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Original Research

Initial versus Subsequent Injury and Illness and Temporal Trends Among Professional Hockey Players

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Background

Research is limited investigating injuries/illness incidence among National Hockey League (NHL) players. This study sought to establish injury/illness incidence, initial versus subsequent injury risk among NHL players, and determine temporal trends of injury and illness incidence.

Hypothesis

Variations in injury incidence by body region, and initial versus subsequent injury would be observed among positions.

Study Design

Retrospective cohort study

Methods

Publicly available data were utilized. NHL players 18 years or older between 2007-2008 to 2018-2019 were included. Injury and illness was stratified by position and body segment. Incidence rate (IR), and initial versus subsequent injury and illness risk ratios were calculated. Temporal trends were reported.

Results

Nine thousand, seven-hundred and thirty four injuries and illnesses were recorded. Centers had the highest overall IR at 15.14 per 1000 athlete game exposures (AGEs) (95%CI:15.12-15.15) and were 1.4 times more likely to sustain a subsequent injury compared to other positions. The groin/hip/thigh was the most commonly injured body region with an IR of 1.14 per 1000 AGEs (95%CI:1.06-1.21), followed by the head/neck (0.72 per 1000 AGEs, 95%CI:0.66-0.78). Combined injury and illness IR peaked in 2009-2010 season at 12.01 (95%CI: 11.22-12.79). The groin/hip/thigh demonstrated peak incidence during the 2007-2008 season (2.53, 95%CI:2.17-2.90); head/neck demonstrated a peak incidence in 2010-2011 season (Overall: 1.03, 95%CI:0.81-1.26). Injuries reported as ‘lower body’ increased over time.

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Conclusions

Positional differences were observed; centers demonstrated the highest overall IR, and subsequent injury risk. Injury by body region was similar to previous literature. Head/neck and concussion decreased over time supporting rule changes in body checking and visor wear. Clinicians should be aware that 'lower body' injuries increased over time; therefore, injuries to the groin/hip/thigh or knee are likely underreported.

Level of Evidence

Level 3

INTRODUCTION

The National Hockey League (NHL) is the professional league for ice hockey in North America.[1] Ice hockey demonstrates a high risk of injury with overall incidence rates ranging from 5.93-15.6 per 1000 athlete exposures.[1,2] This high injury rate is related to the level of physicality required for the sport. Players skate in excess of 32-48km per hour[3,4] with contact occurring via body checking the most common mechanism of injury.[1,5-7] These high rates of injury come at a cost to teams in the league. Fifty point nine percent of NHL players missed at least one game resulting in a total of $218 million dollars in lost salaries (based on individual player salary and number of days missed due to time loss injuries) per season between 2009-2010 to 2011-2012 seasons.[8] Due to the injury and financial burden to players and teams, a comprehensive, transparent approach to injury surveillance is needed to attempt to mitigate injury risk. Further, the time trend analysis of injury patterns is an essential step in this process for both risk factor identification and evaluation of modulators, such as equipment changes[9] or body checking.[4]

A systematic approach in injury prevention research has been suggested by van Mechelen et al. to determine injury incidence and burden to inform future studies on preventative measures.[10] Data among NHL players for injury surveillance are often reported by a singular body region,[11,12] or do not encompass the whole league making comparisons by body region and position challenging.[13] Additionally, given the risk of repeated high impact contact, players are at risk for subsequent injuries, further impacting injury burden.[5,12,14-16] Players who sustain an injury are at risk of sustaining a second or third injury, particularly to the shoulder,[12] groin,[15] or specific to a diagnosis of concussion.[14] One study analyzed league wide injury rates across multiple body regions in the NHL from 2006-2007 to 2011-2012 seasons. Authors of this study demonstrated an incidence rate of 15.6 per 1000 athlete exposures.[1] Since then, rule changes on illegal checks[17] and equipment updates have occurred.[18] During the 2010-2011 NHL season, lateral or blind side hits meant to target the head, known as an 'illegal check to the head' resulted in a two minute minor or a match penalty[18]; furthermore, visor wear was mandated for those entering the league in 2013. This warrants an updated epidemiological injury profile that reflects temporal trends to improve injury mitigation programs and assess efficacy of league rule changes on injury.

