Concussion in Ice Hockey—A Cohort Study Across 29 Seasons

Mascha Pauelsen, MSc, Gusten Nyberg, MD,† Cecilia Tegner, BSc,‡ and Yelverton Tegner, MD, PhD, BA§*

Objective: The aim of this study was to analyze the concussion incidence rate ratios across 29 seasons in a Swedish Hockey League team.

Design: Cohort study over 29 seasons within one Swedish elite series ice hockey team.

Participants: All players who were part of one Swedish elite ice hockey team during the research period gave consent for participation in the study.

Independent Variables: Exposure to top-level Swedish ice hockey.

Main Outcome Measures: Incidence rate ratio for concussion and rehabilitation periods due to concussion were calculated and analyzed.

Results: During the research period, 267 players in total were part of the team. A total of 1638 traumatic injuries were registered, of which 162 were concussions. Incidence rates (IRs) ranged from 0/1000 games during the first season to 118/1000 games for the final recorded season. The incidence rate ratio was 1.06 (confidence interval, 1.03-1.10) for the entire research period. A shift toward longer rehabilitation periods was discovered.

Conclusions: This study showed a significant increase of concussion IR and a trend toward longer rehabilitation periods due to concussion. Possible risk factors were discussed. Risk behavior and rehabilitation protocols should be prioritized areas in the research of concussion in ice hockey.

Key Words: athletic injuries, brain concussion, incidence rate, ice hockey

(*Clin J Sport Med* 2016;0:1–5)

Ice hockey is a fast, physical, and intensive sport. It is played in an ice rink surrounded by hard boards, and body checks are considered an important part of the professional game. This together with the use of sticks and the high speed make players susceptible to injuries.[1,2] To reduce the injury incidence, players wear protective equipment, such as gloves, shoulder pads, and helmets. Despite this, the injury incidence is high, and concussions make up a large part of the injuries.[1]

Concussions in the Swedish Hockey League (SHL) have been studied previously. During the seasons 1986 to 1990, 4% of all recorded injuries in one observed team were concussions.[3] From 1988 to 1992, a study of all SHL teams found that 6% of all recorded injuries were concussions.[4] The concussion incidence rates (IRs) have also been reported, and during the period 1982 to 2001, it ranged from 12/1000 games to 53/1000 games in different SHL teams.[3,5,6]

In a Japanese elite team during 3 seasons, an overall IR during games of 74/1000 player-hours was found. The concussion IR for games was 1.6 [confidence interval (CI), 0.1-3.1] for that team.[7] During a period of 7 years in the National Collegiate Athletic Association, an IR during games of 19/1000 athlete exposures (AEs) was found, whereas the concussion IR was reported as 0.72/1000 AEs.[8]

Inconsistent methodologies make comparisons of concussion injuries between teams over time difficult[9] due to percentage of injuries are compared with IR, different ways of reporting IR and different lengths of research periods are used, criteria for the diagnoses vary, or the diagnosis are set by different and/or differently qualified medical personnel. It remains unclear if the large variation in results between studies is the result of an actual change or if it is a consequence of methodological discrepancies.

In the present study, following one single professional team over a long period with consistent diagnostic criteria allowed us to investigate possible incidence changes over time.

AIM

The aim of this study was to analyze the IRs of sports-related concussion in a Swedish elite ice hockey team over time (1984-2013).

METHODS

Participants

All players of one Swedish Hockey League (SHL) team, during the seasons 1984 to 1985 until 2012 to 2013, were included. When joining the team, written consent to participate in the study was obtained from all participants.

Submitted for publication September 29, 2015; accepted April 1, 2016.

From the *Division of Health and Rehabilitation, Department of Health Sciences, Luleå University of Technology, Luleå, Sweden; †Department of Radiology, Linköping University Hospital, Linköping, Sweden; ‡Swedish University of Agricultural Sciences, Uppsala, Sweden; and §Division of Medical Sciences, Department of Health Sciences, Luleå University of Technology, Luleå, Sweden.

The authors report no conflicts of interest.

