

Evaluation of Musculoskeletal Re-Injury Occurrence in Previously Concussed National Football League Athletes

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Introduction: Increased risk of musculoskeletal (MSK) injury post-concussion has been reported in collegiate athletes, yet it is unknown if professional football athletes are at the same risk of secondary injury. The objective of this study was to determine if the risk of MSK injury in National Football League (NFL) athletes increases after concussion.

Methods: NFL injury reports from 2013 to 2017 were collected from public websites. Concussed athletes (n=91) were equally matched to a non-injured control and an athlete with an incident of musculoskeletal (MSK) injury.

Results: Following their return to sport, concussed athletes were 2.35 times more likely to have a subsequent MSK injury relative to non-injured controls (95% CI: 2.35 [1.25, 4.44], $P = 0.01$), but were no more likely than athletes with an incident MSK injury ($P = 0.55$). Likewise, athletes with an incident MSK injury were no more likely to have a subsequent MSK injury than controls ($P = 0.08$).

Discussion: Increased odds of MSK injury in the 12-week period following a concussion in professional football athletes warrants future research on the acute effects of concussion and the relationship to MSK injury risk.

Keywords: mild traumatic brain injury, musculoskeletal injury, return to play, NFL, professional American football

Introduction

Approximately 1.6 to 3.8 million sport- and recreation-related traumatic brain injuries occur every year.¹ The acute effects of concussion are well defined, with notable changes in postural stability due to impaired integration of the visual, vestibular, and somatosensory systems.² The sensory integration deficit can present clinically as impaired execution of motor tasks,³ such as gait, balance and delayed reaction time.⁴ Historically, it was believed that motor impairments associated with acute concussion returned to pre-morbid levels shortly after injury.⁵ More recent investigations have suggested secondary sports-related concussion (SRC) effects, including increased musculoskeletal (MSK) injury risk following acute SRC resolution.⁶⁻⁸

The biological underpinnings of increased injury rates post-SRC are not clear, but collegiate athletes, across numerous sports, had an increased odds of MSK injury in the 90-day period after return to play from a SRC compared to matched controls.^{6,7} Recently, Harada et al investigated the relationship between SRC and lower extremity injury risk over a 16-year timeframe in Division I collegiate athletes. Researchers concluded those who sustained multiple SRCs were three

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times more likely to sustain lower extremity injuries compared to those who sustained a single concussion and healthy controls.⁸

Despite previous work suggesting an increased risk for MSK injury following SRC in collegiate athlete populations,^{6–8} how these effects may influence professional football athletes is less clear. Since National Football League (NFL) athletes participate in a longer competitive season compared to their collegiate counterparts (17 weeks versus 10–13 weeks, respectively) it follows that the number of athlete exposures also increases for professional athletes. There is limited literature regarding injury risk in terms of athlete exposure in professional American football athletes.^{9,10} Direct comparison between the professional and collegiate population is difficult due to varying definitions of athlete exposure between studies. However, an increase in athlete-exposures in NFL athletes intuitively leads to a greater risk of MSK injuries and SRCs, the relationship of which has yet to be thoroughly investigated. In 2015, Pietrosimone et al conducted a survey of retired NFL athletes, and found those reporting three or more SRCs during their career were between 136% and 248% more likely to report a lower extremity MSK injury than athletes reporting zero SRCs.¹¹ Given this result, it was hypothesized there would be an increased risk of MSK injury after returning to sport following a SRC. Therefore, the purpose of this study is to determine the risk of MSK injury in recently concussed NFL athletes after return to play, compared to those who sustained an acute MSK injury at the same point in the season and healthy controls.

Methods

Participants

A retrospective cohort study was conducted to evaluate the occurrence of MSK injuries in concussed and non-concussed athletes in the NFL. Injury reports from all 32 NFL teams were obtained from an online public source from the 2013–2017 regular and post-season games (The Football Database, www.footballdb.com; Fox Sports NFL Injuries, www.foxsports.com/nfl/injuries; accessed October 2018). This study was conducted as secondary research meeting federal exemption requirements from the University of Michigan's Medical Institutional Review Board. Preseason injuries were excluded from our dataset as they were not required to be reported by the NFL's 2015–2017 "Personnel (Injury) Report Policy". The resulting database included

10,862 injuries from 6146 individual athlete seasons. Exclusion criteria of 1073 athlete seasons included: non-athletic-related injuries, general medical or illness, head or neck injury not labeled as an SRC, undisclosed injury, or an SRC concurrent with an MSK injury. Athletes were grouped into seven general position categories: defensive back, quarterback, linebacker, wide receiver, tight end, running back, and lineman.