One way to identify injury incidence and temporal trends among NHL players is through publicly available data.[8,19-21] Publicly available data improves transparency, and allows for collaboration among organizations to advance data robustness and distribution among stakeholders.[22,23] This transparency and potential for collaboration is essential to promote open science initiatives.[24,25] An open science approach allows researchers to assess, reproduce, and conduct studies for independent research with data that is easily accessible.[24,25] Publicly available data have been utilized across professional leagues and demonstrated high reporting reliability.[21,26] However most public data utilization in the NHL has been for cost analysis of injury[8] and influence of schedule density on injury,[19] not injury surveillance. Publicly available data are accessed via a computer iterative repeatable process which is an efficient method of data extraction.[12,27] This process increases repeatability, and offers the potential for shared league wide injury risk identification and injury mitigation programs.[28] This study sought to use publicly available data to determine injury and illness incidence by position and body region and determine initial versus subsequent injury risk. A secondary purpose of this study was to determine temporal trends of injury and illness incidence by position and body region.

METHODS

STUDY DESIGN

This was a retrospective cohort study. Participants were NHL players 18 years or older who competed in at least one season between 2007-2008 to 2018-2019. Players were categorized by position. Two online resources were used to create a combined data set for this study, including 1) https://www.prosportstransactions.com, and 2) http://www.nhl.com/stats/.[20,21] These data have been previously utilized in Major League Baseball, the National Football League, and the National Basketball Association.[20,21] The data can be accessed through the Open Science Framework data repository **https://osf.io/rx4jb/**. NHL stakeholders were included to aid in research question development and clinical interpretability including team physicians, athletic trainers, data analysts, and performance specialists. Strengthening the Reporting of Observational Studies in Epidemiology for Sport Injury and Illness Surveillance guideline was used.[29]

INJURY AND ILLNESS CLASSIFICATION

Injuries and illnesses that occurred from the first game of the regular season to the last game of the post season were

included in this study. Injury was defined as tissue damage or derangement of normal physical function occurring during any training session or competition that resulted in at least one day time loss.[21,29] Illness was defined as a complaint or disorder reported by a player and his team, not related to injury, resulting in at least one day time loss.[21] The authors defined injury based on a specific joint or body segment as defined by the Orchard Sports Injury Classification System.[30] Concussions were highlighted separately from head/neck injuries, and represented the only distinct diagnosis highlighted separate from body region (i.e. head/neck). Some data points are presented as a crude descriptor (i.e. "upper body") and were reported in this study as general classifications (upper body, lower body, or other), if injury to a joint or segment was not discernable. Initial injury was defined as the first injury documented; subsequent injuries were defined as either multiple or recurrent injuries, or an exacerbation of a previous injury.[31]

ATHLETE EXPOSURE

Athlete exposure was calculated based on game exposure (AGE) only, as determining practice exposure was not possible with this data set. For the 2015-2019 seasons, AGEs were calculated based on all 32 NHL teams and a 23 active man roster (8 defensemen, 8 wing players, 4 centers, 3 goalies) playing 82 regular season games between 2007-2008 to 2011-2012, and 2013-2014 to 2018-2019 seasons. The 2012-2013 season was representative of a player strike; this the AGEs were calculated based on 32 NHL teams and a 23 active man roster (8 defensemen, 8 wing players, 4 centers, 3 goalies) playing 48 regular season games. For all seasons, a postseason exposure adjustment was included to account for post season injuries based on the number of playoff games that occurred each season, with a reduction in the number of active players as teams were eliminated.[1]

DATA EXTRACTION, DATA REDUCTION AND EXTERNAL VALIDATION

For a detailed description of data repository used refer to Supplemental File 1. Data extraction, data reduction, and external validation used have been previously described.[20,21,27] External validation demonstrated high reliability for injury reporting (98%). Refer to Supplemental File 2 for detailed methods.

STATISTICAL ANALYSES

Injury and illness count data was converted to seasonal incidence proportion (IP) and incidence rate (IR). IP was calculated by total number of injuries or illness divided by total number of players per season.[16] IR was calculated by sum of injuries and divided by the sum of player-games, multiplied by 1000 x Athlete-Game Exposures (AGEs). Initial and subsequent injury and illness risk ratios were calculated by specific position incidence for initial or subsequent injury, divided by all other position incidence for initial or subsequent injury for combined 13 seasons. Subsequent injury risk ratios were further stratified by number of subsequent injuries by position to explore injury burden. 95% confidence intervals (CIs) were reported for all IP and IR calculations. Temporal trends were reported. Sensitivity analyses were performed to calculate injury incidence for aggregated four season intervals to evaluate influence of seasonal outliers. All analyses were performed in R version 4.02 (R Core Team, 2020) using the *rvest*, *tm*, and *xm12* packages.