Corresponding Author: Mascha Pauelsen, MSc, Division of Rehabilitation, Department of Health Sciences, Luleå University of Technology, 971 87 Luleå, Sweden (mascha.pauelsen@ltu.se).

Diagnosis and Rehabilitation

The same team physician (Y.T.) led the medical team during the entire period and was consequently responsible for all the diagnoses made. During the 1984/85 season, loss of consciousness (LOC) was required for the injury to be regarded as a concussion. Since the 1985/86 season, concussions were diagnosed according to guidelines of the Committee to Study Head Injury Nomenclature.[10] These guidelines included a range of symptoms, including but not limited to "bell ringer," fatigue, headache, short-lived neurological impairments, and cognitive symptoms. Later, these guidelines were adapted into the first consensus statement of the Concussion in Sports Group (CISG) in 2001.[11] The return to play (RTP) process after a concussion has undergone a change over time. Between 1985 and 2005, a player who was symptom free within 15 minutes could RTP the next day. If the player was symptom-free after >15 minutes or had had a short LOC (<30 seconds), the RTP was after 7 days without symptoms. If the player had a LOC >30 seconds, he was allowed to return after being symptom free for 21 days.[4] From 2005, the rehabilitation and RTP were conformed to the guidelines recommended by the CISG, which includes a gradual stepwise increase of activity.[12]

Injury Definition and Registration

The medical team recorded all injuries leading to absence or medical intervention. All injuries were prospectively recorded in a special medical form designed for statistical evaluation. For all injuries, data concerning activity (league game, exhibition game, play-off game, ice practice, other practice or preseason practice), situation, player's reaction, new/recurring injury, and diagnosis were recorded. For the first 15 seasons, data were primarily recorded on paper and later computerized. From 2000, all injuries were recorded directly in a computerized registration form: the "International Sport Injury System" (ISIS).[13] In this system, attendance records for all games and practice sessions were also registered. During one season (1993/94), the attendance registration for training was not recorded.

Data Validation

The database—both on paper and ISIS—was independently validated by all authors: all injury protocols were compared with the attendance records and all players' medical records from local hospitals were studied. For some games, the team line-up was missing in the records of the hockey club. For these games, the local newspapers' archives were searched for the line-up. For the one season lacking practice participation registration, data were reconstructed using the injury length noted in the medical records.

Statistical Analysis

Descriptive statistics were used not only to present concussion incidence but also to describe other factors that play part in understanding sports-related concussion, such as injury mechanics, time of injury, and player position. Incidence rates for the team were defined as the number of concussions per 1000 games, which has been set as a standard.[14] The negative binomial regression model was used in Statistical Data Analysis, STATA 10.1, to analyze the trend indicated by the descriptive statistics. The χ^2 statistics was used to test the hypothesis of difference in absence length between seasons. Alpha levels were set at 0.05.

ETHICAL CONSIDERATIONS

This study was approved by the ethical committee in Umeå (registration number: 09/135M).

RESULTS

A total of 267 players were on the team roster during the study period. The mean age of players during their first season on the team was 23 (±5) years. Of the 267 participating athletes, 90 players (34%) sustained a total of 162 concussions.

Over the 29 recorded seasons, 1785 games were played—36 games during the first season and 85 games during the last season. Included games were exhibition, SHL, and European Hockey League games. Of the 90 players with concussion, 53 (59%) had 1 concussion during their time with the team, whereas 33 players (37%) had 2 to 4 concussions. Four players sustained 5 or 6 concussions. Two players had to end their career due to multiple concussions. The majority of concussions (85%) were sustained during games and the rest during ice practice. With 137 concussions sustained during games, a concussion IR for the entire period of 77 concussions per 1000 games was found. The IR for the first recorded season was 0/1000 games and rose up to 118/1000 games during the last recorded season (incidence rate ratio, 1.06; 95% CI, 1.03-1.10) (Figure 1). The most common injury mechanism was checking. More concussions were sustained in the second period compared to the first and third periods, but these differences were not significant. Most concussions were the result of actions or situations deemed legal by the referees (no penalty called) (Table).