Concussions were identified as defined by the injury report (n=683) and included for analyses only if return to play (RTP) occurred between the third and eighth week of the regular season (n=186). This approach was taken to avoid analysis of SRCs that occurred in the pre-season, as well as to ensure at least nine remaining weeks of the regular season following RTP to calculate injury occurrences.

Two certified athletic trainers manually classified all MSK injuries (N=8836) from the injury reports of each of the 32 teams, as either repetitive (n=2100) or acute (n=6736) based on location and mode of onset.¹² Both upper and lower extremity injuries were included since SRC could lead to motor cortex dysfunction which disposes an athlete to a wide range of injuries, not limited to lower extremity.¹³ Repetitive injuries were defined by a mechanism indicative of long-term repeated injury and were thus excluded from matching due to the inability to distinguish if injuries occurred from SRC or a pre-existing susceptibility.¹⁴ This study is a secondary analysis of publicly available data and therefore meets the federal exemption requirements from the Institutional Review Board at the University of Michigan.

Participant Matching

Each SRC athlete was matched with two control athletes as illustrated in [Figure 1](#). They were matched on team, season, and position to an athlete who sustained an MSK injury based on time lost (i.e. RTP within two weeks of the concussed athlete's RTP) and second to a healthy control who did not report an injury in the three weeks prior to the SRC athlete's injury. If MSK and control athletes could not be found, the SRC athlete was excluded. This resulted in a final sample of 273 participants split equally among the three groups: SRC (n=91), MSK control (n=91), and healthy control (n=91) athletes. Participant matching was conducted using Python (version 3.7.3; Python Software Foundation, Wilmington, DE) programming language.

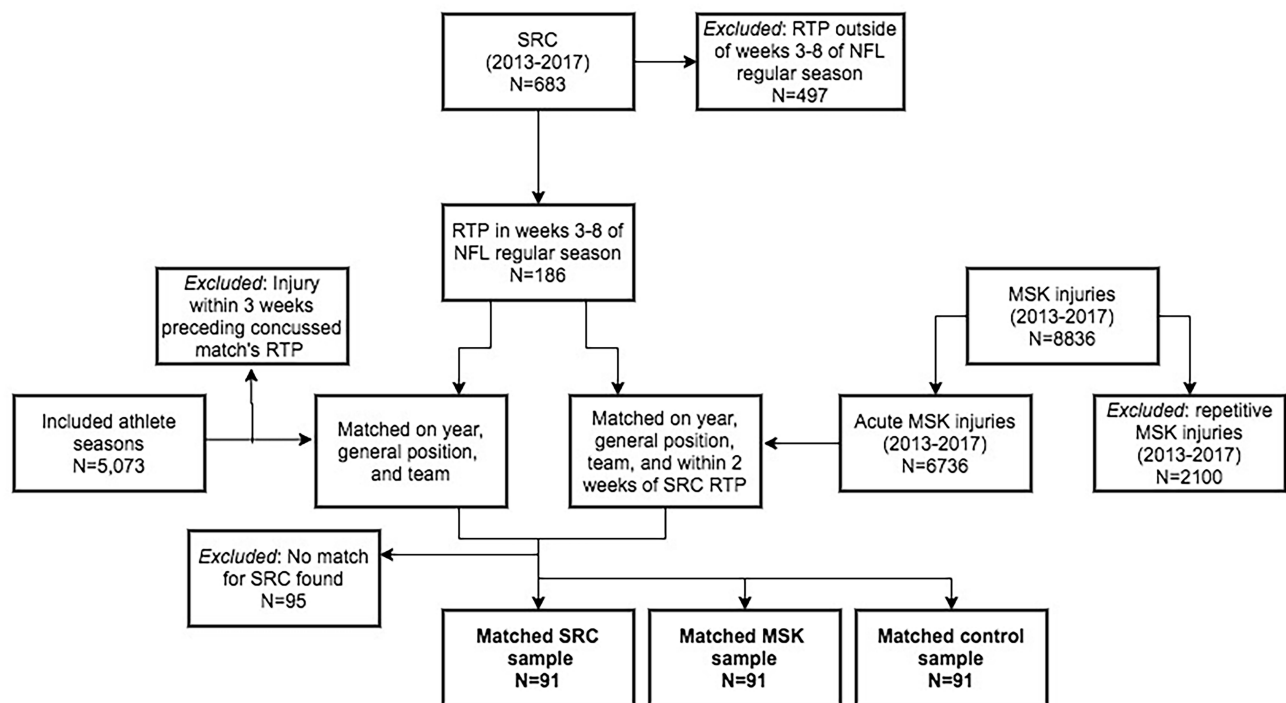


Figure 1 Illustration of matching of SRC to MSK and control athletes, followed by reasons for injury exclusions.

