

Short-term Outcomes Following Concussion in the NFL

A Study of Player Longevity, Performance, and Financial Loss

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Background: A short-term protocol for evaluation of National Football League (NFL) athletes incurring concussion has yet to be fully defined and framed in the context of the short-term potential team and career longevity, financial risk, and performance.

Purpose: To compare the short-term career outcomes for NFL players with concussions by analyzing the effect of concussions on (1) franchise release rate, (2) career length, (3) salary, and (4) performance.

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

Methods: NFL player transaction records and publicly available injury reports from August 2005 to January 2016 were analyzed. All players sustaining documented concussions were evaluated for a change to inactive or DNP (“did not participate”) status. A case-control design compared franchise release rates and remaining NFL career span. Career length was analyzed via survival analysis. Salary and performance differences were analyzed with publicly available contract data and a performance-scoring algorithm based on position/player level.

Results: Of the 5894 eligible NFL players over the 11-year period, 307 sustained publicly reported concussions resulting in the DNP injury protocol. Analysis of the probability of remaining in the league demonstrated a statistically significantly shorter career length for the concussion group at 3 and 5 years after concussion. The year-over-year change in contract value for the concussion group resulted in a mean overall salary reduction of \$300,000 ± \$1,300,000 per year (interquartile range, -\$723,000 to \$450,000 per year). The performance score reduction for all offensive scoring players sustaining concussions was statistically significant.

Conclusion: This retrospective study demonstrated that NFL players who sustain a concussion face a higher overall franchise release rate and shorter career span. Players who sustained concussions may incur significant salary reductions and perform worse after concussion. Short-term reductions in longevity, performance, and salary after concussion exist and deserve additional consideration.

Keywords: concussion; NFL; football; performance; economic and decision analysis

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Concussions and other forms of traumatic brain injury are common football-related injuries. For physically active and athletic patients, management typically requires rest as well as neurological evaluation to return to baseline levels of activity. The effects of concussion in the National Football League (NFL) include but are not limited to the downstream possibility of chronic traumatic encephalopathy. In 2007, the University of North Carolina at Chapel Hill linked the risk of clinical depression with sports-related concussions, with a study in 2013 describing higher rates of depression and dementia among retired NFL players versus matched healthy controls.^{5,6} The extensive data

linking traumatic brain injury with the life-altering effects of chronic traumatic encephalopathy among these elite athletes have led to increased interest in the understanding of brain injury pathogenesis, diagnosis, risk factors, effects, and treatment.²⁸ This cohort represents a population with a high risk of injuries, given the repetitive and high-impact forces experienced by the brain, that may affect a variety of performance outcomes for these patients. However, the conversation surrounding the issue of concussion in football is currently limited to the context of its long-term deleterious effects for “life after football.”⁹ Studies reporting outcomes from concussions in the NFL and other sports, including Major League Baseball and the National Hockey League, reported notable short-term performance decreases in subpopulations as compared with matched uninjured controls.^{9,26} However, evaluation of the financial and short-term career outcomes regarding the differences among sports have been outside the scope of these publications.

The NFL and NFL Players Association have focused on earlier intervention and diagnosis to minimize and mitigate the long-term structural changes in the brain associated with NFL football play.¹² Research has often focused on the clinical and radiographic evidence of NFL-related concussions and earlier diagnosis of its pathophysiology of effects on the brain.^{4,24} Different rules and adaptations to playing style to reduce concussion risk have been studied as well.²⁵ The NFL has responded swiftly and impressively to the consequences of concussion, with several rule changes: (1) creating a policy preventing same-game return to play for any player diagnosed with a concussion^{1,19}; (2) implementing sideline concussion assessment protocols and developing a standardized evidence-based testing algorithm^{11,13,16}; (3) penalizing players for making contact with the crown of the helmet and moving the kickoff line from the 30-yard line to the 35-yard line to reduce injuries^{2,15,17}; (4) administering additional sideline evaluation protocols, including preseason education, baseline testing, and concussion evaluations performed by neurologists^{3,6,10}; and (5) penalizing teams that do not follow established concussion protocol.^{14,21} Indeed, the clinical success and recovery of professional athletes should encompass outcome measures beyond short-term postconcussive neurological questionnaires and include financial impact and performance metrics.

