Concussions in the National Hockey League

Analysis of Incidence, Return to Play, and Performance

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

Purpose: To quantify the effect of concussions on the performance of position players in the National Hockey League (NHL).

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

Methods: Concussion data from the NHL were collected using publicly available databases for the seasons between 2009-2010 and 2015-2016, coinciding with new NHL concussion rules. Age, body mass index, position, number of concussions during a player's NHL career, games played, and time on ice were recorded. Basic and advanced performance metrics were collected for 1 season pre- and postconcussion (short-term period) and 3 seasons before and after concussion (long-term period) to assess short- and long-term changes in performance. A control group of players without an identified concussion who competed during the study period was assembled for comparison. Wilcoxon signed rank tests were used to evaluate pre- to postconcussion data in the short- and long-term settings as well as to compare the cohorts at each time point.

Results: Overall, 48 players were identified as having a concussion during the study period. Players missed 17.2 ± 15.1 days (mean ± standard deviation) and 7.5 ± 6.9 games postconcussion. There were no significant differences in any metric when pre- and postconcussion intraseason performance was assessed. Athletes who were concussed demonstrated significantly deceased performance metrics (assists per 60 minutes, points per 60 minutes, Corsi percentage, and Fenwick percentage) in the 3 years after the concussion as compared with the year before injury ($P < .05$). However, no difference was found between the concussed group and matched control group in the short- or long-term period. Players with concussion played fewer career games (856.4 ± 287.4 vs 725.7 ± 215.0; $P < .05$) than did controls.

Conclusion: A high rate of NHL players were able to return to play after a concussion injury. Players with concussion did not experience a reduction in performance metrics in the short- or long-term setting when compared with matched controls. The concussed cohort maintained a similar workload up to 3 seasons postconcussion but played in fewer career games when compared with matched controls.

Keywords: concussion; NHL; hockey; performance; injury

Ice hockey is a fast-paced contact sport with >50% of National Hockey League (NHL) players reporting games missed attributed to a significant injury.[6] Concussions account for 14% to 30% of hockey-related head injuries, and concussions within the NHL are common, with rates of 5.8 to 6.1 concussions per 100 games.[1,2,9,12,13,24,25,28,29] Over the past 2 decades, more attention has been given to the correlation between concussions or mild traumatic brain injury and negative long-term neurological sequela. In athletes, concussions increase the risk of depression, suicide, lower extremity injury, and time away from the game.[4,19,23] The increased understanding of the consequences of sports-related mild traumatic brain injury has garnered interest among the public.[16,20]

In conjunction with the NHL Players Association, the NHL began to collect data on the incidence of concussions in 1997.[1] Before the 2010-2011 season, the NHL established a new rule in an attempt to eliminate blindside hits to the head; this rule was updated the following season to penalize all targeted hits to the head in an effort to reduce the number of concussions. Furthermore, in January 2010, the NHL concussion protocol (NHLCP) was implemented as a standardized set of rules to guide the management of concussions. Given the concern that players were not being removed from play after head injuries, the NHLCP was updated for the 2015-2016 season to include professionally trained spotters who could objectively identify players displaying visible signs of concussions and remove them from

The Orthopaedic Journal of Sports Medicine, 10(1), 23259671211052069
DOI: 10.1177/23259671211052069

play. Under the current protocol, any player suspected by a spotter of having a concussion is immediately removed from play and evaluated in a distraction-free room. Players diagnosed with a concussion are managed with rest, followed by graded progression of activity. Complete resolution of symptoms and clearance by the team physician are required before return to play (RTP). Prior studies[17,21,22] have shown that the recorded incidence of concussions increases after the implementation of concussion protocols in professional sports leagues. Donaldson et al[5] showed that the incidence of concussions in the NHL increased between the 2010-2011 and 2011-2012 seasons. Since that time, however, there has been a paucity of data on NHL concussion incidence in the literature.[14] Furthermore, there are limited data regarding RTP time after concussions in the NHL, and few studies[10,27] have addressed RTP time since the NHLCP was implemented.

The purpose of this study was to investigate the RTP time after concussions and to assess the effect of concussions on non-goalie NHL player performance during the season of injury and over the 3 seasons after the concussion. Non-goalie NHL players were targeted given their high rate of concussions and the availability of advanced performance metrics. While other studies have shown conflicting results regarding performance outcomes, we hypothesized that the use of advanced performance metrics over short- and long-term periods would reveal postconcussive performance deficits.