Table 1. Overall Incidence Rate by Position

Position	IR	95% CI
Defense	10.90	10.52-11.27
Left Wing + Right Wing	10.94	10.57-11.32
Center	13.01	12.47-13.55
Goalie	5.11	4.73-5.49

IR=Incidence Rate; CI= Confidence Interval; IR was calculated by sum of injuries and divided by the sum of player-games, multiplied by 1000 x Athlete-Game Exposures (AGEs) and adjusted for number of regular and post-season games each year

RESULTS

Over thirteen seasons, 10,549 athletes participated in the NHL and 9,734 injuries and illnesses were recorded. Centers had the highest combined injury and illness incidence rate (15.14 per 1000 AGEs 95% CI:15.12-15.15) (Table 1).

INITIAL AND SUBSEQUENT INJURIES BY POSITION

Centers presented with the highest incidence of multiple injuries reported for two (IP: 22.1 95% CI: 21.2-23.0) and three (IP: 9.0, 95% CI: 8.6-9.4) total injuries per season. (Table 2).

Centers were 1.4 (95% CI: 1.3-1.6) times more likely to sustain a subsequent injury, with a higher likelihood of sustaining multiple injuries, or new body region (RR: 1.9, 95% CI:1.8-2.1) versus an injury exacerbation or recurrent injury (RR: 1.4, 95% CI: 1.2-1.6) (Table 3). Refer to Supplemental file 3-5 for further information on initial versus subsequent injury and illness IP.

INCIDENCE BY BODY REGION AND POSITION

The groin/hip/thigh was the most commonly injured body region with an IR of 1.14 per 1000 AGEs (95% CI: 1.06-1.21), followed by the head/neck (0.72 per 1000 AGEs, 95% CI: 0.66-0.78), and knee (0.60 per 1000 AGEs, 95% CI: 0.55-0.66) (Table 4). By position, centers demonstrated the highest IR among the top three most injured body regions (groin/hip/thigh: 1.41 per 1000 AGEs, 95% CI: 1.23-1.59; Head/Neck: 0.86 per 1000 AGEs, 95% CI: 0.72-1.00; knee: 0.80 per 1000 AGEs, 95% CI: 0.66-0.93) (Table 4).

TEMPORAL TRENDS

Combined injury and illness IR peaked in 2009-2010 season at 12.01 (95% CI: 11.22-12.79) (Supplemental File 6). Among the most commonly injured body regions, the

Table 2. Athletes with One or More Injuries

Position	IP	95% CI
Defense		
1 Injury	53.09	51.45-54.73
2 injuries	18.78	18.21-19.35
3 injuries	7.32	7.11-7.53
4+ Injuries	5.88	5.72-6.05
Left Wing + Right Wing		
1 Injury	54.43	52.75-56.11
2 injuries	18.68	18.12-19.25
3 injuries	7.20	6.99-7.40
4+ Injuries	4.92	4.79-5.06
Center		
1 Injury	76.55	73.20-79.89
2 injuries	22.06	21.12-23.01
3 injuries	8.99	8.61-9.36
4+ Injuries	5.76	5.53-5.99
Goalie		
1 Injury	32.11	30.51-33.72
2 injuries	10.97	10.44-11.51
3 injuries	3.57	3.41-3.72
4+ Injuries	1.41	1.37-1.45

IP=Incidence Proportion; CI= Confidence Interval; IP was calculated by total number of injuries or illness divided by total number of players per season

groin/hip/thigh demonstrated peak incidence during the 2007-2008 season (Overall: 2.53, 95% CI: 2.17-2.90) (Supplemental File 7) along with the knee (Overall: 1.46, 95% CI: 1.19-1.74) (Supplemental File 8); head/neck demonstrated a peak incidence in 2010-2011 season (Overall: 1.03, 95% CI: 0.81-1.26) (Supplemental File 9). All three body regions demonstrated a variable, though declining incidence over the study time frame. Injuries reported as 'Lower Body' demonstrated an increase in incidence over time peaking in 2015-2016 (Defense: 2.68, 95% CI: 2.09-3.28; Goalie: 1.45, 95% CI: 0.80-2.11) or 2016-2017 seasons (LW+RW: 2.31, 95% CI: 1.75-2.86, Center: 2.57, 95% CI: 1.78-3.35) (Supplemental File 12). For further breakdown of temporal trends, please reference Supplemental Files 6-13.