While multisport epidemiological data on concussions have been reported for collegiate athletes, there are limitations in the use of this information to evaluate short-term career and financial outcomes. To date, no study has compared the postconcussion financial consequences, longevity, and performance of professional athletes in the NFL. Such information may be useful to identify and quantify the impact of concussions and traumatic brain injury in NFL athletes. A short-term protocol and standard for evaluation of NFL athletes incurring concussion have yet to be fully defined and framed in the context of the short-term potential performance and financial risk.²³ The primary goal of this retrospective study was to assess the short-term outcomes of concussion among NFL players in terms of franchise release rate, career length, salary, and performance. Our hypothesis was that there would be

significant differences in performance-based outcomes based on these metrics.

METHODS

Study Design

The study design comprised 2 retrospective comparisons. First, a case-control design compared concussion and non-concussion groups of NFL players in terms of franchise release rate (trade rate, cut rate, retirement rate, and overall franchise release rate) and career length. For the concussion group, we additionally compared the players' pre- and postconcussion metrics of salary and performance.

Study Population and Inclusion Criteria

A total of 5894 NFL players were included in the study, which was based on full active NFL rosters from August 2005 to January 2016. Practice squad players who had never played an NFL game were excluded. Only players with concussions who played during the regular season and who were on active league rosters were included. Players who met the criteria for inclusion in the concussion group had (1) a documented concussion based on the NFL's public weekly injury report and (2) at least 1 missed game with the designation of DNP (“did not participate”) or inactive status. A total of 307 NFL players met these criteria and were included in the concussion pool. The remaining 5587 NFL players were included in the non-concussion pool. For the concussion pool, the mean numbers of concussions sustained and regular-season games missed due to concussion-related symptoms were 1.2 ± 0.4 and 2.2 ± 2.0 , respectively.

Database

Data for the study were gathered from profootballreference.com, prosportstransactions.com, Spotrac.com, FantasyData.com, and the NFL.com weekly injury report, all of which are based on publicly available and searchable data.

Franchise Release Rate

The 1- and 3-year franchise release rates following concussion were defined as any player leaving his current team and transitioning to inactivation, retirement, free agency, or any other failure to return for a successive season on the same team's active roster after 1 and 3 years from the initial concussion. The overall team rate comprised the retirement rate, trade rate, and cut rate.

Career Length

A Kaplan-Meier survival curve was generated to compare the career longevity of the players remaining in the NFL for incremental lengths of time up to 14 years based on concussion and nonconcussion status. The full career start and end seasons were populated for all players on a full-season roster from August 2005 to January 2016.

Salary

The regular-season salaries of the concussion group were compiled from sports contracts of the Spotrac.com database to determine any potential impact of concussion injuries on player salaries. For seasons without a concussion, the full salary value was noted. For seasons where a concussion took place, the preconcussion salary value was noted for the year before injury, and the postconcussion salary value was noted for the year of the injury. If a player was traded to another team, the total annual salary that the player received for that year was included and adjusted for contract renegotiation fees. The mean year-over-year change in contract value for the concussion group after DNP protocol activation was calculated for overall salary reduction across all players. To account for potentially large standard deviations from players sustaining concussion after signing lucrative guaranteed contracts, additional analysis of post-concussion salary reduction was performed, as stratified by the player's NFL career length.

Performance

Performance data were collected for the concussion group based on fantasy football point (FFP) scoring from Fantasy Data.com and NFL.com. Offensive linemen and defensive players (defensive lineman, defensive backs, and linebackers) were excluded from performance analysis given the limitations of the FFP scoring system. Searches were corrected for name changes, and underlying statistical performance values were confirmed on NFL.com. The mean performance of all career contests in the athlete's preconcussive career was compared with that in the postconcussive era in terms of FFPs per game. If the concussion occurred midseason, games during that season before the concussion were included in the preconcussive performance, while games after the concussion were included in postconcussive performance. Performance scores were adjusted for games that the athlete was available to play. Subanalysis of performance was conducted by player position.

