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Concussion in National Football League Athletes Is Not Associated With Increased Risk of Acute, Noncontact Lower Extremity Musculoskeletal Injury

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

Background: Impaired neuromuscular function after concussion has recently been linked to increased risk of lower extremity injuries in athletes.

Purpose: To determine if National Football League (NFL) athletes have an increased risk of sustaining an acute, noncontact lower extremity injury in the 90-day period after return to play (RTP) and whether on-field performance differs pre- and postconcussion.

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

Methods: NFL concussions in offensive players from the 2012-2013 to the 2016-2017 seasons were studied. Age, position, injury location/type, RTP, and athlete factors were noted. A 90-day RTP postconcussive period was analyzed for lower extremity injuries. Concussion and injury data were obtained from publicly available sources. Nonconcussed, offensive skill position NFL athletes from the same period were used as a control cohort, with the 2014 season as the reference season. Power rating performance metrics were calculated for ±1, ±2, and ±3 seasons pre- and postconcussion. Conditional logistic regression was used to determine associations between concussion and lower extremity injury as well as the relationship of concussions to on-field performance.

Results: In total, 116 concussions were recorded in 108 NFL athletes during the study period. There was no statistically significant difference in the incidence of an acute, noncontact lower extremity injury between concussed and control athletes (8.5% vs 12.8%; $P = .143$), which correlates with an odds ratio of 0.573 (95% CI, 0.270-1.217). Days (66.4 ± 81.9 days vs 45.1 ± 69.2 days; $P = .423$) and games missed (3.67 ± 3.0 vs 2.9 ± 2.7 games; $P = .470$) were similar in concussed athletes and control athletes after a lower extremity injury. No significant changes in power ratings were noted in concussed athletes in the acute period (±1 season to injury) when comparing pre- and postconcussion.

Conclusion: Concussed, NFL offensive athletes did not demonstrate increased odds of acute, noncontact, lower extremity injury in a 90-day RTP period when compared with nonconcussed controls. Immediate on-field performance of skill position players did not appear to be affected by concussion.

Keywords: concussion; lower extremity; NFL; football; performance; injury

Concussions in the National Football League (NFL) occur at the highest rate in professional sports. With concussions occurring at a rate of around 150 per season, the NFL has long been the model for concussion research.[20] In the NFL, the majority (67.7%) of concussions result from helmet-to-helmet contact with another player.[25] From the 1996 to 2007 seasons, 56.5% of reported concussions were the result of a tackle and 32.2% resulted from blocking.[25] Tight ends and quarterbacks are the most frequently concussed players throughout the league, with estimated rates from the 2002 to 2007 seasons of 1.45 and 1.20 concussions per 100 games at position, respectively.[25] In addition, these positions had the greatest odds for repeat concussion after returning to play.[1] Although the epidemiology of concussions in the NFL is well-documented, much needs to be learned about the lasting effects on the musculoskeletal system and on-field performance.

Concussive events present with varying effects, such as headache, confusion, amnesia, and other cognitive deficits. In most cases, these acute symptoms regress in days to weeks with proper cognitive rest. While most symptoms resolve in days to weeks, lingering deficits in cognition,

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conduct, and motor function can result from repetitive concussive events.[31] In addition to the cerebral effects, changes in proprioception, reaction time, and gait pattern have been documented in athletes after concussion.[4,8,17,29] There has been recent evidence to suggest that these deficits increase the risk for a musculoskeletal injury, especially to the lower extremity.[2,7,32] This phenomenon has been demonstrated in several different demographics, including National Collegiate Athletic Association (NCAA) Division I collegiate athletes across several men's and women's sports as well as military personnel returning to combat after a concussion.[7,9] Recently, increased odds of lower extremity musculoskeletal injury after a concussion were demonstrated in National Basketball Association (NBA) athletes; however, it remains to be seen if this phenomenon is generalizable across all professional sports.[9]

Lower extremity injuries plague the NFL athletes on a yearly basis; however, it is not known to what extent concussions contribute to these numbers. This study sought to find out if there were increased odds for lower extremity injury within the 90-day return-to-play (RTP) period after a concussion and whether lingering concussive effects altered on-field performance. We hypothesized that concussed NFL athletes would not be at greater risk for a lower extremity injury and would have no change in on-field performance postinjury.