METHODS

This study did not require institutional review board approval given that all data were collected via publicly available records, no private patient information was accessed, and no medical records were included. From publicly available injury reports, player profiles, and gaming summaries and using methods validated by previous studies,[7,8,11,15] we identified 297 confirmed concussions sustained by professional athletes in the NHL between the 2009-2010 and 2015-2016 seasons. In addition to confirmed concussions, 206 players who had sustained a documented "head injury" or "neck injury" were identified. These injuries were then cross-referenced with player profiles and public press reports to confirm the occurrence and timing of the concussions, resulting in 67 players being identified for inclusion.

Only players who experienced a first-time documented concussion during the regular season (index season) were included in the study. Players with a previous concussion during an NHL career were not included to limit the confounding effect of repeat concussions. To generate a matched control cohort, we did not include players in the final analysis if they returned to play during the playoffs or in a subsequent season. Players who were not active in the NHL 3 seasons before and after the index season, players with repeat concussions during the period of study, players with concussions that occurred with other injuries, and goalies were not included in analysis (Figure 1). We identified 48 players who met the inclusion criteria. Of these 48 players with concussion events, 8 had documented "head injuries," later confirmed to be concussions; 3 had documented "upper body injuries," later confirmed to be concussions; and the other 37 had been identified as being concussed in their injury reports.

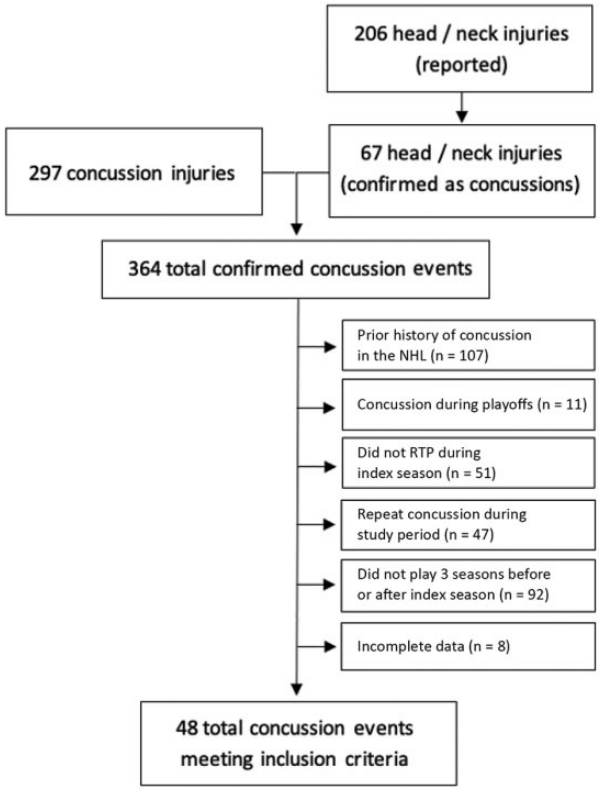

Figure 1. Flow diagram of players with concussion events meeting inclusion criteria. NHL, National Hockey League; RTP, return to play.

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Final revision submitted May 23, 2021; accepted July 14, 2021.
One or more of the authors has declared the following potential conflict of interest or source of funding: T.R.J. has received education payments from DePuy and Pinnacle and hospitality payments from Exactech and Zimmer Biomet. K.R.O. has received grant support from Arthrex; education payments from Arthrex, Medwest, Pinnacle, and Smith & Nephew; and hospitality payments from Stryker and Wright Medical. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval was not sought for the present study.

A 2:1 cohort of players without concussion who were active in the NHL during the period of study was established for the control group. This cohort was matched to the sample group by age, body mass index (BMI), NHL experience, and position. Players who missed games attributed to a nonconcussion injury during the index season as well as those with a documented concussion before or during the study period were not included in the control group to remove the potential confounding effects of these injuries.

For each player who was concussed, the number of days and games missed before RTP were calculated. Descriptive and performance metrics were collected for the injured group and the control group. Descriptive information included age, BMI, position, and number of concussions during an NHL career. Career statistics, including games played (GP) and time on ice (TOI), were collected.

Player Performance

Performance metrics were collected during 2 periods: 1 season before and after the index season (short-term period) and 3 seasons before and after the index season (long-term period). Basic performance metrics were as follows: GP, TOI per GP, points per 60 minutes, shooting percentage, goals per 60 minutes, and assists per 60 minutes. Advanced performance metrics comprised Corsi percentage, Fenwick percentage, and PDO. All statistical data were collected from the NHL's official website and www.hockey-reference.com.

