

Performance After Concussion in National Hockey League Players

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Context: Concussions in ice hockey players are an interesting area of study due to the fast-paced and high-impact nature of the sport. Recently, researchers have focused on player performance after return from concussion to evaluate subclinical deficits that were previously missed.

Objective: To examine National Hockey League (NHL) player performance from 2013 to 2019 and compare performance before a concussion with performance immediately after recovering to assess the current NHL return-to-play protocol.

Design: Cross-sectional study.

Setting: The NHL Injury Viz and sports reporting websites.

Patients or Other Participants: Players in the NHL who sustained concussions from 2013 to 2019.

Main Outcome Measure(s): Goals, assists, points, plus-minus, time on ice (TOI), and hits.

Results: When goals, assists, points, plus-minus, TOI, and hits were examined, only TOI was different after the players returned from injury, and this TOI difference was not substantively important.

Conclusions: After concussion, NHL player performance did not change.

Key Words: mild traumatic brain injury, recovery, return to play

Key Points

- As measured by goals, assists, points, plus-minus, and hits, National Hockey League (NHL) player performance was not affected after recovery from concussion.
- These results corroborate previous studies of the NHL as well as similar studies in other major professional sports.
- Although not conclusive, these findings indicate that the NHL return-to-play protocol is likely doing an adequate job of safely returning athletes to play.

Sport-related concussions (SRCs) have gained national attention due to both their prevalence and increased concerns about long-term outcomes among professional athletes in high-impact sports such as ice hockey. Researchers^{1,2} reported estimates in the National Hockey League (NHL) that suggested SRCs occurred at rates of 5.8 to 6.1 per 100 games (1.8 concussions per 1000 player-hours), and forwards experienced more concussions than defensemen and goalies. Recent rule changes, including limiting hits to the head, were intended to decrease SRC rates. However, these rates in the NHL have continued to rise, which may be explained in part by heightened awareness and increased reporting.

Typically, concussed athletes recover and return to play within 2 weeks using current SRC protocols. Investigators^{3,4} have studied laboratory biomarkers, neuroimaging, and electrophysiological variables to identify deficits that may exist after apparent clinical recovery. However, possible ongoing neurologic deficits may not have been previously identified in clinical settings.^{4,5} High-performance athletes are an appropriate population for characterizing subtle deficits that may affect high-level competitive performance. The evaluation of athletic performance immediately after return to play is an important research area.

However, the performance of NHL athletes after SRC and on return to play has seldom been assessed. From 2008 to 2015, NHL players who returned from SRC showed no differences in performance or style of play, as measured via standard statistics (eg, goals and assists), compared with uninjured players.⁶ Recently, researchers⁷ who used advanced analytical statistics that detect more subtle performance changes found no change in player performance after returning from SRC.

Before the 2016–2017 season, the NHL implemented new SRC protocols that included spotters to better identify athletes who sustained possible concussions during games. An athlete with a possible SRC is removed from play and allowed to return to competition only if “(1) there is complete recovery of concussion-related symptoms at rest; (2) there is no emergence of concussion-related symptoms at exertion levels required for competitive play; and (3) the player has been judged by the Club’s Physician to have returned to his neurocognitive baseline after an evaluation by the Club consulting neuropsychologist.”^{8(p7)} This standardized protocol and increased concern for head injuries resulting from aggressive hits have focused additional attention on SRCs in the NHL. The protocols were intended to ensure that players do not return until they have safely and fully recovered to their baseline level.

Table. National Hockey League Player Performance: Baseline and Postconcussion^a

Outcome	Mean \pm SD		P Value
	Baseline	Postinjury	
Goals	0.87 \pm 1.09	0.84 \pm 1.11	.759
Assists	1.23 \pm 1.28	1.29 \pm 1.32	.66
Points	2.10 \pm 1.85	2.13 \pm 1.83	.859
Plus-minus	-0.06 \pm 2.25	-0.17 \pm 2.58	.672
Time on ice (min:s)	16:36 \pm 3.36	16.12 \pm 3.42	.013
Hits	6.38 \pm 4.74	6.48 \pm 4.84	.812

^a All metrics are reported as averages over 5 games.

The goal of our study was to compare NHL athletes' performance after returning from SRC with their baseline performance by evaluating a more recent sample than in earlier work and one that reflects implementation of the new NHL concussion protocol. We hypothesized that player performance would be unaffected on return to play because of the NHL's improved SRC protocol.