Definitions

Change to DNP/Inactive Status. All players in the concussion group were designated DNP or inactive based on publically available and searchable NFL injury reports published on a weekly basis. The injury period was defined as the time when an NFL player was given inactive or DNP status until the time when he was moved from that status. To be classified as concussive, the player must have been designated as concussed and been placed on inactive or DNP status in the weekly NFL injury report following his injury.

Career Length. The career lengths of the NFL athletes in the study were obtained. A full season was considered any season where the player participated in ≥ 7 games, which is in line with the standard definition for playing a full season per NFL.com. The full seasons were noted and totaled.

Cut Rate. The cut rate was defined as (1) the yearly frequency of a player's transition to another team or his no longer being available on any NFL team roster (ie, without

TABLE 1
Player Demographic Characteristics:
Concussion vs Nonconcussion Groups^a

| Position | Demographic Data | | |
|------------------------|------------------|---------------------------|-------------|
| | No. | Mean Career Experience, y | Mean Age, y |
| Concussion | 307 | 3.2 | 27.5 |
| QB | 23 | 4.7 | 31.2 |
| WR | 45 | 3.6 | 28.4 |
| RB | 36 | 2.4 | 26.2 |
| TE | 32 | 3.3 | 28.2 |
| OL | 42 | 2.0 | 26.2 |
| DL | 21 | 1.5 | 25.0 |
| LB | 34 | 2.8 | 26.4 |
| DB | 59 | 4.1 | 28.6 |
| Other | 15 | 4.4 | 26.0 |
| Nonconcussion | 5587 | 3.2 | 25.8 |
| QB | 231 | 4.7 | 28.1 |
| WR | 683 | 3.1 | 25.7 |
| RB | 531 | 3.1 | 25.6 |
| TE | 331 | 3.4 | 26.4 |
| OL | 878 | 2.0 | 24.4 |
| DL | 838 | 1.8 | 23.7 |
| LB | 800 | 3.7 | 26.4 |
| DB | 1074 | 4.2 | 27.5 |
| Other | 221 | 5.5 | 27.0 |
| Total | 5894 | 3.2 | 25.9 |
| P value between groups | | .294 | .065 |

^aDB, defensive back; DL, defensive lineman; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; TE, tight end; WR, wide receiver.

a recorded trade transaction and without appearing on a subsequent NFL team roster) divided by (2) the total number of active NFL players in that corresponding year.

Retirement Rate. The retirement rate was defined as (1) the yearly frequency of a player's transitioning off an active NFL team roster (ie, without a recorded trade transaction and without appearing on a subsequent NFL team roster) divided by (2) the total number of active NFL players in that corresponding year.

Trade Rate. The trade rate was defined as (1) the yearly frequency of a player's being actively traded (based on a trade transactions published on NFL transactions databases: protransactionsdatabase.com, protransactions.com) divided by (2) the total number of active NFL players in that corresponding year.

Statistical Analysis

A demographic comparison of the concussion and nonconcussion groups was conducted (Table 1), which confirmed that there were no statistically significant between-group differences in age ($P = .065$) and career length ($P = .294$). The mean age and career length were 27.5 and 3.2 years, respectively, for the players with a concussion versus 25.8 and 3.2 years for players without. Release rates for the concussion and nonconcussion groups were compared with a Student t test. The career length data were generated as a