Corsi percentage is an assessment of the percentage of shot attempts taken by a player's team out of the total shot attempts while the player is on the ice. This statistic illustrates a team's offensive control as well as scoring opportunities. A Corsi percentage >50% indicates that the team produced more shot attempts than its opponent with the player on the ice, and a Corsi percentage >55% is considered elite. The Fenwick percentage is similar to Corsi except it includes only unblocked shot attempts. Fenwick may be viewed as a more refined statistic representing scoring opportunities, as blocked shots may not represent true scoring chances and may vary by an opponent's skill or defensive strategy. PDO represents the sum of the team's shooting percentage and its save percentage. Over an extended period, PDO is expected to regress to a mean of 100.

Statistical Analysis

All continuous data are presented as mean and standard deviation, and categorical data are presented as counts and percentages. Normality assumptions for each continuous variable within each group were examined using measures of skewness and kurtosis, Shapiro-Wilk tests, and QQ plots. Univariate comparisons between cases and controls were carried out via 1-way analysis of variance or Wilcoxon rank sum tests for continuous variables and chi-square test to compare positions between cases and controls. All data between pre- and postconcussion time points were continuous and were analyzed using nonparametric Wilcoxon signed rank tests because of nonnormal distributions. A generalized estimating equations approach was used to examine the effect of group and time on several performance measures. Statistical significance was set at $P < .05$. All analyses were performed using SAS 9.4 (SAS Institute Inc).

TABLE 1
Concussed vs Control Group Characteristics and Index Season Performance[a]

	Control (n = 96)	Concussed (n = 48)	*P*
Age, y	27.53 ± 3.75	26.27 ± 3.64	.055
Body mass index	26.83 ± 1.46	26.53 ± 1.36	.232
Career GP	856.37 ± 287.44	725.65 ± 215.01	**.006**
Career TOI, min	14,888.85 ± 6062.64	12,973.25 ± 5013.04	.059
Player position			.914
Center	35 (34.31)	14 (29.17)	
Left winger	15 (14.71)	7 (14.58)	
Right winger	21 (20.59)	10 (20.83)	
Defenseman	31 (30.39)	17 (35.42)	
TOI/GP	18.31 ± 3.65	17.86 ± 3.51	.479
Goals/60 min	0.62 ± 0.4	0.67 ± 0.64	.578
Assists/60 min	1.03 ± 0.44	0.98 ± 0.63	.582
Points/60 min	1.65 ± 0.72	1.65 ± 0.94	.996
Shooting %	9.07 ± 4.56	8.46 ± 5.55	.474
Corsi %	50.92 ± 3.99	51.09 ± 3.64	.804
Fenwick %	50.64 ± 3.8	51.65 ± 4.21	.145
PDO	100.1 ± 1.92	99.99 ± 4.05	.819

[a]Data are reported as mean ± SD or n (%). Bold *P* value indicates statistically significant difference between groups ($P < .05$). GP, games played; TOI, time on ice.

RESULTS

Characteristics and Return to Sport

A total of 364 players with a concussion were identified between the 2009-2010 and 2015-2016 seasons. Of these, 48 players met inclusion criteria and were included for analysis. A matched control population of 96 players who played during the seasons between 2009-2010 and 2015-2016 was constructed for comparison. There were no statistically significant differences in age, BMI, career TOI, or player position between the groups (Table 1). Among those who sustained a concussion, the mean time for RTP was 17.2 ± 15.1 days, and the mean number of games missed was 7.5 ± 6.9.

Player Performance

Index Year: Pre- Versus Postconcussion. Regarding player performance before and after a concussion during the season of injury, there was no statistically significant difference in goals, assists, or points per 60 minutes; shooting, Corsi, or Fenwick percentage; or PDO (Table 2).

Index Year: Cohort Versus Control. In terms of player performance during the index year, there was no

statistically significant difference in any metric between the cohorts (Table 1).

3 Seasons Pre- Versus Postconcussion. When the 3-season preconcussion performance (index season –3) versus the 3-season postconcussion performance (index season +3) was evaluated, players had significantly fewer assists per 60 minutes (0.98 ± 0.4 vs 0.93 ± 0.43; $P < .05$) and points per 60 minutes (1.65 ± 0.94 vs 1.56 ± 0.74; $P < .05$) in the 3 seasons postconcussion (Table 3). For the advanced performance metrics, players who experienced concussions showed a decreased Corsi percentage (51.16% ± 3.21% vs 49.39% ± 2.75%; $P < .05$) and Fenwick percentage (51.23% ± 3.34% vs 49.42% ± 2.5%; $P < .05$) in the 3 seasons postconcussion. Regarding player performance for the 3 seasons postconcussion, there was no statistically significant difference in any metric when compared with matched controls.