Concussion as a percentage of all injuries has changed from 0% during the first season to 17% during the last season (Figure 2), with a mean for the entire period of 10%. In Figure 3, mild, moderate, and severe concussions (RTP after 0-7 days, 8-27 days, and >27 days) are compared. It is shown that longer rehabilitation periods become more common over the years ($P = 0.015$).

DISCUSSION

The present study has shown an increase in concussion IR over a 29-season period, a shift in injury pattern toward relatively more concussions and an increased concussion severity.

Earlier studies have reported both higher and lower IR but have not been able to show an increase or decrease.[3,5,6,9] The present study shows that there is a yearly variability in IR, which shows the necessity of prospective studies over long periods. In studies comparing concussion IR between games and practice, it was found that the IR for games is much higher.[7,15–17] This is in accordance with the present study.

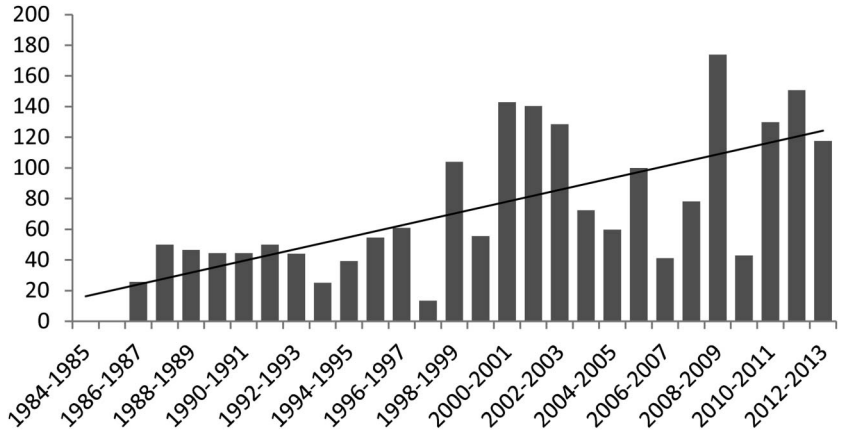

FIGURE 1. Incidence rates for concussion during games (and trendline). Number of concussions per 1000 games for each season.

The reasons for the rise in IR are probably multiple. Ice hockey has changed over the years, with the game becoming faster while players have become bigger and stronger.[18,19] Equipment, playing tactics, and rules have changed. In the 1998/99 season, the International Ice Hockey Federation (IIHF) removed the red-line offside rule. The rule dictated that when the puck was passed from the defensive zone, the receiving teammate could not pass the center (red) line in the middle of the neutral zone before the puck did. With that rule gone, players can now maintain a higher speed to receive a pass just before entering the offensive zone. This higher speed may have an effect on the injury incidence.

In 2002, the IIHF adopted a new rule on checking to the head to reduce the rising concussion incidence. The expected positive effect of this rule cannot be seen in our study. Compliance to the changes of this rule may be difficult due to the speed of the game and that players may be showing less respect for one another (Peter Andersson, head of Swedish referees, oral communication, 2015).

Not only the rules but also the protective gear has undergone changes. Shoulder and elbow pads are bigger than before and may increase the risk for a hit to the head when checking. The improvement of the protective gear in ice hockey might also lead to players feeling less vulnerable and therefore using more force in body checks. A false sense of protection may lead to players being less careful about how and where they land their initial contact. This can be explained as risk compensation, which has been described as situations where the athlete takes bigger risks due to trusting improved protective gear.[20] It was documented that in American football, the introduction of "better" helmets in 1959 caused a shift in the injury pattern in years to follow due to players trusting the new technology leading to an increased use of the head as the primary point of contact.[21]

All these factors might play a part in increasing the incidence and the severity of concussion in ice hockey. With the possible long-term problems of sports-related concussion,[22–30] this increasing trend is a very serious one that needs immediate attention.

