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Concussions in the NHL: A narrative review of the literature

Jason Izraelski, BSc (Hons), MSc, DC, D.Ac*

Ice hockey has been identified as a sport with a high risk for concussions. Given the health sequelae associated with the injury, a great deal of attention has been placed on its diagnosis, management and return-to-play protocols. The highest level of ice hockey in North America is played in the National Hockey League (NHL), and concussions pose a serious threat to the health of the players and the game itself. Unfortunately, the scientific literature on concussions in ice hockey is derived mostly from research conducted on youth and amateur levels of play, leaving a gap in our knowledge at the professional level. This narrative review attempts to summarize what is known about concussion incidence, mechanisms of injury and risk factors in the NHL.

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KEY WORDS: concussion, incidence, injury, risk, hockey, chiropractic

Le hockey sur glace est reconnu comme un sport à haut risque pour les commotions cérébrales. Compte tenu des séquelles pour la santé associées à la blessure, son diagnostic, son traitement et les protocoles de retour au jeu font l'objet de beaucoup d'attention. Le plus haut niveau de hockey sur glace en Amérique du Nord est joué dans la Ligue nationale de hockey (LNH), et les commotions cérébrales constituent une menace grave pour la santé des joueurs, voire pour le jeu. Malheureusement, les ouvrages scientifiques sur les commotions cérébrales dans le hockey sur glace proviennent principalement de la recherche menée sur les jeunes et les niveaux amateurs du jeu, laissant un vide au niveau professionnel. Cet examen narratif est un effort pour résumer ce que l'on sait sur l'incidence de la commotion cérébrale, les mécanismes de blessure et les facteurs de risque dans la LNH.

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MOTS CLÉS : commotion cérébrale, incidence, blessure, risque, hockey, chiropratique

Introduction

Ice hockey is a popular North American sport played on a sheet of ice between two teams with 5 players and one goalie per side. Youth registration rates attest to its popularity, approaching 600,000 per year in Canada[1] with USA Hockey reporting similar registration rates[2]. It is an aggressive fast moving game that sees players moving at speeds up to 30 kilometers per hour.[3] Given the speed and aggressiveness with which the game is played, it should come as no surprise that ice hockey has the highest rate of concussion incidence amongst contact sports.[4,5] Concussions have become a topic of considerable interest

* Sport Science Resident, CMCC
jizraelski@gmail.com

amongst the scientific community, media and general public due to the sensational mechanisms of injury and deleterious consequences they can impart. Since 2000, four international conferences have been held with the aim of streamlining information and providing guidelines for the medical community on its diagnosis and management.[6,7,8,9]

Concussion Incidence

Concussions occur at all skill and age levels in ice hockey, and have been reported to account for 2-14% of all hockey injuries[10,11,12,13] and 15-30% of all hockey head injuries[10,14]. The large range of concussion incidence may be partially explained by the varied outcome measures used by researchers (i.e. athletic exposures vs. game hours vs. overall percentages). Unfortunately, the lack of a streamlined approach has made it difficult to draw conclusions and comparisons across studies.

In North America, the highest level of ice hockey is played in the National Hockey League (NHL). Between 1993 and 2003 it has been estimated that at least eight players were forced to retire due to lingering concussion symptoms, while many more missed weeks, months and entire seasons.[15] However, this estimate is believed to be conservative, and the true number of concussion-induced retirements is thought to be at least double this estimate.[16] Part of the reason for uncertainty regarding the data's accuracy is the NHL's vigilance in not lending its epidemiological data to researchers, due to stated issues of medical confidentiality.[17]

While epidemiological data at the NHL level is sparse, a small but growing body of literature is beginning to emerge. Wennberg and Tator (2003)[18] studied concussion in the NHL using data from published media reports, which have been cited as a reliable source of information[17,18]. The authors justified their use, explaining that injuries suffered by professional athletes are part of the overall entertainment package supplied by sport, and that the media and public demand eventually uncover the nature of injuries incurred by the athlete. The authors found that from the 1986-1987 to 1995-1996 seasons, there was a mean of 12 concussions per season. From the 1996-1997 to 2001-2002 seasons, there was a mean of 56 concussions per season, more than triple that of the previous decade. The authors attributed this drastic increase in concussion incidence to the commencement of the NHL Concussion Program in 1997. Therefore, the authors postulated that the findings were not a true increase in concussion incidence, but rather due to heightened awareness and diagnosis of the condition.