TABLE 2
Player Release Rates: Concussion vs Nonconcussion Groups

| | 1-y Release Rates | | | | 3-y Release Rates | | | |
|--------------------------|-------------------|---------|--------|-----|-------------------|---------|--------|------|
| | Total Release | Retired | Traded | Cut | Total Release | Retired | Traded | Cut |
| Concussion (n = 307) | | | | | | | | |
| No. | 103 | 96 | 7 | 0 | 206 | 142 | 15 | 49 |
| % | 33.6 | 31.3 | 2.3 | 0.0 | 67.1 | 46.3 | 4.9 | 16.0 |
| Nonconcussion (n = 5587) | | | | | | | | |
| No. | 1209 | 998 | 46 | 165 | 2404 | 1351 | 50 | 1003 |
| % | 21.6 | 17.9 | 0.8 | 3.0 | 43.0 | 24.2 | 0.9 | 18.0 |
| P value between groups | 4.02E-06 | | | | 7.61E-20 | | | |

Kaplan-Meier survival curve, from which a Student *t* test was performed to analyze the difference between the concussion and nonconcussion groups. For players with concussions, the change in annual salary and performance was calculated as a mean with a standard deviation. All statistical analysis was performed with STATA 14 (StataCorp LLC).

RESULTS

Release Rate

Analysis revealed notable differences in the 1- and 3-year franchise release rates of players postconcussion versus their nonconcussed counterparts (Table 2). The 1-year retirement rate, trade rate, and cut rate of players, in terms of postconcussion versus nonconcussion, were 31.3% versus 17.9%, 2.3% versus 0.8%, and 0.0% versus 3.0%, respectively. The overall 1-year release rate for concussion versus nonconcussion was 33.6% versus 21.6% (*P* < .001). The 3-year retirement rate, trade rate, and cut rate of players, in terms of postconcussion versus nonconcussion, were 46.3% versus 24.2%, 4.9% versus 0.9%, and 16.0% versus 18.0%, respectively. The overall 3-year release rate for concussion versus nonconcussion was 67.1% versus 43.0% (*P* < .001).

Career Length

Kaplan-Meier survival curves were generated for analysis of career length. Figure 1 demonstrates that the nonconcussive group incurred a significantly lower survival rate as compared with the concussion group (*P* = 8.50E-10, Pearson chi-square). The probabilities of remaining in the NFL at 1, 3, and 5 years for players with concussion versus those without were 77.7% versus 78.3%, 30.1% versus 54.3%, and 11.6% versus 36.6%, respectively (Table 3).

Salary

After analysis of individual player contracts, the mean year-over-year change in contract value for the concussion group after DNP protocol activation was an overall salary reduction of \$300,000 per year. The standard deviation was \$1,300,000 per year, and the interquartile range was -\$723,000 to \$450,000. Additional analysis of

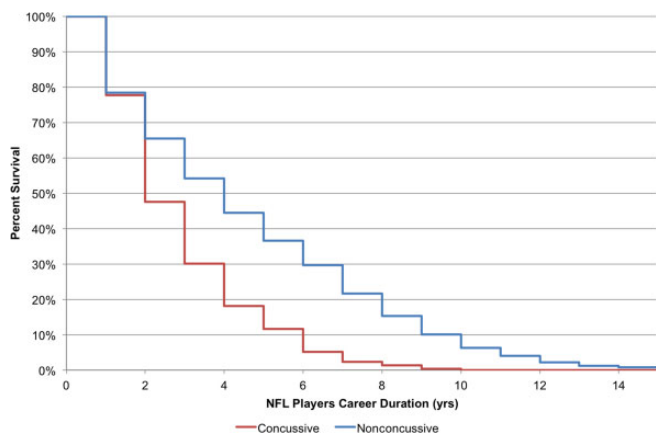


Figure 1. Kaplan-Meier survival curves for National Football League (NFL) players: concussive versus nonconcussive.

TABLE 3
Player Career Survival Probabilities:
Concussion vs Nonconcussion Groups

| Years | Probability of Remaining in the NFL, % | | Hazard Ratio | P Value Between Groups |
|-------|--|--------------------------|--------------|------------------------|
| | Concussion (n = 307) | Nonconcussion (n = 5587) | | |
| 1 | 77.7 | 78.3 | 1.02075 | .87 |
| 3 | 30.1 | 54.2 | 1.85794 | 4.39E-18 |
| 5 | 11.6 | 36.6 | 1.91947 | 2.13E-27 |

postconcussive salary reduction based on career length, as shown in Figure 2, illustrates a bimodal distribution of salary change for the newer players and the veteran players. The largest salary declines were for players with a career length >5 years at the time of concussion: mean decline of \$460,000 per year for the 5- to 7-year career group and \$1,000,000 per year for the 7- to 10-year career group.