During the 4 seasons of 1988/89 to 1991/92, a parallel study was conducted including the entire SHL. In that prospective study, it was found that 6% of all injuries were concussions.[4] We found the same percentage for our team for that period. During the last 4 seasons of our research period, however, we found that concussion constituted 14% of all injuries. This finding indicates a shift in injury pattern toward more concussions.

Of all players who had a concussion, 41% sustained more than one. As many of the players transferred to or from

TABLE. Number and Percentages for Injury Mechanism and Player Position (All Concussions, n = 162), and Period and Penalty (Game Concussions, n = 137)

	Number (%)
Injury mechanism (n = 162)	
Checking	106 (65)
Collision	20 (12)
Puck	16 (10)
Stick	9 (6)
Fall	3 (2)
Skate	1 (1)
Fight	1 (1)
Other/unclear	6 (4)
Player position (n = 162)	
Forward	76 (47)
Defense	55 (34)
Center	18 (11)
Goal keeper	13 (8)
Period in the game (n = 137)	
Period 1	36 (26)
Period 2	47 (34)
Period 3	40 (29)
Sudden death	2 (2)
Warming up	1 (1)
Unclear	11 (8)
Penalty for opposing player (n = 137)	
No penalty	82 (60)
2 min	17 (12)
5 min + game	8 (6)
2 + 10 min	1 (1)
5 min	1 (1)
Unclear	28 (20)

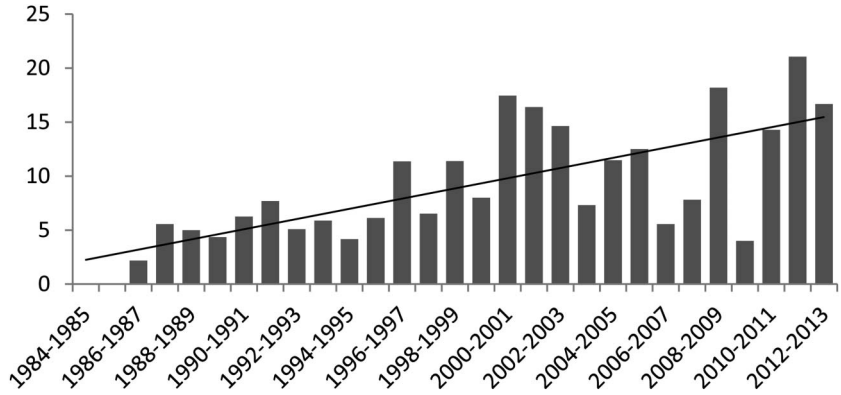

FIGURE 2. Concussion as a percentage of all injuries (and trendline).

other teams at some stage, the number of players sustaining more than 1 concussion during their career is most likely underestimated. Previous concussions sustained during play for other teams were not documented for individual players. It has been suggested that having had 1 or more concussions is a risk factor for sustaining subsequent concussions.[31,32] The rates we found might indicate the same, but causality cannot be claimed based on our data. Players who seem to have a higher risk for subsequent concussions could have had a higher risk for concussion before they sustained their first one. The higher risk could in that case possibly be linked to risk behavior rather than previous concussions generating a predisposition for more concussions (Burman et al., unpublished data, 2012). Another reason to find an increased risk after a first concussion could be that the earlier injury was not fully rehabilitated.[31] To understand where prophylactic actions could provide the best results, risk behavior as a possible cause for concussion in ice hockey and rehabilitation protocols in relation to subsequent concussions need to be investigated further.

Limitations and Strengths

Due to its design, this study grants a unique insight into how concussion IR in this Swedish ice hockey team has evolved. This is the first study that has followed the concussion IR over such a long period. During this period, the same criteria for diagnosing a concussion have been used (apart from the first year). The material in this study has high credibility due to the team playing in the SHL during all seasons while the diagnosing team physician has remained the same person.

The data's validity is strengthened by the injury registration procedures. A special software (ISIS) was developed to be able to prospectively register all information about all sustained injuries as well as exposures and rehabilitation periods.