METHODS

Participants

The participants were NHL players who incurred publicly documented SRCs between the 2013–2014 and 2018–2019 seasons. To obtain injury data on NHL players with publicly documented concussions during the 2013–2014 through 2018–2019 seasons, we consulted NHL Injury Viz and confirmed the information on sports reporting websites, including TSN.ca, ESPN, and FoxSports.com.⁹ Statistics were recorded for the 5 games before an injury and 5 games after returning from the injury, not including the game in which the player sustained the SRC.

Data were analyzed only for athletes who played in 5 consecutive games before and immediately after their return from SRC. We chose the 5-game window for consistency with prior research and because it allowed for a large enough sample size to account for differences in opponents and other game-by-game variabilities that may affect player performance. Any lingering performance deficits after the return from injury would most likely have been captured immediately on returning to play, justifying the analysis of 5 games after return rather than expanding the sample. Athletes who never returned to play after their SRCs were excluded and considered retired. Among players who sustained multiple SRCs in the same season, only the first injury was assessed. Those who experienced concomitant injuries in the same game were excluded, as these injuries may have affected their performance. Athletes who were injured in the preseason or postseason were excluded, as were those who were injured in the regular season and did not return until the postseason. Goalies were excluded, as the performance metrics we used do not apply to them (Table). The Institutional Review Board at Georgetown University determined that the research did not involve human subjects as defined by the Department of Health and Human Services and Food and Drug Administration regulations and, thus, review and approval were not necessary.

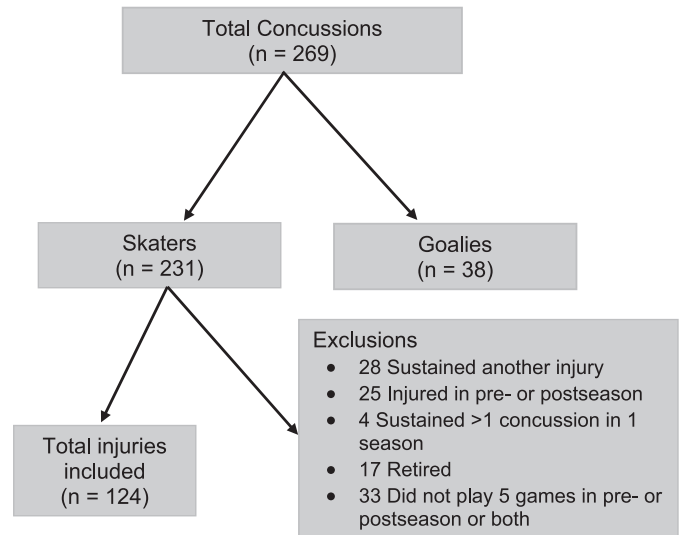


Figure. Flow chart of participants.

Performance Metrics

The primary performance outcomes were goals, assists, points, plus-minus, time on ice (TOI), and hits. No distinction was made between primary and secondary assists. All performance metrics were compiled from the website Hockey Reference.¹⁰ We conducted a secondary analysis comparing performance metrics before and after the NHL implemented the change in return-to-play guidelines before the 2016–2017 season.

Statistical Analysis

Player performance during the 5 games after returning from SRC was compared with performance in the 5 preinjury games via a paired *t* test. Using a regression model, we also analyzed all performance metrics against the number of games missed to determine if the time lost affected any measure of player performance after the return from SRC. To assess performance differences from before to after the rule changes, we regressed each of the individual metrics (eg, goals, assists, points, plus-minus, and hits) on an indicator variable for rule change and assessed the interaction with a measurement of TOI, controlled for the length of injury (games missed). All statistical analysis was performed using STATA (version 16.1; StataCorp).

RESULTS

A total of 269 SRCs were identified between the 2013–2014 and 2018–2019 seasons, and of those, 124 met the inclusion criteria for this study. (Exclusion criteria are described in the Figure.) The mean number of games missed was 7.04 (95% CI = 6.6, 7.5), which in an NHL season accounts for 2 to 3 weeks. A linear regression model comparing all performance metrics against the length of injury, measured in games, showed no relationship between the number of games missed and any of the performance metrics. When we compared performance metrics before and after the NHL change in return-to-play guidelines, the rule change was not significantly correlated with any of the metrics.

Only TOI demonstrated a difference between the preinjury games and the players' first 5 postinjury games. On average, athletes returning from injury played 23.37 fewer seconds during the 5 postinjury games than in the 5 preinjury games ($16:36 \pm 3.36$ versus 16.12 ± 3.42 , respectively; 95% CI = 4.96, 41.78; $P = .013$; Table). No other performance metrics were different when we compared preinjury with postinjury play.