Performance

For players in the concussion group for which offensive position scoring performance data were available (n =

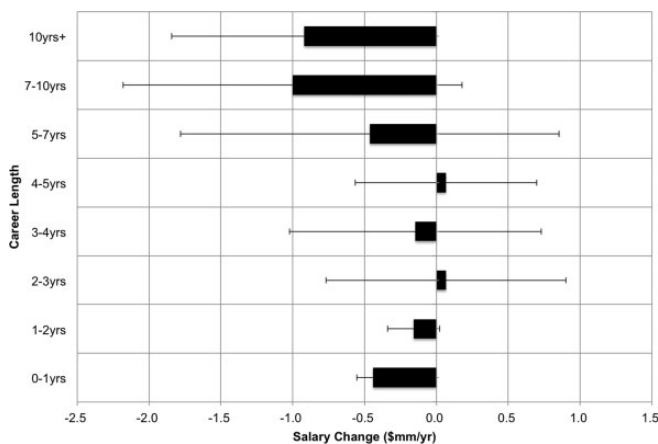


Figure 2. Annualized salary contract changes for National Football League players with concussion after DNP (“did not participate”) protocol. Values are presented as mean \pm SD.

136), there was a preconcussion mean of 8.62 ± 6.2 FFPs per game versus a postconcussive mean of 7.29 ± 3.5 FFPs per game, and this difference was statistically significant ($P = .042$). The results of position-based analysis (Table 4) indicate a statistically significant decrease in performance for tight ends, running backs, wide receivers, and quarterbacks ($P = .032, .048, .029, \text{ and } .040$, respectively).

DISCUSSION

The prevalence of concussions in professional American football has been reported and studied over the past 2 decades, resulting in recent protocol and safety changes in the NFL. While approximately 40% of retired NFL players reportedly have signs of long-term brain remodeling, little is known about the short-term impact of concussion on a player’s career from a performance and financial perspective.²⁴ Our retrospective 11-year study of 5894 NFL players, 307 of whom sustained concussions, demonstrated that these players experience a higher rate of roster instability after sustaining concussion requiring designation of DNP status. From the perspective of their status with the franchise, players with concussions are being released from teams at a greater rate than those who are nonconcussed (33.6% vs 21.6% at 1 year and 67.1% vs 43.0% at 3 years). In terms of their likelihood of remaining in the league at all, 70% of the concussion group was no longer playing in the NFL 3 years after concussion, and 88% were no longer playing at 5 years. Comparatively, the percentages of players in the nonconcussion group who were no longer in the league at 3 and 5 years were 46% and 63%, respectively. The NFL players who sustained concussion experienced a mean loss of \$300,000 per year since the event. Subsequent salary analysis revealed a bimodal distribution among new players and veteran players, who financially lost the most following concussion. Furthermore, a statistically significant decline in performance was noted for the offensive

player positions of tight end, running back, wide receiver, and quarterback.

Few studies have analyzed the effects of concussions on the career of an NFL player. To our knowledge, no existing studies have investigated the effect of release rate and career length on players with concussion. The significantly greater release rate and lower career length of the concussion group suggest that these injuries have negative impacts on the ability of a player to continue their career. Indeed, various reasons exist for a player’s career length to be negatively affected following a concussion—whether because of the increased risk of additional injuries, team managerial moves based on games played in a season, or early retirement based on the multiple recurrence of concussions. In a 4-year retrospective study of 219 injuries, Secrist et al²² reported that anterior cruciate ligament tears among NFL players have cost athletes approximately \$500,000 per year and decreased their likelihood of remaining in the NFL. Thus, the overall salary reduction of \$300,000 per year reported in our study parallels the results seen in other injury types in the NFL. Additionally, the authors noted that a player’s experience in the league affects this reduction, which supports the bimodal salary distribution change noted in our study.