SENSITIVITY ANALYSES

Centers reported the greatest mean consecutive four-season incidence proportion for the groin/hip/thigh (13.09) (Supplemental Files 14, 17), knee (7.40) (Supplemental Files 14, 18), concussion (5.66) (Supplemental Files 14, 19) and shoulder/arm/elbow (5.43) (Supplemental Files 14, 20). The mean difference was similar between season and four-season analyses across all body parts for overall, and most commonly injured body regions (Supplemental Files 14, 15). For most commonly injured body region by position, the Groin/Hip/Thigh mean difference comparing season and four-season analyses were: defense (Season: 5.48 vs 5 Season: 5.93), LW+RW (9.37 vs 10.17), centers (12.07 vs 13.09), and goalies (4.31 vs 4.69) (Supplemental Files 14, 15). Further information on sensitivity analyses can be found in Supplemental Files 14- 22.

DISCUSSION

This study sought to establish injury incidence, initial versus subsequent injury incidence and determine temporal trends of injury incidence among NHL players. Centers had the highest combined injury and illness IR and the greatest incidence of subsequent injury. The groin/hip/thigh, knee, and head/neck were the most commonly injured body regions for all positions except LW+RW, which demonstrated the highest incidence for the groin/hip/thigh, head/neck, followed by equal injury incidence for the Shoulder/Arm/Elbow, and concussion. This suggests some position specific variability in injury may occur. Temporal trends for combined injury and illness incidence demonstrated the highest incidence during the 2009-2010 season. Head/neck injuries peaked in 2010-2011 season, prior to implementation of rule changes identifying illegal checks to the head. Groin/hip/thigh and knee injuries demonstrated declines over the study time frame, although 'lower body' injuries demonstrated an increase over time. Similar results were found in the sensitivity analyses using four-year increments for all temporal trends by body region and position suggesting four year or seasonal variance in injures may still capture the overall trends in injury data.

INITIAL AND SUBSEQUENT INJURIES BY POSITION

Centers demonstrated the highest overall injury and illness IR and were 1.4 times more likely to sustain a subsequent injury within the same season. Research on injury by position is limited among NHL players and distribution can be conflicting depending on the league and level of play.[32-34] A previous one-year prospective study among Swiss professional ice hockey players demonstrated near equal distribution of injuries by position for in-game injuries (i.e., right forwards: 23%, left forwards: 20%, centers: 17%, right defenders: 21%, left defenders: 15%). However this study did not include all teams in the league, and ice surface area is larger compared to the NHL (Swiss: 60 x 30 meters, NHL: 61.0 x 25.9 meters) potentially impacting injury incidence or severity.[33] Similar to our findings, collegiate male ice hockey players have demonstrated that forwards account for 48.3-61.1% of injuries, but did not account for specific offensive positions.[32,34] The increased incidence of initial and subsequent injury demonstrated among centers may be attributed to the demands of the position. Centers are expected to cover the largest zone of ice, may have increased defensive responsibilities compared to wing (LW+RW) players, and handle the puck more than other positions, all of which may influence contact with other players in open ice areas, or contribute to recurrent injuries. However, variability in coaching strategies for how centers are used are likely, and may not fully explain the higher injury incidence among centers.

Table 3. Risk Ratios by Position

Defense			
Injury Type	**n**	**RR**	**95% CI**
Initial Injury	2103	0.97	0.94-1.01
Subsequent Injury	1267	1.14	1.08-1.22
Reinjury to same body location	443	1.07	0.96-1.20
Injury to new body location	824	1.05	0.97-1.13
Left Wing + Right Wing			
Injury Type	**n**	**RR**	**95% CI**
Initial Injury	2156	1.01	0.97-1.04
Subsequent Injury	1220	1.10	1.04-1.16
Reinjury to same body location	433	1.04	0.93-1.16
Injury to new body location	787	1.00	0.92-1.08
Center			
Injury Type	**n**	**RR**	**95% CI**
Initial Injury	1516	1.66	1.60-1.71
Subsequent Injury	729	1.40	1.31-1.49
Reinjury to same body location	264	1.37	1.21-1.56
Injury to new body location	465	1.91	1.75-2.09
Goalie			
Injury Type	**n**	**RR**	**95% CI**
Initial Injury	477	0.52	00.48-0.56
Subsequent Injury	237	0.48	0.43-0.54
Reinjury to same body location	106	0.59	0.49-0.72
Injury to new body location	131	0.34	0.29-0.40

RR=Risk Ratio; CI=confidence interval; Risk ratio calculated by specific position incidence/all other positions incidence (i.e. defense incidence/left wing+right wing, center, goal incidence)