DISCUSSION

Performance changes after concussive injury in elite athletes may indicate the value of current return-to-play protocols. The only difference in player performance between preconcussion and postconcussion performance we identified was a trivial decrease in playing time. A 1-second decrease in TOI over the course of five 60-minute NHL games amounts to less than 1 extra shift. Thus, this small difference was neither clinically significant nor a reflection of a major difference in performance. The other results showed no statistical or substantive difference in performance, suggesting that a single SRC in an NHL season may not affect return-to-play performance. Our results support those of previous researchers who also found no changes in performance after concussion in the NHL, National Football League, National Basketball Association, Major League Baseball (MLB), and Australian rules football, as discussed in the following paragraphs.

Multiple authors have examined postconcussive performance in the NHL. Kuhn et al⁶ studied players from 2008 to 2015 and found no differences in athletes returning after SRC compared with healthy controls. Their primary outcomes and performance indicators were similar to ours. Buckley et al⁷ investigated the same cohort of injuries but used advanced hockey metrics in an attempt to detect more subtle metrics of player decline after injury; they included an expanded postinjury time frame (5 games, 10 games, and the remainder of the season) to detect more long-term effects of SRC. However, they also noted no deficits at any of the 3 time points after the return from injury. Buckley et al⁷ explored a control group of players who missed time for noninjury reasons and determined that their postconcussion performance was similar to that of the control participants. Our results support the evidence from previous researchers that players did not experience performance deficits when returning to the NHL after an SRC.

In 2 earlier studies, investigators found evidence that NHL player performance was worse after returning from SRC. First, Navarro et al¹¹ studied injuries from 2008 through 2017 and compared players with SRC and those who missed games for other reasons, including nonhead injuries. The primary outcomes were player performance and salary and contract changes. After even a single SRC, NHL players displayed reductions in career length, career earnings, and performance. On average, athletes recorded 2.5 fewer points per year if they had sustained an SRC in the prior season. Limitations of this work included a control group that did not distinguish those who missed games for injury purposes from those who missed time for noninjury purposes. The authors also compared performance metrics for an entire season of play, which would be susceptible to far more confounding variables than the 5-game stretch we measured. It is important to note that over an 82-game

season, a 2.5-point difference likely has minimal significance. Van Pelt et al¹² compared player performance data from the 2013 through 2015 seasons in players who experienced SRCs versus those with lower body orthopaedic injuries. They found similar decreases in performance for those with SRCs and lower body injuries in the first 1 to 2 weeks after return to play that improved to baseline by 5 to 6 weeks. This initial decline in performance contradicted our results, but their study was limited by a small sample size ($n = 22$ SRCs) and by the use of only 1 performance metric (a modified plus-minus statistic). In addition, no metrics were obtained from after the time when the NHL implemented new return-to-play protocols.

Related research has been conducted among high-level athletes in other sports. Neither Kumar et al¹³ nor Reams et al¹⁴ observed a difference in NFL player performance after returning from SRC. Investigators¹⁵ evaluating Australian rules football players demonstrated no decline in performance in their cohort with 138 injuries over 4 seasons. In a comparison¹⁶ of a decade's worth of concussions in the National Basketball Association versus a healthy matched control group, no performance deficit was evident in athletes who missed time for noninjury reasons or when measured against their own healthy baselines. All of these findings in high-performance athletes supported our results that indicated our current clinical evaluations for recovery from SRCs were adequate to safely guide players' return to sport.

In a similar study of baseball players from 2007 to 2013, Wasserman et al¹⁷ identified decreases in batting average, on-base percentage, slugging percentage, and on-base plus slugging in athletes with SRC versus healthy control individuals. Chow et al¹⁸ assessed MLB batting performance after an SRC versus nonconcussion postinjury performance and showed that after returning from injury, performance decreased. However, performance after SRC did not differ from that after other types of injuries.¹⁸ Batting average, on-base percentage, and pitching metrics after returning from SRC did not differ among 112 MLB players who were put on the disabled list from 2005 to 2016.¹⁹ These conflicting findings indicate that more research is needed to evaluate baseball player performance after SRC. The skills required to hit a baseball may be more vulnerable to subtle neurocognitive deficits after concussion, which may be why deficits have been observed in these players. Alternatively, the MLB return-to-play policy may be less rigorous than that of other sports. For instance, players hit by a pitch are not automatically removed from play for a concussion evaluation.

A secondary analysis examining whether performance after SRC was affected by the NHL's stricter return-to-play guidelines in 2016–2017 revealed no differences. Therefore, the NHL's change in guidelines did not affect player performance in the short term. Because the groups did not differ, the return-to-play protocol in the NHL appeared to be adequate for addressing an athlete's readiness to resume play. Our results did not address any potential long-term effects of SRC and return to play.