Several studies have found no significant difference in performance after concussions.^{10,21} In a 4-year retrospective study of 131 NFL concussions, Kumar et al¹⁰ found no on-field performance differences regardless of missed games. While this conclusion was not supported by our study, since the decline from 8.0 to 6.6 FFPs per game was statistically significant, our position-based analysis is the first (to our knowledge) to reveal a performance decline for certain offensive positions: tight end, running back, wide receiver, and quarterback. This finding may suggest that concussions for these players are more severe or have particular effects that prohibit on-field return to prior performance. That said, other comorbidities and conditions potentially contributing to performance decline were not evaluated.

Note that the continual evolution of the NFL’s concussion protocol during the study period may have had a secondary impact on this study’s findings, given that the NFL has increased diagnosis and monitoring of player concussions. In 2013, the NFL introduced new protocol and guidelines for sideline concussion evaluation, including rules on preseason education, baseline testing, and the involvement of multidisciplinary personnel (ie, neurologists) to conduct concussion evaluations.^{3,6,23} To examine the effects of potential underreporting of concussions prior to 2013, a statistical analysis was conducted that compared performance and concussion frequency between the periods of 2005-2012 and 2013-2016, and it found no statistically significant difference in FFPs per game or frequency of concussions ($P = .86$ and $.23$, respectively).

Concussion studies examining the impact on professional athletes in other sports found varied relationships between concussions and short-term performance.^{7,8,18,27} One cohort study on Major League Baseball players found that players’ postconcussion batting performance worsened upon return to play as compared with that of players

TABLE 4
Offensive Player Performance Comparison: Pre- and Postconcussion^a

| Position | Mean FFPs/per Game | | Change | 95% CI | P Value |
|-----------------|--------------------|----------------|--------|--------------|---------|
| | Preconcussion | Postconcussion | | | |
| TE (n = 32) | 5.74 | 3.96 | -1.78 | -6.9 to 2.1 | .032 |
| RB (n = 36) | 10.98 | 9.71 | -1.28 | -9.8 to 6.1 | .048 |
| WR (n = 45) | 6.69 | 5.45 | -1.23 | -10.0 to 3.1 | .029 |
| QB (n = 23) | 8.81 | 7.62 | -1.19 | -9.2 to 2.1 | .040 |
| Total (n = 136) | 7.96 | 6.59 | -1.33 | -7.9 to 2.8 | .042 |

^aFFP, fantasy football points; QB, quarterback; RB, running back; TE, tight end; WR, wide receiver.

missing time for noninjury reasons.²⁶ A cross-sectional study on Major League Lacrosse player cognitive performance found that athletes with a history of concussion had a lower baseline neurocognitive performance when compared with those without such a history.²⁰ Preliminary studies on National Basketball Association players did not find a significant difference in postconcussion performance in the 5 games after return to play.²⁸ National Hockey League concussion studies found no difference between the concussion and control groups across performance or style of play after returning from concussion based on evaluation of the 5 games after return to play.⁹

This study is not without limitations. The retrospective review of concussion effects fails to wholly control for other comorbidities and subclinical injuries that may also affect financial and performance changes. Additionally, since many football concussions go unreported, there may be multiple players in the nonconcussion group who sustained injuries that were not detected or reported, thus leading to an underrepresentation in the concussion group.¹¹ Furthermore, it is possible that many players sustained concussions before entering the NFL and these previous concussions were not accounted for. Additionally, while the FFP scoring system used to evaluate performance provides a good estimation of player performance, this metric has its own limitations. As each component of performance is broken down numerically, it is possible that certain contributions of a player's performance are missed with this measurement. Because this metric inherently favors offensive players over defensive players, we removed defensive players from analysis; we removed offensive linemen as well for this reason. Additionally, this metric does not control for a player's age, team, or difficulty of schedule. Given the absence of a "gold standard" performance metric for all NFL positions, the FFP system was favored as a comprehensive, consistent, and broadly used metric. Although the FFP system indirectly accounts for the snap count of the player, there was no direct variable with regard to the time spent on the field by each player.