In a follow-up study, Wennberg and Tator (2008) documented the incidence of concussion and time lost from play due to concussive injury during the 1997-1998 to 2007-2008 seasons.[19] The authors found the mean incidence over the ten seasons to be 1.45 concussions per 1000 athletic exposures, and reported a significant downward trend in concussions over that time period. In contrast to this decrease, a gradual increase in the average number of games missed per concussion was recorded and the mean number of missed games per concussion during the last five seasons was significantly greater than during the first five seasons. The authors hypothesized that this may represent an increase in concussion severity, or perhaps, more stringent concussion management protocols that are more rigid in their return-to-play (RTP) timelines. Without access to NHL data, an issue fraught with concerns regarding medical confidentiality, it is impossible to discern which is more likely to account for the increase in games missed per concussion in the latter five seasons examined.

Recognizing a significant problem within the league, the NHL in conjunction with the National Hockey League Player Association (NHLPA), established the NHL-NHLPA Concussion Program in 1997, with the purpose of examining the science of concussion as well as the education of its members on all aspects of the injury.[20] The program helps the NHL accumulate data on concussion incidence, mechanism of injury and RTP timelines. The data collected have not been released to the public and only two studies have been published to date. The first was an abstract authored by Meeuwisse, Burke and Benson (2003) reporting data collected from team physicians who reported on all players sustaining concussions during the 1997-1998 to 2002-2003 NHL regular seasons.[20] They reported an average of 97 concussions per year and found that the median games missed per concussion doubled from one to two over the 5 years of the study. As it was only an abstract, no detailed statistics were provided.

To date, only one detailed study has emerged from the NHL Concussion Program. Benson et al (2011) had NHL team physicians document all concussions sustained during the 1997-1998 to 2003-2004 seasons in a

Table 1.
Summary of reported concussion incidence

	Wennberg & Tator (2003)	Meeuwisse, Burke & Benson (2003)	Stevens et al (2008)	Wennberg & Tator (2008)	Benson et al (2011)	Hutchison et al (2013)	Izraelski et al (2013)
	Concussions						
Season							
1986/1987	Mean: 11.6/ season						
1987/1988							
1988/1989							
1989/1990							
1990/1991							
1991/1992							
1992/1993							
1993/1994							
1994/1995*							
1995/1996							
1996/1997	Mean: 55.8/ season						
1997/1998		Mean: 97/ season		Mean: 68.8/ season	Mean: 80/ season		
1998/1999							
1999/2000							
2000/2001							
2001/2002			44				
2002/2003							
2003/2004							
2005/2006							Mean: 63.8/ season
2006/2007						Mean: 74.2/ season	
2007/2008							
2008/2009							
2009/2010							
2010/2011							
2011/2012							

prospective case series format.[21] The authors reported a total of 559 physician-diagnosed, regular season in-game concussions with a mean of 80 concussions per season. The median time lost from play was six days. In line with the two studies by Wennberg and Tator[18,19], the authors established that concussion rates were declining, from 7.7 concussions per 100 players during the 2001-2002 season down to 4.9 per 100 players during the 2003-2004 season. The authors concluded that this may be due to a variety of reasons including underreporting of symptoms by players to avoid missing time, more conservative management by team medical personnel, higher thresholds for diagnosis of concussion and increased use of neuropsychological testing results before making RTP decisions. The results of the studies, while indicating a decrease in concussion incidence, should be taken with caution. The authors stated issues of underreporting, and that more conservative management of concussions theoretically helped prevent repeat incidents by ensuring complete recovery before RTP.