To tackle the issue of changed RTP protocols during the research period, we decided to not look at the absolute number of rehabilitation days but rather chose to categorize absence into 3 groups: symptom free after 0 to 6 days (mild), symptom free after 7 to 28 days (moderate), and symptom free after 28 days or more (severe). Doing this eliminated the differences in rehabilitation times prescribed by the different protocols, giving us the chance to look at actual changes over time caused by severity rather than by protocol differences. The categories used are very common for studying absence due to injury in sports.[33,34]

All players in the team over the 29-season period participated in the study. That way, we eliminated bias for selection and time. It can be assumed that other professional European teams follow similar seasonal procedures when it comes to practice, number of games, and heterogeneity in team composition. Therefore, they most likely experience concussion IR increases similar to the rise we found for this

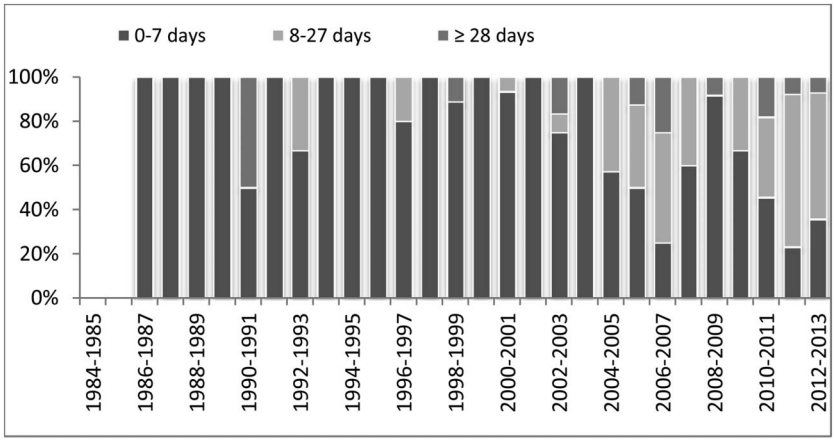

FIGURE 3. Percentage of concussions needing 0 to 7 days (mild), 8 to 27 days (moderate), or ≥28 days (severe) of rehabilitation.

team. The differences—for example, rink size and number of games—between the SHL and the National Hockey League (NHL) in North America are reason for caution when applying our results to the NHL. That caution is backed by earlier findings about differences in injury pattern between North American and European leagues.[9]

CONCLUSIONS

This study shows a significant increase of concussion IR and a rise in longer rehabilitation periods due to concussion. Athlete risk behavior, game speed, and athlete physiology may be important factors for this change. Risk behavior and rehabilitation protocols should be prioritized areas of research for concussion in ice hockey.