Player Workload

Index Year: Pre- Versus Postconcussion. When the workload of players before and after a concussion during the season of injury was examined, there was no statistically significant difference in the GP (30.98 ± 17.92 vs 31.75 ± 19.19; $P = .904$) or TOI per game (17.86 ± 3.51 vs 17.79 ± 3.92; $P = .903$) between cohorts (Table 2).

3 Seasons Pre- Versus Postconcussion. Upon evaluation of long-term changes in workload, players who were concussed had no significant change in GP (178.27 ± 50.41 vs 187.52 ± 43.58; $P = .128$) or TOI per game (17.64 ± 3.77 vs 17.96 ± 3.57; $P = .424$) 3 seasons after RTP when compared with their cumulative 3 seasons before a concussion. Additionally, no significant difference was seen in GP or TOI per game 3 seasons postindex when the concussed group was compared with the matched control group (Table 3).

TABLE 2
Concussion Group Index Season Performance Pre- and Postconcussion[a]

	Preconcussion (n = 48)	Postconcussion (n = 48)	*P*
GP	30.98 ± 17.92	31.75 ± 19.19	.904
TOI/GP	17.86 ± 3.51	17.79 ± 3.92	.903
Goals/60 min	0.67 ± 0.64	0.68 ± 0.54	.388
Assists/60 min	0.98 ± 0.63	1.26 ± 1.83	.438
Points/60 min	1.65 ± 0.94	1.94 ± 1.85	.578
Shooting %	8.46 ± 5.55	9.3 ± 6.39	.391
Corsi %	51.09 ± 3.64	51.4 ± 5.96	.521
Fenwick %	51.65 ± 4.21	51.94 ± 8.03	.305
PDO	99.99 ± 4.05	100.31 ± 3.39	.949

[a]Data are reported as mean ± SD. GP, games played; TOI, time on ice.

DISCUSSION

The present study found that non-goalie NHL players are able to quickly RTP after a concussion injury at a comparable level to their preconcussion performance. The mean time to RTP was 17 days with no statistically significant difference in any performance metrics immediately after RTP ($P > .05$). When compared with matched controls, players who had concussions were able to perform at a similar level in the short- and long-term settings ($P > .05$); however, those with concussions saw a reduction in the number of GP throughout the remainder of their careers (856.37 ± 287.44 vs 725.65 ± 215.01; $P < .01$). This study's findings suggest that after a concussion, professional athletes are able to RTP with similar performance, although career longevity may be affected.

In the present study, NHL players between the 2009-2010 and 2015-2016 seasons missed approximately 17 days and 7.5 games after a concussion. In an epidemiological study of Ontario Hockey League and NHL players conducted between the 2009-2010 and 2011-2012 seasons by Donaldson et al,[5] players returned to play after 8 games. Benson et al[1] investigated initial and subsequent concussions between the 1997-1998 and 2003-2004 seasons and reported a mean 6 days of time loss for first concussion, with a mean increase of 2.25 days of time off for every subsequent concussion. Our study showed agreement with

TABLE 3
Three-Season Performance Preindex Season (Concussion Group) vs Three-Season Performance Postindex Season (Concussion and Control Groups)[a]

	Concussion Group			Control Group	
	Preindex (n = 48)	Postindex (n = 48)	*P*	Postindex (n = 96)	*P*
GP	178.27 ± 50.41	187.52 ± 43.58	.128	196.54 ± 29	.135
TOI/GP	17.64 ± 3.77	17.96 ± 3.57	.424	17.92 ± 3.67	.954
Goals/60 min	0.66 ± 0.41	0.62 ± 0.38	.063	0.57 ± 0.35	.423
Assists/60 min	0.98 ± 0.4	0.93 ± 0.43	**.035**	1 ± 0.44	.371
Points/60 min	1.65 ± 0.94	1.56 ± 0.74	**.034**	1.57 ± 0.7	.882
Shooting %	8.71 ± 3.7	8.88 ± 4.12	.994	8.54 ± 3.7	.616
Corsi %	51.16 ± 3.21	49.39 ± 2.75	**<.001**	50.24 ± 3.37	.127
Fenwick %	51.23 ± 3.34	49.42 ± 2.5	**<.001**	50.17 ± 3.16	.153
PDO	100.05 ± 1.4	99.98 ± 1.34	.35	99.83 ± 1.46	.541