In an unpublished thesis, Izraelski et al. (2013)[22] examined reported concussions between the 2005-2006 and 2011-2012 seasons, recording a mean of 64 reported concussions per season during that time frame. This data is lower than Meeuwisse, Burke and Benson[20] (mean of 97 concussions per season between 1997-1998 to 2002-2003) and Benson et al.[21] (mean of 80 concussions per season between 1997-1998 to 2003-2004). The authors speculat-

ed that the decrease in mean concussions may be a result of numerous rule changes implemented by the NHL after the 2004-2005 lockout intended to protect players and reduce concussions. Additionally, the study was the first to examine reported concussions in the NHL following the lockout of 2004-2005. While these concussion totals are lower than previous work cited by the NHL-NHLPA researchers, there was an upward trend in reported concussions over the examined time period with a sharp increase in the 2011-2012 season. The study concluded that there was a trend towards rising concussion incidence rates to the high levels seen pre-lockout.

Recent work by Hutchison et al. (2013) has helped add data to emerging concussion statistics in the NHL.[23] For this study, the NHL isolated digital video records of events in which players had been medically diagnosed with concussions. Using these videos and an objective standardized tool to record concussions[24], the authors recorded 197 regular season concussions from the beginning of the 2006/2007 season to until the end of December 2009. It should be noted that 63 concussions were excluded due to "inconclusive evidence" or that simply had no video records available. Unfortunately, the authors provided no statistical breakdown per season, means or athletic exposures for comparison to previous work.

Mechanism of Injury

Concussion is a form of mild traumatic brain injury that is induced by the transmission of force to the brain from either a direct or indirect impact to the head, face, neck or elsewhere along the body.[9] Forces that occur as a result of impulsive head motions (the absence of the head striking an object) are believed to be directly responsible for concussions.[25] While the type of force incurred by the brain is important, the manner in which the brain responds to the force is just as significant. There is considerable evidence that the primary cause of concussion is the acceleration loading experienced by the brain at the moment of contact. While the brain is highly resistant to changing its shape in response to slow or transient forces, it deforms quite easily when shearing forces are applied due to the physical properties of the brain itself.[26,27,28] Rapid head rotations generate shear forces in the brain, and therefore, rotational acceleration forces applied to the skull have a high potential to cause shear-induced damage to brain tissue. Further to this point, a number of studies have led to the belief that shear deformation caused by rotational acceleration is the predominant mechanism of action in concussive injury.[29,30,31] Whether this mechanism of injury holds true in the sport of ice hockey had not been examined until recent work by Hutchison et al (2013).[32] The authors reported that the most common body part initially contacted was the concussed player's head (68%), followed by the torso (28%) and below the waist or inconclusive (4%). The lateral aspect of the head was most commonly contacted area (58%), and when these results are combined with initial contact, almost half of the events (47%) were classified as direct contact to the lateral aspect of the head by the opponent's shoulders, elbows or gloves. The head was observed to accelerate in multiple planes, typically in the sagittal and transverse planes (39%). There was a relatively even distribution of events classified as sagittal or coronal plane (25%) and transverse plane (27%). Also of note, the authors concluded that the concussed player was often not in possession of the puck, and that no penalty was called on the play.

Concussion Risk Factors in the NHL

The most commonly investigated injury risk factors include age, session type, level of play, player position and the presence/absence of body checking.[33] Additional factors such as participation in fair play programmes, aggression and empathy, weight and height, level of hockey experience, relative age and gender have received limited attention and have produced conflicting results.[33] However, these risk factors are investigated from a generalized injury perspective and are not-concussion specific. Furthermore, much of the research is based on minor, junior and collegiate hockey and has produced conflicting results. This has left us with an absence of high quality research on concussive risk factors at the professional level.