METHODS

Data on all concussions sustained by professional offensive skill players (quarterback, halfback, wide receiver, tight end) in the NFL from the 2012-2013 to the 2016-2017 seasons were collected using publicly attainable injury reports and postgame reporting using methods validated by previous studies.[10,16,17,23] Specific online sources for data acquisition included the official sports websites of ESPN (ESPN.com), CBS (CBSsports.com), NBC (NBCsports.com), and Fox (FoxSports.com) as well as a transactional sports database (prosportstransactions.com). Team websites, local game reports, and media guides were then used to further cross-reference and verify concussions. The NFL mandates that teams quickly and accurately disseminate injury information to the league office, opponents, local and national media, and the league's broadcast partners. Alongside each concussion, primary position, date of injury, season year, athlete age, lower extremity injury within 90 days of RTP, injury type, and RTP date were also recorded. Injury locations were broadly categorized as hip, groin, thigh, knee, shin, ankle, or foot. Injuries were further classified by type: acute fracture, muscle strain and/or tear, or ligament sprain and/or tear. A 90-day analysis was chosen because previous literature showed an increased risk of lower extremity injury in this time frame.[2,7] This study was exempt from institutional review board approval given the nature of the publicly available data used.

$$Power\ rating = \left(\frac{Total\ yards}{10}\right) + (6 \times Touchdowns)$$

Figure 1. Power rating metric used to assess on-field performance of offensive National Football League players.

All offensive skill players who returned to regular season NFL play for at least 1 play after their documented concussion were included in this analysis. The number of days and games missed were calculated for each player, referenced from the RTP date. To assess on-field performance, the offensive power rating (PR) metric shown in Figure 1 was used to monitor players' offensive productivity before and after the concussion. Performance was analyzed for each player using offensive metrics including games played, total yards (receiving or rushing), and touchdowns. From these variables, the offensive PR was calculated for each athlete. The offensive PR was previously described and has been proven reliable and validated for use as an outcome instrument in the orthopaedic literature.[10,19,22,33] In the PR equation shown in Figure 1, yards and touchdowns are weighted by dividing by 10 and multiplying by 6, respectively. PRs were calculated for ±1, ±2, and ±3 seasons, if applicable, in which a null value was recorded if a player did not participate in 1 of those seasons.

A matched-cohort analysis of all nonconcussed NFL offensive skill position athletes (quarterback, halfback, wide receiver, tight end) from the 2012-2013 to 2016-2017 seasons was gathered to compare the incidence of lower extremity injury. The 2014-2015 NFL regular season was used as the reference period for control players. Adhering to previously used methodology, an age-, body mass index–, and NFL experience–matched control group consisting of all halfbacks and wide receivers that did not sustain a documented concussion in their professional career and completed the 2012 NFL season was assembled.[5,11,23,24] Any control player who had a previous concussion was removed from the control. The incidence of

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Ethical approval was not sought for the present study.

TABLE 1
Athlete and Return-to-Play Data of Concussed NFL Athletes With LE Injuries and Nonconcussed Control NFL Athletes[a]

	Nonconcussed (n = 328)	Concussed Without LE Injury (n = 107)	Concussed With LE Injury (n = 9)[b]	*P* Value
Age, y	26.27 ± 3.28	26.66 ± 2.96	24.88 ± 1.4	.206
Body mass index	28.86 ± 2.10	29.17 ± 2.17	28.44 ± 2.43	.326
Primary position				
Quarterback	32 (10)	18 (17)	0 (0)	.112
Wide receiver	130 (40)	35 (33)	5 (56)	
Halfback	98 (30)	25 (23)	1 (11)	
Tight end	68 (21)	29 (27)	3 (33)	
Days missed after LE injury	45.13 ± 69.18		66.44 ± 81.85	.423
Games missed after LE injury	2.93 ± 2.71		3.67 ± 3.00	.470

[a]Data are reported as mean ± SD or n (%). Univariate 2-group comparisons. LE, lower extremity; NFL, National Football League.
[b]One player with a concussion and subsequent LE injury was excluded because the LE injury occurred outside of the 90-day postconcussive window.

lower extremity injury in the 90-day RTP period and PRs for ±1, ±2, and ±3 seasons were compared between the control and concussed groups.

Statistical Analysis

For continuous variables, group comparisons were performed using 1-way analysis of variance. For categorical variables, group comparisons were performed using chi-square tests when expected cell counts were >5 and Fisher exact tests when expected cell counts were <5. For comparing pre- and postperformance, paired *t* tests were performed if the differences between the variables were normally distributed, and Wilcoxon signed-rank test were used when differences were nonnormally distributed. All differences were calculated by subtracting preinjury values from postinjury values. Statistical significance was set at $P < .05$. All analyses were performed using SAS 9.4 (SAS Institute).