[a]Data are reported as mean ± SD. Bold *P* values indicate statistically significant difference between groups ($P < .05$). GP, games played; TOI, time on ice.

the more contemporary findings of Donaldson et al but almost 3 times the number of days lost when compared with the Benson et al study, which studied players before NHL rule changes. This disparity in finding is likely due to a greater awareness and acknowledgment of head injuries in the NHL, a more concerted effort to recognize and prevent head injuries, and a stringent stepwise RTP policy that was adopted with the NHLCP.

When compared with matched controls, players after a concussion demonstrated no statistically significant difference in short- and long-term performance. The maintained short-term performance revealed in our study corroborated the findings of Buckley et al,[3] who conducted a case series on the performance on 93 NHL players after concussion. The authors reported no difference in points per 60 minutes, Corsi percentage, Fenwick percentage, penalty difference, or PDO at 5 games, at 10 games, or for the remainder of the index season after concussion. They did not conduct follow-up beyond 1 season, however, and did not comment on long-term changes in performance. In a meta-analysis of 9 studies investigating concussion in the NHL, Kuhn and Solomon[14] found no short-term changes to player output in the first 5 games after RTP from concussion. While the long-term implications of concussions on the performance of NHL players have yet to be elucidated, Jildeh et al[11] performed a cohort study to evaluate the performance of 38 professional wide receivers and running backs after concussion against matched controls. They found no significant difference in the change of power rating per season of the concussed group in the long-term setting (±3 years from injury; –3.6 ± 8.0 vs –3.0 ± 4.5; $P = .219$). These findings suggest that professional athletes continue to perform at comparable levels to those of matched controls in the short- and long-term settings after RTP from a concussion. This is likely due to the fact that the short-term effect of concussions typically subsides within 5 to 10 days of injury.[26]

Players in the concussion cohort had a significantly fewer number of career GP when compared with matched controls. However, this present study cannot make any claims to causation or correlation of this finding as it relates to a player's history of concussions. This is a potential area of further study. Additionally, NHL players in the concussion cohort saw no reduction in GP and TOI at 1 and 3 years after RTP. This finding is at odds with the work of Navarro et al.[18] In a retrospective study of 399 concussion events in the NHL between 2008 and 2017, Navarro et al reported that players who experienced concussion had a statistically significant decrease in the probability of playing a full NHL season 1 year after RTP (65.0% vs 81.2%; $P < .05$). The present study showed that NHL players achieved similar performance after a concussion and that players demonstrated durability, as they had no decrease in TOI or GP at 1 or 3 years after injury.

Limitations

This study had several limitations. Player injury and statistical information were collected from the internet and were subject to potential inaccuracies. The data were cross-referenced across multiple sources (publicly available injury reports, player profiles, and game summaries) to ensure the highest-quality data possible. The methods to collect player data were used in several previous studies relying on publicly available injury data.[11,15] Furthermore, we analyzed player performance using advanced metrics in addition to their basic statistical output. These metrics are the best available to grade a player's output, but given the multifactorial nature of a player's importance to a team and his respective role within the offensive/defensive scheme, this could be an oversimplification of a more complex entity. However, prior studies[8,18] have validated the advanced metrics utilized in this research and shown their applicability to utility and production on the ice. We cannot be certain that this sample is generalizable to the entire NHL, as it does not include goalies in the analysis. Additionally, the strict inclusion criteria may have identified players with less severe concussions. Because players who did not RTP during the index season were excluded to analyze post-concussion performance, players with the most severe concussions and the longest RTP time may have been excluded. This study was unable to control for history of concussion. Players did not have a prior documented concussion while in the NHL since these data were made available, but given the frequency of concussions in the sport and the number of years that players would have competed to make it to the NHL, it is likely that they had prior concussions in their playing careers. Concussion data were poorly documented by the NHL, especially before the NHLCP implementation in 2010. Before that time, many concussions were simply reported as upper body injuries.

CONCLUSION

NHL players are able to rapidly RTP at a level consistent with preinjury performance after a concussion injury. When compared with matched controls, players who were concussed did not experience a reduction in performance metrics in the short- or long-term setting. Although players with concussion maintained similar workloads up to 3 seasons postconcussion, they played in fewer career games when compared with matched controls.

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