With respect to the salary analysis, a large standard deviation was found (\$1,300,000), which may lead to the misleading conclusion that some players may have received greater pay after sustaining a concussion. While salary changes are affected by factors other than concussion history, this large standard deviation demonstrating potential

net gains after concussion may be due to the athlete sustaining the concussion after signing a guaranteed contract. Analyzing players by their level of experience addressed this limitation, and we found a bimodal distribution among newer players and veteran players, with shorter-term contracts enduring the greatest reductions in salary after concussion. In terms of the FFP scoring analysis, there is no precedent for a minimal discrepancy of clinical or professional significance; although our study found statistical significance with less than an FFP difference, this may not translate to professional importance to the athlete. Additionally, players with and without concussion may have suffered other injuries, a variable that was not accounted for. Despite these limitations, this study provides unique insights into the short-term effects on a player's career if a concussion is sustained.

The short-term effects of severe concussions on total career length, on-the-field performance, financial outcomes, and contracted roster status from the player's perspective are not well elucidated. This study of NFL players with concussions demonstrated a noted increase in franchise release rates and decreases in career length, salary, and on-field performance for specific positions. While this study does not diminish the need for concussion prevention, early diagnosis, and follow-up, it may provide useful counseling information to NFL players and personnel. In terms of concussion and NFL players, this review represents the largest evaluation to date in the literature; as such, a more in-depth prospective analysis is warranted to better understand the factors that affect the short- and long-term effects of concussions on player performance.

CONCLUSION

This retrospective study demonstrates that NFL players sustaining concussion face a greater overall franchise release rate and lower probability of remaining in the NFL when compared with a nonconcussed cohort. Additionally, NFL players incur significant reductions in salary and, at certain positions, perform worse after concussion. As such, there exist important short-term reductions in player longevity, performance, and salary after concussion that deserve consideration.