RESULTS

A total of 116 concussions were recorded in 108 NFL offensive skill players. Concussed players had a mean age of 26.7 ± 3.0 years. Athletes who sustained a concussion were most often wide receivers (33%), followed by tight ends (27%). Concussed athletes with lower extremity injuries showed similar trends, as 56% were wide receivers and 33% were tight ends (Table 1). Injury specifics are reported in Table 2.

In the concussed group, 9 athletes sustained a noncontact lower extremity injury within the 90-day RTP period. There was no statistically significant difference in the incidence of an acute, noncontact lower extremity injury between concussed athletes and the control (8.5% vs 12.8%; $P = .143$), correlating with an odds ratio of 0.573 (95% CI, 0.270-1.217). In comparing time and games missed after an acute lower extremity injury, there was no statistically significant difference between the concussed and control groups in days missed (66.4 ± 81.9 days vs 45.1 ± 69.2 days; $P = .423$) or games missed (3.67 ± 3.0 games vs 2.9 ± 2.7 games; $P = .470$).

TABLE 2
Injury Characteristics for Concussed NFL Athletes With LE Injuries and Nonconcussed Control NFL Athletes[a]

	Nonconcussed With LE Injury (n = 43)	Concussed With LE Injury (n = 9)	*P* Value
Injury location			.786
Hip	2 (5)	0 (0)	
Groin	4 (9)	0 (0)	
Thigh	14 (33)	2 (22)	
Knee	2 (5)	1 (11)	
Shin	2 (5)	1 (11)	
Ankle	9 (21)	2 (22)	
Foot	10 (23)	3 (33)	
Injury type			.401
Acute fracture	1 (2)	0 (0)	
Muscle strain/tear	24 (56)	3 (33)	
Ligament sprain/tear	18 (42)	6 (67)	
Multiple LE injuries	13 (30)	2 (22)	.697

[a]Data are reported as n (%). Univariate 2-group comparisons. LE, lower extremity; NFL, National Football League.

Ligamentous sprains/tears were the most common injury type in concussed athletes (67%), followed by muscle strains/tears (33%). The control group sustained a majority of muscle strains/tears (56%), followed by ligamentous sprains/tears (42%). The most common locations for injury in the concussed athletes were the foot (33%), followed by the thigh (22%) and ankle (22%).

For concussed athletes who did not sustain a lower extremity injury, the PR from 3 seasons after the injury was significantly less than for 3 seasons before the injury and, on average, down 33.25 ($P = .0088$). Concussed athletes with lower extremity injuries displayed no significant differences in PR when comparing ±1, ±2, and ±3 seasons pre- and postconcussion. There are no significant differences in PR when comparing groups of concussed athletes with lower extremity injury, concussed athletes without lower extremity injury, and controls (Table 3).

TABLE 3
Power Ratings for Concussed NFL Athletes With and Without LE Injuries and Nonconcussed Control NFL Athletes[a]

Power Rating	Nonconcussed (n = 328)	Concussed Without LE Injury (n = 107)	Concussed With LE Injury (n = 9)	*P* Value
3 seasons preinjury	60.41 ± 131.72	65.24 ± 123.24	9.84 ± 21.85	.4629
2 seasons preinjury	73.40 ± 135.69	74.47 ± 133.28	27.69 ± 33.01	.5937
1 season preinjury	81.14 ± 135.61	82.05 ± 119.29	39.09 ± 35.98	.6295
1 season postinjury	75.82 ± 131.14	72.97 ± 105.34	46.36 ± 46.02	.7734
2 seasons postinjury	61.53 ± 127.53	65.82 ± 126.62	31.79 ± 46.55	.7345
3 seasons postinjury	48.84 ± 109.06	31.99 ± 78.13	19.03 ± 39.06	.2497

[a]Data are reported as mean ± SD. Univariate 2-group comparisons. LE, lower extremity; NFL, National Football League.