Notes: Of the 683 athletes who sustained an SRC, only 186 returned to play during the third through eighth week of the regular NFL season, and 91 could be matched with appropriate MSK and healthy controls.

Abbreviations: SRC, sports-related concussion; MSK, musculoskeletal; NFL, National Football League; RTP, return to play.

Reinjury Occurrence

MSK occurrence following the incident SRC or MSK injury was calculated by counting all subsequent MSK injuries (including repetitive, acute and cervical pathologies) up to 12 weeks post-RTP for each athlete, including at least 9 or 8 weeks of the regular season for SRC and MSK athletes, respectively. If the 12 weeks post-RTP window extended into the post-season, all subsequent MSK injuries within the window were counted until either the team was eliminated from the playoffs or the Conference Championships were completed. MSK injury counts for the matched healthy controls began on the week of return for the SRC athlete and was equivalent in duration. The post-injury follow-up is consistent with previous studies regarding injury surveillance.^{6,7}

Statistics

Demographics for players with incident SRC, MSK and controls were compared using a one-way multivariate analysis of variance (ANOVA) to identify significant differences in confounding factors between groups. The Wilcoxon rank-sum test was used to calculate the pairwise

difference in the number of MSK injuries between groups in the 12 weeks following RTP from their initial injury. This analysis was necessary since homogeneity of variance was violated and data were not normally distributed. To reduce the impact of players with multiple injuries, Fisher's exact test was used to calculate pairwise odds ratios for the existence of any MSK injury in the 12 weeks following RTP. Standardized differences for comparisons were analyzed using Cohen's *d* effect size (*d*) using the following thresholds: ≤ 0.2 small, 0.2–0.5 medium, ≥ 0.8 large.¹⁵ All analyses were conducted using MATLAB (version 9.2.0; MathWorks, Inc., Natick, MA) statistical software and the significance threshold was set at 0.05.

Results

Demographic information regarding SRC, MSK, and control matched samples are presented in Table 1. The ANOVA test showed no significant differences in the age, height, and mass between groups ($P > 0.05$). Table 2 presents the distribution of the matched sample by position, week of RTP, weeks missed and location of original injury. The majority of the matched sample

Table 1 Player Demographics by Injury Type

	Total (N = 273)	SRC (N=91)	MSK (N=91)	Control (N=91)	P-value
Age in years, mean (SD)	25.99 (2.90)	25.54 (2.55)	26.07 (3.15)	26.36 (2.96)	0.15
Age range, yr	21–36	21–33	21–36	21–34	
Height in meters, mean (SD)	1.87 (0.07)	1.88 (0.07)	1.87 (0.06)	1.87 (0.06)	0.43
Height range, m	1.73–2.03	1.75–2.03	1.75–2.01	1.73–2.01	
Mass in kilograms, mean (SD)	108.37 (20.77)	108.24 (20.82)	108.69 (21.66)	108.17 (20.02)	0.98
Mass range, kg	77.56–154.22	77.56–149.23	79.38–154.22	78.47–152.41	

Notes: One-way ANOVA comparing means of SRC, MSK, and control demographics proved to be non-significant ($P > 0.05$).

Abbreviations: SRC, sports-related concussion; MSK, musculoskeletal injury; yr, year; m, meters; kg, kilograms; SD, standard deviation.

(80.3%) were defensive-backs, linemen, or linebackers. Running backs, tight ends, and wide receivers accounted for the remaining sample (19.7%). A significant difference ($t = 2.35$; mean difference = 0.42 weeks, 95% confidence interval [CI] 0.06 to 0.77; $d = 2.2$, $P = 0.02$) was noted between the average number of weeks missed for a concussive injury (1.74 weeks) relative to the time missed for an MSK injury (2.15 weeks). The locations of MSK injuries for the MSK injury matches are detailed in Table 2.