It has been hypothesized that concussion incidence and severity will continue to increase if athletes continue to grow bigger, faster and stronger.[34] This has been attributed to simple physics, as the magnitude of any collision is dictated by the size and speed of the two objects colliding. Demographic data from the NHL between 1986-1987 to 2001-2002 corroborates the notion that NHL players are getting progressively taller and heavier.[18] Over the 16-year period analyzed, there was an average height increase of one inch and weight increase of almost 10

pounds (72 inches, 191 pounds to 73 inches, 200 pounds). Hutchison et al (2013)[23] reported that injured players were on average 185.73 cm tall and weighed 92.78 kg. For concussions involving direct contact with another player (88%, n=174/197), the authors reported that the player delivering the contact was on average 186.87 cm tall and weighed 96.32 kg. The hitter was significantly taller (1.26 cm) and 3.58 kg (heavier) than the player he concussed. The hitter was taller than the injured player in 52% of events, with the hitter being heavier than the injured player in 65% of the cases.

Position as a risk factor has been examined previously, and between the 1997-1998 and 2004-2005 season, 341 (64.1%) of concussions were suffered by forwards, 179 (31.4%) by defensemen and 24 (4.5%) by goalies.[21] Hutchison et al. (2013)[23] reported that 65% (129/197) of the analyzed concussions were sustained by forwards, 32% (63/197) by defensemen and 3% (5/197) by goalies. The authors remarked that the number of concussions suffered by forwards was significantly higher than expected compared with their on-ice representation.

Research on concussion and age in the NHL cited the median age of concussion to be 27 years[21], while another study cited the mean age to be 28.0 years[23]. Work by Izraelski et al. (2013)[22] discovered a trend to younger and older players suffering concussions at an increased frequency, supported by findings in logistic regression during two of the examined seasons (2008-2009 and 2011-2012). While causation was not apparent, the author speculated that younger and older players may be more reckless in their style of play, leading to increased concussions.

Fatigue has been shown to increase injury risk in both rugby[35] and soccer[36], and it has been reported that concussions are more likely to occur under fatigued conditions in female ice hockey[37]. In male youth and Junior A ice hockey, time-on-ice has been implicated as a risk factor for concussion[38] and injuries in general[39]. One study examining fatigue in the NHL reported a significant effect for time-on-ice per game.[40] Those who played more than 15.22 minute per game had an increased likelihood of suffering a concussion. The authors suggested that in-game fatigue may explain their findings, that is, players may suffer a concussion more often when fatigued due to a reduction in physical abilities and awareness. Izraelski et al. (2013)[22] found that average time on ice was a significant predictor of injury, with those players in the 15-20 minute range 2.6 times more likely to suffer a concussion than those in the 0-5 minute range. However, if the underlying mechanism for this is indeed fatigue, one would expect to see an increase in concussive risk for the 20-25 minute and 25+ minute groupings. It is possible however, that there is an interaction between average time on ice and skill/performance in that concussions decreased following the 15-20 minute grouping due to an increase in skill in the 20-25 and 25+ minute groupings. Players in those groupings typically represent higher skill levels and perhaps their increased situational awareness helped decrease the number of concussions suffered.

Conclusion

Concussive injury is a serious form of mild traumatic brain injury that deserves the attention it has been given. While much still needs to be learned regarding the injury, a small body of literature is beginning to emerge. Epidemiological data are becoming clearer as researchers examine the topic in greater detail. While a drop in concussion incidence occurred following the NHL lockout of 2004-2005, it appears that the incidence of concussion is again rising and further research is required to help elucidate the reasons for this rise. As we begin to gain a better understanding of concussions and the manner in which they occur, the NHL should continue to take strict action in enforcing bans on hits to head, specifically to the lateral aspect, as it has been demonstrated to be the most likely manner to induce concussive injury. While reasons such as fatigue and increased height/weight have been speculated upon, it is clear that further investigation is required.

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