DISCUSSION

As our understanding of concussions in the NFL continues to evolve, the potential long-term consequences are well-documented, but much is to be learned about the immediate effect on athlete performance and well-being. Our study suggests that there is not an increase in the odds of an acute noncontact lower extremity musculoskeletal injury in offensive NFL players in a 90-day RTP period postconcussion. In addition, we found that there was no immediate decline in play after a concussion to an NFL athlete as compared with controls when 3 seasons pre- and postinjury. These findings suggest that although severe long-term repercussions from concussions are evident, NFL players may not experience additional risks to injury or changes in quality of play in the acute setting after initial recovery from a concussive event.

Several previous studies have suggested that concussions increase the risk of sustaining an acute noncontact lower extremity musculoskeletal injury after returning to play. Brooks et al[1] displayed this phenomenon in a retrospective study of 87 concussion cases in 75 NCAA Division I collegiate athletes across football, soccer, hockey, softball, basketball, wrestling, and volleyball at a single institution from 2011 to 2014. Because of the contact nature of the NFL, we suspect that we have a decreased sample size of noncontact injuries, potentially contributing to the difference in our findings. In a similar study, Herman et al[7] evaluated 73 Division I collegiate athletes across men's football and women's basketball, soccer, and lacrosse from 2006 to 2011. This study reached similar conclusions, with a higher incidence of lower extremity musculoskeletal injuries in concussed athletes when compared with nonconcussed controls.[7] However, this study did not isolate injuries as noncontact in nature and also included multiple sports. Without identifying injuries as noncontact, it may be difficult to correlate injury causality with changes in neuromuscular function or due to direct physical blow, altering biomechanics, especially in football. When compared with other professional sports, such as basketball, we suspect that increased rest time between games (6 days vs 2-3 days) also contributes to lower rates in NFL athletes. In addition, NFL players have up to 60 minutes of in-game play time per week, in comparison with NBA athletes, who could have up to 144 minutes of play time in a 3-game week. This phenomenon has been documented in NBA athletes, showing increased odds of injury by 2.67% ($P < .001$) for each 96 minutes played. It was also found that in the context of constant game load and fatigue level found in the NBA, the odds of injury increase by 3.03% for each year played in the NBA.[15] Increased play time over the 90-day RTP in NBA athletes could result in a higher prevalence of the previously stated phenomenon regarding lower extremity injuries. Recent discoveries of sports-related concussions affecting gait pattern, reaction times, and proprioception are suspected to account for an increased risk of lower extremity injury in previous studies.[4,8,18,29] A decline in neuromuscular function could affect the odds of sustaining a lower extremity injury and could play a role in recovery protocols to assess an athlete's readiness for RTP.

Along with increased risk for injury, Herman et al[7] hypothesized that concussed athletes would sustain more severe lower extremity injuries, leading to prolonged RTP periods. However, their findings showed that there was an insignificant difference in RTP times after lower extremity injury between concussed athletes and controls. In a previous study on the incidence of lower extremity injuries in concussed NBA athletes reciprocating these results, Jildeh et al[9] found no significant difference in days or games missed between concussed NBA athletes and nonconcussed controls after a noncontact lower extremity injury. The current study further supports previous work, as we found no significant difference in days (66.4 ± 81.9 vs 45.1 ± 69.2; $P = .423$) or games (3.67 ± 3.0 vs 2.93 ± 2.71; $P = .470$) missed when comparing concussed NFL athletes and nonconcussed controls after a lower extremity injury. We support the previous hypothesis that the mechanism of these findings stems from changes in specific neuromuscular function persisting long after acute recovery from a concussion.[3,15,28] Specifically, decreased maximal muscle activation and motor evoked potential amplitudes likely equate to lower muscle force production and activation, correlating to less severe injuries in concussed athletes and similar RTP times when compared with nonconcussed controls.

There have been several studies on the performance of NFL athletes after concussion. Kumar et al[14] studied 131 concussion cases in 124 NFL players using ProFootballFocus performance scores and found that scores were similar pre- and postconcussion for players missing no games and those missing at least 1 game. Reams et al[30] performed a similar study using Football Outsiders' defense-adjusted yards above replacement (DYAR) metric. They assessed