In the 12 weeks following RTP, a significantly greater total number of subsequent MSK injuries occurred among the SRC athletes ($U = 5037.50$, $d = 0.3$, $P < 0.01$) and MSK athletes ($U = 4734.50$, $d = 0.2$, $P = 0.04$) relative to the healthy control athletes (Figure 2). However, there was no difference in number of subsequent MSK injuries between the MSK and SRC athletes ($U = 3798.50$, $d = 0.1$, $P = 0.27$). The Fisher's exact test suggested SRC athletes were 2.35 times more likely to have a subsequent MSK than healthy controls (odds ratio [OR] 2.35, 95% CI 1.25 to 4.44; $P = 0.01$), but not more likely than athletes with an initial MSK injury (OR 0.80, 95% CI 0.44 to 1.44; $P = 0.55$). Those with an initial MSK were not at greater risk for subsequent MSK than controls (OR 1.87, 95% CI 0.99 to 3.55; $P = 0.08$) (Table 3).

Discussion

Based on our findings, athletes sustaining an MSK injury did not have an increased odds of sustaining a subsequent MSK injury in the 12-week period following RTP than controls matched by team, year, and position. However, considering multiple MSK injuries per athlete during this same period, athletes sustaining an

MSK injury had significantly more MSK injuries than their matched controls. This result validates prior literature that previous MSK injuries can be a risk factor for subsequent injury.^{16–19} Alternatively, athletes sustaining an SRC were 2.35 times more likely to sustain a MSK injury and sustained significantly more MSK injuries than their matched healthy controls in the 12 weeks following RTP.

Although there is previous research suggesting greater risk of MSK injury when an athlete returns to play after sustaining a SRC,^{6,8,11} the current study provides insight into the conditional occurrence of MSK injury acutely following SRC in a professional athlete cohort. These results are consistent with previous studies in collegiate populations.^{6–8} Brooks et al reported a 2.48-fold increased risk of acute lower extremity MSK injury among recently concussed collegiate athletes across seven different sports compared to controls.⁶ Further, Herman et al reported collegiate athletes, across numerous sports, were at a 3.79 times greater risk of lower extremity MSK injury in the 90-days following RTP from SRC.⁷ The results presented here reflect those of Pietrosimone et al in the same population, in such that athletes reporting one, two, or more concussions during their career were, respectively, 1.59, 2.29, 2.86 times more likely to report lower extremity MSK injuries relative to former NFL athletes who did not report a concussion in their career.¹¹

The results reported herein support a growing body of literature demonstrating an increased risk of MSK injury after an SRC or MSK injury. Following an SRC, it is the standard of care to use clinically objective measures in determining when an athlete is ready to return to sport.²⁰ Indeed, medical professionals base

Table 2 Position Type and Injury Characteristics

	Total (N=273)	SRC (n=91)	MSK (n=91)	Control (n=91)
Position, number of players (%)				
Defensive Back	90 (33.0%)	30 (33.0%)	30 (33.0%)	30 (33.0%)
Linebacker	51 (18.7%)	17 (18.7%)	17 (18.7%)	17 (18.7%)
Linemen	78 (28.6%)	26 (28.6%)	26 (28.6%)	26 (28.6%)
Running Back	12 (4.4%)	4 (4.4%)	4 (4.4%)	4 (4.4%)
Tight End	9 (3.3%)	3 (3.3%)	3 (3.3%)	3 (3.3%)
Wide Receiver	33 (12.1%)	11 (12.1%)	11 (12.1%)	11 (12.1%)
Quarterback	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Week of RTP^a, number of players (%)				
2–4 ^b	60 (22.0%)	32 (35.2%)	28 (30.8%)	0 (0.0%)
5–6	53 (19.4%)	25 (27.5%)	28 (30.8%)	0 (0.0%)
7–9 ^c	69 (25.3%)	34 (37.4%)	35 (38.5%)	0 (0.0%)
No original injury	91 (33.3%)	0 (0.0%)	0 (0.0%)	91 (100.0%)
Weeks missed^d, number of players (%)				
1	89 (32.6%)	45 (49.5%)	44 (48.4%)	0 (0.0%)
2	52 (19.0%)	34 (37.4%)	18 (19.8%)	0 (0.0%)
≥3	41 (15.0%)	12 (13.2%)	29 (31.9%)	0 (0.0%)
No original injury	91 (33.3%)	0 (0.0%)	0 (0.0%)	91 (100.0%)
Location of original injury, number of players (%)				
Head (Concussion)	91 (33.3%)	91 (100.0%)	0 (0.0%)	0 (0.0%)
Shoulder	13 (4.8%)	0 (0.0%)	13 (14.3%)	0 (0.0%)
Arm	8 (2.9%)	0 (0.0%)	8 (8.8%)	0 (0.0%)
Chest	5 (1.8%)	0 (0.0%)	5 (5.5%)	0 (0.0%)
Hip/Pelvis	2 (0.7%)	0 (0.0%)	2 (2.2%)	0 (0.0%)
Leg	14 (5.1%)	0 (0.0%)	14 (15.4%)	0 (0.0%)
Knee	23 (8.4%)	0 (0.0%)	23 (25.3%)	0 (0.0%)
Ankle	17 (6.2%)	0 (0.0%)	17 (18.7%)	0 (0.0%)
Foot	9 (3.3%)	0 (0.0%)	9 (9.9%)	0 (0.0%)
No original injury	91 (33.3%)	0 (0.0%)	0 (0.0%)	91 (100.0%)

