.279
2-year delta (95% CI)	-2.5 ± 5.4 (-5.9, 0.94)	-0.17 ± 4.1 (-1.51, 1.17)	.799
3-year delta (95% CI)	-0.6 ± 9.3 (-15.5, 14.2)	-3.7 ± 5.2 (-6.8, -0.5)	.282

^aUnless otherwise stated, data are presented as mean ± SD. Only players with a total power rating (sum of all 7 seasons) >200 points were included in the player analysis.

Regarding player performance, mean power ratings for concussed players were similar to those for controls throughout the 7-season study period, including the index season (Table 2). The mean power rating per game played did not differ significantly between concussed players and controls in the 1-year setting (-1.2 ± 4.8 vs -1.1 ± 3.9, respectively; $P = .199$) or in the 3-year setting (-3.6 ± 8.0 vs -3.0 ± 4.5, respectively; $P = .219$) (Table 2). Furthermore, concussed players

experienced no significant decline in their performance pre- and postinjury within the index season (8.1 ± 4.3 vs 7.8 ± 3.7, $P = .41$).

After controlling for age and NFL experience in a repeated measures analysis, the mean power rating change between the control and concussed groups was not significantly different when evaluating wide receivers (coefficient, -0.568; $P = .951$) or running backs (coefficient, -17.2; $P = .153$) (Tables 3 and 4).

DISCUSSION

Our study found that a high rate of NFL running backs and wide receivers are able to RTP after a concussion injury. After the concussion event, these players were able to perform at a similar level in both the acute and long-term period postinjury. The violent nature of American football lends itself to a high prevalence of concussions experienced by its players, regardless of skill level.^{6,10,24} While recent clinical research has uncovered potential links between traumatic brain injuries and multiple long-term neurological consequences, no immediate effects of these injuries on player performance have been discovered.

In our study, players sustaining a concussion were able to RTP at approximately 19 days (range, 6-35 days) after injury while missing an average of 1.5 games. All concussed players successfully returned to competition in either the index or next season (depending on timing of injury within the season). Casson et al⁶ investigated 12 years of NFL concussion data from 1996 to 2007 and found that the average RTP in all NFL athletes sustaining a concussion was approximately 4.7 ± 15.6 days, compared with our findings of 18.9 ± 7.6 days. In 2004, Pellman et al²⁴ used a standardized reporting form to analyze the epidemiological features of 787 reported concussions recorded by NFL teams between 1996 and 2001 and found that 92% of concussed players had 6 or fewer days away from play, and 97% were absent for fewer than 10 days. The difference in RTP timing in our study likely reflects a change of data and knowledge, and as a result, a much more stringent RTP protocol compared with the earlier time period of the previous study. While it is encouraging that NFL players were able to RTP, their high incidence of concussion remains a matter of concern. In an epidemiological study of concussions and all-cause injuries of the 2012 to 2014 NFL seasons, Lawrence et al¹⁵ found that concussion rates had significantly increased in multiple positions (including running backs and wide receivers) compared with rates from 2002 to 2007. Furthermore, they noted a higher incidence in NFL players compared with other professional contact sport athletes and even collegiate football players.

With respect to on-field production, the running backs and wide receivers included in our study demonstrated no significant decline in their individual performance based on a power rating scale. In fact, the mean power rating on a per game basis in the concussed players remained similar to that of preinjury levels up to 3 seasons after injury. Recent studies utilizing other measures of player performance have also shown similar performance levels between pre- and post-concussion states on an acute basis (same season). A study by Kumar et al¹⁴ utilizing ProFootballFocus performance scores to examine the short-term effect of concussions on on-field performance demonstrated similar postinjury performance in players without games missed (0.16 vs 0.33, $P = .129$) and players who missed at least 1 game (-0.06 vs 0.10, $P = .219$). Reams et al²⁶ retrospectively examined 140 concussed skilled position players and 57 controls with other head and neck injuries who played in the NFL during the 2007 to 2010 seasons using the Football Outsiders calculation of defense-adjusted yards above replacement and found that

there was no change in pre- and postconcussion performance in NFL players. By contrast, in an 11-year retrospective study, Navarro et al²¹ showed a decline in offensive player performance using a fantasy football point system (8.62 ± 6.2 fantasy football points per game vs 7.29 ± 3.5 fantasy football points per game, $P = .042$). The authors attributed this finding to athletes sustaining more severe concussions; however, they acknowledge that no attempt was made to control for potential confounders such as player starting status, number of snaps played, concomitant injuries, or player age. In contrast to the previous paper, our study evaluated player outcomes with the use of a validated power rating metric. Additionally, we compared players with a matched control group to limit potential confounders. Our results were consistent with reports in the literature that demonstrated no significant change in player performance after a concussion event. These results suggest that, despite literature reporting long-term effects in player cognition and function after concussion, no significant alteration in acute or long-term player performance was found.

Among NFL running backs and wide receivers who sustained a concussion, 89% were able to RTP in their career. The high rate of RTP and level of performance success of NFL players sustaining a concussion, as demonstrated in this study, are in stark contrast to those of NFL players who sustain common bony and soft tissue injuries, which have historically required a longer time to RTP and a lower RTP rate. This includes anterior cruciate ligament tears (82.4% RTP, 378 ± 144 days), Achilles ruptures (72.4% RTP, 339.8 ± 84.8 days), and extensor mechanism tendon rupture (79% RTP, 391 ± 157 days).^{2,3,12,16} Perhaps not surprising, a media survey of 293 NFL players revealed that about half of the athletes were most concerned about leg injuries versus only a quarter who were worried about head injuries.¹

This study had several limitations. Player injury and statistical information were collected from the internet and is subject to potential inaccuracies; however, the NFL mandates that teams quickly and accurately disseminate injury information to the league office, their opponents, local and national media, and the league's broadcast partners.²⁰ Therefore, a certain level of accuracy can be inferred when evaluating publicly available data. Additionally, the data in this study were cross-referenced by multiple sources (publicly available injury reports, player profiles, and game summaries) to ensure the highest-quality and most accurate data. These methods have been used in several previous studies relying on publicly available injury data.^{13,17,18} Furthermore, we analyzed player performance using a calculated single-value power rating measurement. Given the multifactorial nature of human performance (speed, size, strength, etc), this could represent an oversimplification of a complex entity. However, a prior study has validated the use of the power rating metric and has confirmed its responsiveness to injury in NFL skilled position players.^{5,19,22} The authors cannot be certain that this sample is generalizable to the entire NFL as only wide receivers and running backs were analyzed. History of concussion was not controlled in this study and may have an effect on player RTP and

outcomes. Athletes were not stratified on the number of concussions they sustained, which may be a future research direction. The concussion cohort may have been subject to a time period bias, as data from players who sustained a concussion spanned the time period from 2009 to 2018, whereas data for controls spanned the time period between 2009 and 2015; however, there were no rule changes during these time periods that would affect NFL play. It is important to note that in both groups players missed on average 2 to 4 games per season. This could be explained by a multitude of factors including illness, minor musculoskeletal injury, off-field behavior, and fatigue. These factors may affect player performance and could not be controlled in this retrospective review. Finally, concussion reporting is dependent on a number of factors, including athlete self-reporting and organizational standards. Athletes may refrain from reporting concussion symptoms to remain playing, and organizational standards may vary between teams and medical personnel. Therefore, we believe concussions may be underreported.

CONCLUSION

In conclusion, the current study shows a high rate of RTP in NFL running backs and wide receivers after a concussion injury. Although there may be long-term neurological effects, concussions appear to have no effect on immediate player performance, as players were able to perform at a similar level in both the acute and long-term period postinjury.

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