Despite the NHL's overall satisfactory protocol for returning players with SRC to sport, we may have missed subtler deficits that were difficult to measure. Also, we did not include a healthy, matched control group but rather compared players with their own baselines. This may have

limited our findings if players had been playing below their baselines before injury, which could have made them more susceptible to injury in the first place. Additionally, these results may not be generalizable to players who incurred multiple SRCs in the same season. A potential confounding variable was the changing definition of *concussion* and increased reporting of SRC in the NHL over the course of this study. As our examination was limited to short-term performance immediately after recovery, we would not have captured any long-term deficits that may have arisen over the course of a season or multiple seasons.

CONCLUSIONS

We evaluated NHL player performance after SRC during regular-season play over 6 seasons. The only difference between preinjury and postinjury play was a minor decrease in the amount of time a player participated, which in the context of a hockey game is not significant. Based on these results and the findings of similar studies, we concluded that NHL players did not appear to display performance deficits on returning after the current SRC return-to-play protocol. If athletes are informed that they are likely to return to their baseline performance level by following the current protocol, the pressure to return to play sooner may be less. Ultimately, more research should be conducted to ensure that players returning to play after SRC have no subclinical deficits or long-term effects.

REFERENCES

- Hutchinson MG, Comper P, Meeuwisse WH, Echemendia RJ. A systematic video analysis of National Hockey League (NHL) concussions, part 1: who, when, where and what? *Br J Sports Med*. 2015;49(8):547–551. doi:10.1136/bjsports-2013-092234
- Benson BW, Meeuwisse WH, Rizos J, Kang J, Burke CJ. A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. *CMAJ*. 2011;183(8):905–911. doi:10.1503/cmaj.092190
- McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA*. 2003;290(19):2556–2563. doi:10.1001/jama.290.19.2556
- Kamins J, Bigler E, Covassin T, et al. What is the physiological time to recovery after concussion? A systematic review. *Br J Sports Med*. 2017;51(12):935–940. doi:10.1136/bjsports-2016-097464
- Teel EF, Ray WJ, Geronimo AM, Slobounov SM. Residual alterations of brain electrical activity in clinically asymptomatic concussed individuals: an EEG study. *Clin Neurophysiol*. 2014;125(4):703–707. doi:10.1016/j.clinph.2013.08.027
- 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. doi:10.1177/0363546516638327
- Buckley TA, Bryk KN, Van Pelt KL, et al. Concussion and National Hockey League player performance: an advanced hockey metrics analysis. *J Athl Train*. 2019;54(5):527–533. doi:10.4085/1062-6050-200-18
- Concussion evaluation and management protocol: 2016/2017 season. National Hockey League Web site. <https://nhl.bamcontent.com/images/assets/binary/282574512/binary-file/file.pdf>. Published October 5, 2016. Accessed October 8, 2020.
- NHL Injury Viz Web site. <https://nhlinjuryviz.blogspot.com/p/index-page.html>. Accessed October 8, 2020.
- Hockey Reference Web site. <https://www.hockey-reference.com>. Accessed October 8, 2020.
- Navarro SM, Pettit RW, Haeberle HS, et al. Short-term impact of concussion in the NHL: an analysis of player longevity, performance, and financial loss. *J Neurotrauma*. 2018;35(20):2391–2399. doi:10.1089/neu.2017.5611
- Van Pelt KL, Lapointe AP, Galdys MC, Dougherty LA, Buckley TA, Broglio SP. Evaluating performance of National Hockey League players after a concussion versus lower body injury. *J Athl Train*. 2019;54(5):534–540. doi:10.4085/1062-6050-218-18
- 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. doi:10.1177/0363546514539449
- 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. doi:10.1123/ijsp.2016-0508
- Makdissi M, McCrory P, Ugoni A, Darby D, Brukner P. A prospective study of postconcussive outcomes after return to play in Australian football. *Am J Sports Med*. 2009;37(5):877–883. doi:10.1177/0363546508328118
- 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. doi:10.1080/00913847.2016.1200956
- 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. doi:10.1177/0363546515576130
- Chow BH, Stevenson AM, Burke JF, Adelman EE. The effect of concussion on batting performance of Major League Baseball players. *Open Access J Sports Med*. 2019;10:41–48. doi:10.2147/OAJSM.S192338
- Sabesan VJ, Prey B, Smith R, Lombardo DJ, Borroto WJ, Whaley JD. Concussion rates and effects on player performance in Major League Baseball players. *Open Access J Sports Med*. 2018;9:253–260. doi:10.2147/OAJSM.S157433

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