Notes: ^aWeek of RTP from original injury, either MSK or SRC. ^bThree athletes returning to play from MSK injuries in Week 2 were matched within one week of return to play to SRC athletes returning to play in Week 3. ^cTwo athletes returning to play from MSK injuries in Week 9 were matched within one week of return to play to SRC athletes returning to play in Week 8. ^dWeeks missed due to original injury, either MSK or SRC.

Abbreviations: SRC, sports-related concussion; MSK, musculoskeletal injury; RTP, return to play.

the post-concussion RTP progression on clinical data and the physical examination, but a growing body of work suggests on-going, sub-clinical alterations that may extend beyond the clinical recovery time point.²¹ For example, Sosnoff et al (2011) concluded those with SRC history demonstrated altered postural dynamics compared to those controls, suggesting cerebral functionality directly associated with postural control may persist well beyond the acute timeline post-SRC.²² Furthermore, resting motor threshold, and intracortical inhibition and facilitation continue to be impaired long after clinical recovery from SRC.¹³ Findings included a positive, linear association between subsequent concussions and cortical silent periods, further indicating

SRC may lead to greater motor cortex dysfunction, which ultimately may result in increased risk of MSK injury.²³

The current study provides additional evidence for the association between concussion and MSK injuries by examining the period acutely following SRC for causality with subsequent MSK injuries. However, a major limitation of this study is the complex nature of injury reporting in the NFL which was used for this analysis. Undiagnosed injuries or those lasting less than a week may not be present on injury reports. Further, injuries occurring during the preseason or bye weeks were also not reported if the athlete recovered before the next regular season game. Injuries that