140 concussed NFL players from 2007 to 2010 and found no significant change in DYAR in concussed athletes when compared with controls with head and neck injuries other than concussion. In a study utilizing the PR metric to assess the on-field performance of NFL running backs and wide receivers pre- and postconcussion, Jildeh et al[9] found that the change of PR in both the acute (±1 year from injury) and chronic (±3 years from injury) settings was similar in concussed and nonconcussed control athletes. Our current study further echoes these findings, as we found no significant differences in change of PR when comparing groups of concussed athletes with lower extremity injury, concussed athletes without lower extremity injury, and controls in the acute (7.27 ± 46.11 vs –9.08 ± 136.81 vs –5.32 ± 104.38) setting (±1 year from injury). We did find there to be a significant difference in the PR of concussed athletes without lower extremity injuries ±3 years from the injury with a mean difference of –33.25 ± 128.83 ($P < .01$). However, since this is a 6-year period and there are no significant differences in the ±1-year and ±2-year metrics, we suspect this difference is due to natural career progression rather than concussive effects. These findings suggest that, while the long-term ramifications of concussions are well-documented, they do not appear to affect immediate on-field performance in NFL athletes.

In a prospective cohort study of 76 Division I collegiate football players, Wilkerson[34] found that decline in neurocognitive reaction time appears to increase risk for ligament sprains/tears. Wilkerson assessed reaction time using the Immediate Post-Concussion Assessment and Cognitive Testing and found slower reaction times in starters who sustained a lower extremity sprain or strain when compared with uninjured starters, contributing to a relative risk of 2.17 (90% CI, 1.40-4.30) for sustaining a lower extremity sprain or strain in athletes with a prolonged reaction time (≥0.545 s). Herman et al[7] corroborated this finding, showing a 3.39 greater risk of sustaining a ligament sprain/tear or muscle sprain/tear in the 90-day RTP period after a concussion. Jildeh et al[9] found that the most common acute injury in NBA athletes after concussion was ligament sprains/tears (64%). The current study, although showing no increased risk for lower extremity injury after concussion, found that the most common injury type in concussed athletes was ligament sprains/tears (67%) compared with muscle strains/tears (56%) in nonconcussed controls. To explain this phenomenon, a decline in maximum muscle activation has been demonstrated in anterior cruciate ligament injury and chronic ankle instability.[13,26,27] Concussive effects on the motor cortex are suspected to contribute to altered muscle activation, creating joint laxity and increased susceptibility to these injuries.[7] Knee injuries are the most common injury in the NFL (24%), most often being ligamentous in nature (anterior cruciate or medial cruciate ligament).[12] The prominence of lower extremity injuries in the NFL make them a crucial area of investigation for player safety. Establishing clear risk factors for acute noncontact lower extremity injuries after concussive events can help team physicians treat athletes with new preventative guidelines to promote athlete well-being.

Limitations

This study has several limitations. Potential inaccuracies could exist in publicly available injury information; however, the NFL authorizes each organization to accurately report records pertaining to injuries, illness, or rest each game day, so a fair amount of accuracy can be expected. Furthermore, each potential concussion or lower extremity injury was cross-referenced with team websites and NFL game summaries/media guides to confirm time missed and documented reasons for injury. In addition, there was no way to control for athletic exposure in regard to minutes and plays per game. This could account for some inaccuracy in an athlete's risk for injury, as higher exposure likely increases risk for injury. Players injured late in the season were likely not participating in games for the full 90-day period. The postconcussive period of documented athletic exposure could underestimate the number of lower extremity injuries after concussion. Nonetheless, the current study reports data of professional athletes who are returning to an elite level of competition after a concussion.

With a specific focus on offensive NFL football players, these findings may not be generalizable to the entire NFL or other sports, although similar results have been shown in different demographics.[2,7,21] On-field performance was assessed with a single PR metric, which fails to account for other aspects of athletic performance (speed, strength, size, etc), leading to a potential oversimplification. History of concussion was not accounted for in this study, which could have left some players more at risk for lower extremity injury than others. Furthermore, more severe or recurrent concussions may lead to more severe neuromuscular and cognitive deficits, which may have implications on RTP and lower extremity injury risk; however, determination of concussion severity is challenging and more rarely reported. Therefore, stratification of risk by severity was not performed in this study. Finally, concussions may be underreported because of reliance on athletes self-reporting their symptoms and varying standards between organizations.[6]

CONCLUSION

Concussed offensive NFL athletes appeared to have no increased risk for acute noncontact lower extremity injury in a 90-day RTP period when compared with nonconcussed controls. Increased time between games and fewer minutes played per week as compared with noncontact professional sports may contribute to this assumption. Concussed players did appear to sustain a higher percentage of ligamentous sprains/tears when compared with nonconcussed controls. Concussed NFL athletes had no apparent change in performance pre- and postconcussion, suggesting that production longevity can be maintained after a concussion.

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