REFERENCES

1. Associated Press. Goodell issues memo changing return-to-play rules for concussions. National Football League website. <http://www.nfl.com/news/story/09000d5d814a9ecd/article/goodell-issues-memo-changing-return-to-play-rules-for-concussions>. Accessed April 8, 2017.
2. Bradley B. New NFL rules: crown-of-helmet change to help runner, defender. National Football League website. <http://www.nfl.com/news/story/0ap1000000238662/article/new-nfl-rules-crown-of-helmet-change-to-help-runner-defender>. Accessed April 8, 2017.
3. Bradley B. NFL's 2013 protocol for players with concussions. National Football League website. <http://www.nfl.com/news/story/0ap2000000253716/article/nfls-2013-protocol-for-players-with-concussions>. Accessed April 8, 2017.
4. Duma S, Manoogian S, Bussone W, et al. Analysis of real-time head accelerations in collegiate football players. *Clin J Sport Med*. 2005;15(1):3-8.
5. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc*. 2007;39(6):903-909.
6. Hart J, Kraut MA, Womack KB, et al. Neuroimaging of cognitive dysfunction and depression in aging retired National Football League players: a cross-sectional study. *JAMA Neurol*. 2013;70(3):326.
7. Izraeliski J. Concussions in the NHL: a narrative review of the literature. *J Can Chiropr Assoc*. 2014;58(4):346-352.
8. Kontos AP, Elbin RJ, Sufirinko A, et al. Incidence of concussion in youth ice hockey players. *Pediatrics*. 2016;137(2):e20151633.
9. Kuhn AW, Zuckerman SL, Totten D, Solomon GS. Performance and style of play after returning from concussion in the National Hockey League. *Am J Sports Med*. 2016;44(8):2152-2157.
10. Kumar NS, Chin M, O'Neill C, Jakoi AM, Tabb L, Wolf M. On-field performance of National Football League players after return from concussion. *Am J Sports Med*. 2014;42(9):2050-2055.
11. Llewellyn T, Burdette GT, Joyner AB, Buckley TA. Concussion reporting rates at the conclusion of an intercollegiate athletic career. *Clin J Sport Med*. 2014;24(1):76-79.
12. Maroon JC, Winkelman R, Bost J, Amos A, Mathyssek C, Miele V. Chronic traumatic encephalopathy in contact sports: a systematic review of all reported pathological cases. *PLoS One*. 2015;10(2):e0117338.
13. National Football League. NFL announces new sideline concussion assessment protocol. <http://www.nfl.com/news/story/09000d5d81e78cc4/article/nfl-announces-new-sideline-concussion-assessment-protocol>. Accessed April 8, 2017.
14. National Football League. NFL, NFLPA announce policy to enforce concussion protocol. <http://www.nfl.com/news/story/0ap3000000676669/article/nfl-nflpa-announce-policy-to-enforce-concussion-protocol>. Accessed April 8, 2017.
15. National Football League. NFL player health and safety fact sheet—NFL play smart, play safe. <https://www.playsmartplaysafe.com/newsroom/fact-sheets/nfl-player-health-safety-fact-sheet/>. Accessed April 2, 2017.
16. NFL Head, Neck and Spine Committee. NFL Head, Neck and Spine Committee's protocols regarding diagnosis and management of concussion. National Football League website. <http://www.nfl.com/news/story/09000d5d81e78cc4/article/nfl-announces-new-sideline-concussion-assessment-protocol>. Accessed April 8, 2017.
17. NFL Wire Reports. NFL moves kickoffs to 35-yard line; touchbacks unchanged. National Football League website. <http://www.nfl.com/news/story/09000d5d81e78cc4/article/nfl-moves-kickoffs-to-35yard-line-touchbacks-unchanged>. Accessed April 8, 2017.
18. Padaki AS, Cole BJ, Ahmad CS. Concussion incidence and return-to-play time in National Basketball Association players: results from 2006 to 2014. *Am J Sports Med*. 2016;44(9):2263-2268.
19. Pellman EJ, Viano DC, Casson IR, Arfken C, Feuer H. Concussion in Professional Football: Players Returning to the Same Game—part 7. *Neurosurgery*. 2005;56(1):79-92.
20. Plancher KD, Brooks-James A, Nissen CW, Diduch BK, Petterson SC. Baseline neurocognitive performance in professional lacrosse athletes. *Orthop J Sports Med*. 2014;2(9):232596711455062.
21. Reams N, Hayward RA, Kutcher JS, Burke JF. Effect of concussion on performance of National Football League players. *Int J Sports Physiol Perform*. 2017;12(8):1100-1104.
22. Secrist ES, Bhat SB, Dodson CC. The financial and professional impact of anterior cruciate ligament injuries in National Football League athletes. *Orthop J Sports Med*. 2016;4(8):2325967116663921.
23. Stites A. How does the NFL's concussion protocol work? SB Nation website. <http://www.sbnation.com/platform/amp/nfl/2016/9/18/12940926/nfl-concussion-protocol-explained>. Accessed April 2, 2017.
24. Study: more than 40 percent of retired NFL players had brain injury. American Academy of Neurology website. <https://www.aan.com/PressRoom/Home/PressRelease/1453>.
25. Teramoto M, Petron DJ, Cross CL, Willick SE. Style of play and rate of concussions in the National Football League. *Orthop J Sports Med*. 2015;3(12):232596711562036.
26. Wasserman EB, Abar B, Shah MN, Wasserman D, Bazarian JJ. Concussions are associated with decreased batting performance among Major League Baseball players. *Am J Sports Med*. 2015;43(5):1127-1133.
27. Wennberg RA, Tator CH. Concussion incidence and time lost from play in the NHL during the past ten years. *Can J Neurol Sci*. 2008;35(5):647-651.
28. Yengo-Kahn AM, Zuckerman SL, Stotts J, et al. Performance following a first professional concussion among National Basketball Association players. *Phys Sportsmed*. 2016;44(3):297-303.