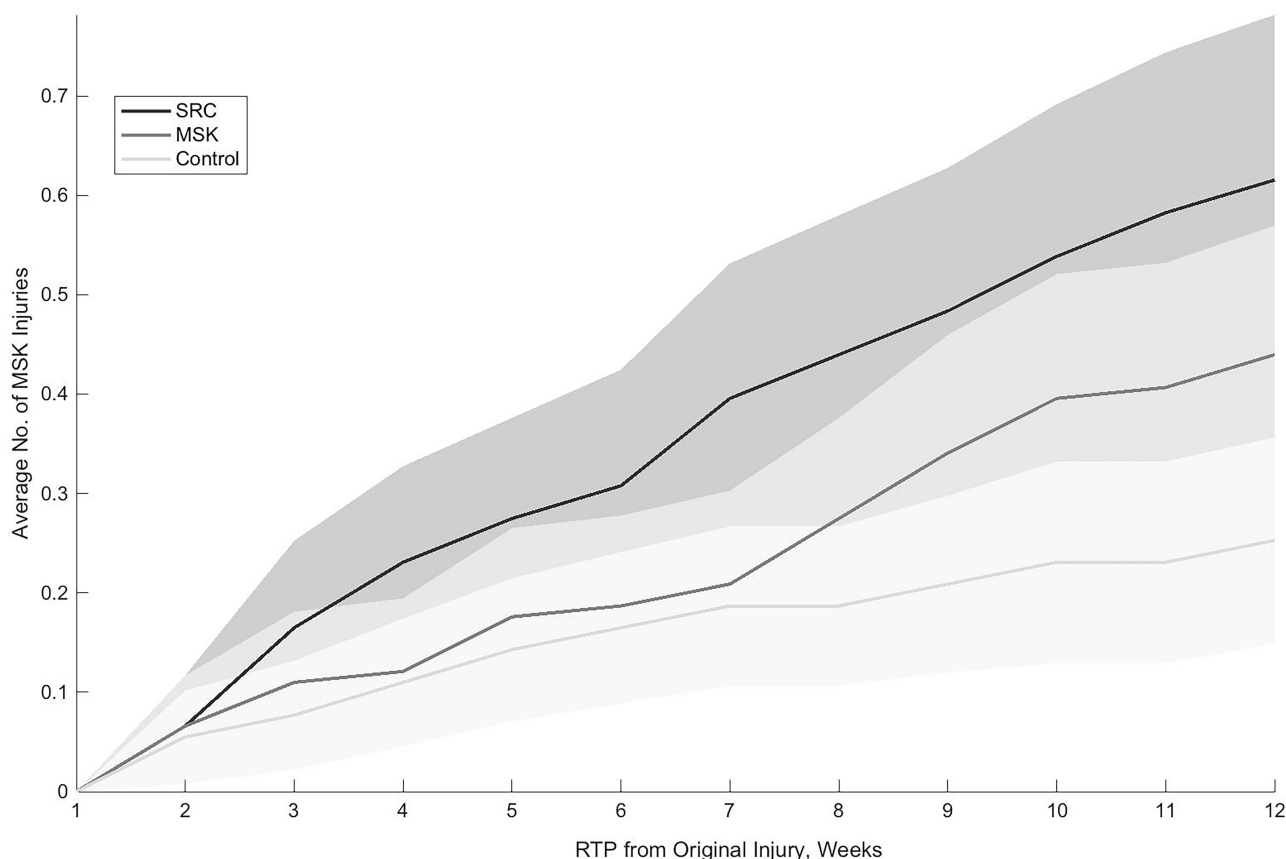


Figure 2 Average cumulative MSK injury occurrence for 12 weeks following RTP from original injury of SRC, MSK, or healthy controls. **Notes:** SRC athletes 2.35 times more likely to sustain an MSK compared to controls. MSK athletes were 1.87 times more likely. **Abbreviations:** MSK, musculoskeletal; RTP, return to play; SRC, sports-related concussion; No, number.

are reported lack detail, and comprehensive severity metrics outside of weeks missed. In addition, previous injuries were not considered which may influence the risk of MSK injuries. Additionally, it was assumed that injury deficits, whether they be due directly from injury or from sedentary behaviors following an MSK injury (such as a post-surgical athlete), may influence the risk of future injury. Due to this assumption, each

successive SRC or MSK injury that followed an initial injury was considered to be conditional relative to the 12-week recovery period. Furthermore, each athlete was assumed to have equal playing time and therefore equal injury risk exposure, as some athletes are engaged in longer playing time than others which may ultimately increase their exposure to injury risk. Lastly, NFL bye-weeks were not taken into

Table 3 Reinjury Occurrences

	Player (Co)	Injuries (Co)	Average Injuries per Player Mean (SD)	Fisher's Exact Test ^a OR(95% CI)
SRC	39	59	0.65 (0.87)	2.35 (1.25, 4.44)*
MSK	34	43	0.47 (0.67)	0.08 (0.44, 1.44)
Control	22	25	0.27 (0.52)	–
Total	95	127	0.47 (0.72)	–

Notes: ^aFisher's Exact Test was calculated for SRC and MSK groups, respectively, against controls on the existence of any MSK injury in the 12 weeks following RTP from their original injury. *p < 0.05.

Abbreviations: Co, count; SD, standard deviation; OR, odds ratio; CI, confidence interval; SRC, sports-related concussion; MSK, musculoskeletal injury.

consideration for weeks missed calculations, which may have resulted in athletes with longer recovery timelines than what was reported on the original injury report. However, since athletes were matched on the same team, this should have minimal impact on the results.

Conclusion

Previous research has examined the impact of SRC on risk of re-injury in collegiate athletics,^{6–8} yet few have examined the potential for this risk in NFL athletes.¹¹ Our findings suggest NFL athletes are more likely to sustain a MSK injury within the 12-week period following RTP from an SRC, relative to a non-injured control. These findings were present despite the implementation of a league wide concussion protocol beginning in 2013. As previously suggested,¹¹ future work should evaluate this issue prospectively and, if replicated, develop interventions to mitigate risk. Additional research should also seek to define physiological recovery following SRCs and further develop objective guidelines for each stage of the RTP progression.

Disclosure

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