REFERENCES

1. Tuominen M, Stuart MJ, Aubry M, et al. Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *Br J Sports Med.* 2015;49:30–36.
2. Biasca N, Witrth W, Tegner Y. Head injuries and facial injuries in ice hockey. *Eur J Trauma.* 2005;4:396–474.
3. Pettersson M, Lorentzon R. Ice hockey injuries: a 4-year prospective study of a Swedish elite ice hockey team. *Br J Sports Med.* 1993;27: 251–254.
4. Tegner Y, Lorentzon R. Concussion among Swedish elite ice hockey players. *Br J Sports Med.* 1996;30:251–255.
5. Lorentzon R, Wedren H, Pietila T. Incidence, nature, and causes of ice hockey injuries. A three-year prospective study of a Swedish elite ice hockey team. *Am J Sports Med.* 1988;16:392–396.
6. Tegner Y, Lorentzon R. Ice hockey injuries: incidence, nature and causes. *Br J Sports Med.* 1991;25:87–89.
7. Kuzuhara K, Shimamoto H, Mase Y. Ice hockey injuries in a Japanese elite team: a 3-year prospective study. *J Athl Train.* 2009;44:208–214.
8. Agel J, Harvey EJ. A 7-year review of men's and women's ice hockey injuries in the NCAA. *Can J Surg.* 2010;53:319–323.
9. Ruhe A, Gansslen A, Klein W. The incidence of concussion in professional and collegiate ice hockey: are we making progress? A systematic review of the literature. *Br J Sports Med.* 2014;48:102–106.
10. Cook AW, Hunt WE, Mosberg WH, et al. Glossary of Head injury, including some definitions of injury to the cervical spine. *Clin Neurosurg.* 1966;12:386–394.
11. Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med.* 2002;36:6–10.
12. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med.* 2013;47: 250–258.
13. Tegner Y. Injury registration for concussion prevention. *Br J Sports Med.* 2004;38:663.
14. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Br J Sports Med.* 2006;40:193–201.
15. Noble JM, Hesdorffer DC. Sport-related concussions: a review of epidemiology, challenges in diagnosis, and potential risk factors. *Neuropsychol Rev.* 2013;23:273–284.
16. King DA, Hume PA, Milburn PD, et al. Match and training injuries in rugby league: a review of published studies. *Sports Med.* 2010;40:163–178.
17. Rishiraj N, Lloyd-Smith R, Lorenz T, et al. University men's ice hockey: rates and risk of injuries over 6-years. *J Sports Med Phys Fitness.* 2009; 49:159–166.
18. Quinney HA, Dewart R, Game A, et al. A 26 year physiological description of a National Hockey League team. *Appl Physiol Nutr Metab.* 2008; 33:753–760.
19. Sedeaud A, Marc A, Schipman J, et al. Secular trend: morphology and performance. *J Sports Sci.* 2014;32:1146–1154.
20. Hagel B, Meeuwisse W. Risk compensation: a "Side effect" of sport injury prevention?. *Clin J Sport Med.* 2004;14:193–196.
21. Torg JS, Truex R Jr, Quedenfeld TC, et al. The National Football Head and Neck Injury Registry. Report and conclusions 1978. *JAMA*. 1979; 241:1477–1479.
22. Andersson EE, Bedics BK, Falkmer T. Mild traumatic brain injuries: a 10-year follow-up. *J Rehabil Med.* 2011;43:323–329.
23. Bergemalm PO, Lyxell B. Appearances are deceptive? Long-term cognitive and central auditory sequelae from closed head injury. *Int J Audiol.* 2005;44:39–49.
24. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc.* 2007;39:903–909.
25. Jafari S, Etminan M, Aminzadeh F, et al. Head injury and risk of Parkinson disease: a systematic review and meta-analysis. *Mov Disord.* 2013;28:1222–1229.
26. Konrad C, Geburek AJ, Rist F, et al. Long-term cognitive and emotional consequences of mild traumatic brain injury. *Psychol Med.* 2011;41: 1197–1211.
27. McKee AC, Stein TD, Nowinski CJ, et al. The spectrum of disease in chronic traumatic encephalopathy. *Brain*. 2013;136:43–64.
28. Ryan LM, Warden DL. Post concussion syndrome. *Int Rev Psychiatry.* 2003;15:310–316.
29. Stalnacke BM, Bjornstig U, Karlsson K, et al. One-year follow-up of mild traumatic brain injury: post-concussion symptoms, disabilities and life satisfaction in relation to serum levels of S-100B and neurone-specific enolase in acute phase. *J Rehabil Med.* 2005;37:300–305.
30. Tremblay S, De Beaumont L, Henry LC, et al. Sports concussions and aging: a neuroimaging investigation. *Cereb Cortex.* 2013;23:1159–1166.
31. Giza CC, Kutcher JS, Ashwal S, et al. Summary of evidence-based guideline update: evaluation and management of concussion in sports: report of the Guideline Development Subcommittee of the American Academy of Neurology. *Neurology*. 2013;80:2250–2257.
32. Selassie AW, Wilson DA, Pickelsimer EE, et al. Incidence of sport-related traumatic brain injury and risk factors of severity: a population-based epidemiologic study. *Ann Epidemiol.* 2013;23:750–756.
33. Hagglund M, Walden M, Ekstrand J. UEFA injury study–an injury audit of European Championships 2006 to 2008. *Br J Sports Med.* 2009;43: 483–489.
34. Jacobson I, Tegner Y. Injuries among swedish female elite football players: a prospective population study. *Scand J Med Sci Sports.* 2007;17: 84–91.