INCIDENCE BY BODY REGION AND POSITION

The groin/hip/thigh, knee and head/neck were the most commonly injured body regions for centers, defense, and goalies. This finding is similar to previous studies among collegiate[8] and professional players.[33] Swiss professional players reported the most common injury to the hip/groin/thigh (23%), followed by head (17%)[33]; whereas a recent study among collegiate male players demonstrated that the head or face was the second most injured body region (15.2%) followed by the hip or groin (12.1%).[35] Groin and hip injuries have previously been shown to be evenly distributed across all players,[34] although intra-articular injuries are more common in goalies.[36] Hip/groin/thigh injuries in hockey can be acute or chronic in nature[36] and may present as intra-articular[36] or extra-articular issues.[6] Additionally, hip/groin/thigh injuries that present as chronic in nature may be related to overuse mechanisms, and may be underreported.[34] Among knee injuries, medial collateral ligament tears followed by anterior cruciate ligament tears are the most common knee injuries resulting in time loss via contact.[4] Head/neck injuries often include facial injuries (4.1 per 1000 player games),[7] as well as cervical spine injuries.[35] The NHL requires players to wear half shields on helmets, compared to collegiate ice hockey full face shield requirements. Previous literature has suggested a lower incidence of facial injuries when wearing a full facial shield among collegiate players.[37] The current data are similar to or lower than previous collegiate ice hockey reports comparing head/neck injuries (0.72 per 1000 AGEs versus 0.34-4.71 per 1000 Athlete Exposures).[38] The current study did not differentiate among players who wore full versus half shield protection. Therefore, the impact of face shield type on head/neck injuries cannot be determined from our data and warrants further investigation. The high incidence demonstrated among hip/groin/thigh, knee, and head/neck injuries for a majority of players informs clinicians on need to consider injury mitigation programs for the lower extremity and cervical region, keeping in mind positional needs (i.e., goalie's positional stance versus skaters).

One position subcategory, LW+RW, demonstrated differences among highest injured body regions after hip/groin/thigh. These players demonstrated the second highest injury incidence for the trunk/back/buttock, followed by equal injury incidence for the shoulder/arm/elbow, and concussion. Similar to our results, collegiate and Swiss professional players demonstrated the trunk or abdomen/thorax injuries accounted for 9-9.04% of all injuries and the fourth or fifth most commonly injured body region[2,33,34]; however these studies did not report specific incidence by individual positions. The shoulder is the most commonly injured joint

Table 4. Overall Incidence Rate by Body Region and Position

Body Region	IR	95% CI
Ankle		
Overall	0.29	0.25-0.33
Defense	0.36	0.30-0.43
Left Wing + Right Wing	0.20	0.15-0.25
Center	0.27	0.19-0.35
Goalie	0.11	0.05-0.17
Concussion		
	0.47	0.42-0.52
Defense	0.32	0.26-0.39
Left Wing + Right Wing	0.50	0.42-0.58
Center	0.61	0.50-0.73
Goalie	0.15	0.09-0.22
Head/Neck		
Overall	0.72	0.66-0.78
Defense	0.80	0.69-0.90
Left Wing + Right Wing	0.48	0.40-0.56
Center	0.86	0.72-1.00
Goalie	0.35	0.25-0.44
Foot/Toe		
Overall	0.33	0.30-0.38
Defense	0.40	0.33-0.47
Left Wing + Right Wing	0.27	0.21-0.33
Center	0.35	0.26-0.44
Goalie	0.10	0.04-0.15
Forearm/Wrist/Hand		
Overall	0.51	0.46-0.56
Defense	0.49	0.41-0.57
Left Wing + Right Wing	0.48	0.41-0.56
Center	0.53	0.42-0.64
Goalie	0.19	0.12-0.26
Groin/Hip/Thigh		
Overall	1.14	1.06-1.21
Defense	0.72	0.62-0.82
Left Wing + Right Wing	1.23	1.10-1.36
Center	1.41	1.23-1.59
Goalie	0.47	0.36-0.59
Knee		
Overall	0.60	0.55-0.66
Defense	0.54	0.45-0.62
Left Wing + Right Wing	0.47	0.39-0.54
Center	0.80	0.66-0.93
Goalie	0.31	0.22-0.40
Shoulder/Arm/Elbow		
Overall	0.50	0.45-0.55
Defense	0.38	0.31-0.45
Left Wing + Right Wing	0.50	0.42-0.58
Center	0.59	0.47-0.70
Goalie	0.27	0.18-0.36
Trunk/Back/Buttock		
Overall	0.52	0.47-0.57
Defense	0.46	0.39-0.54
Left Wing + Right Wing	0.65	0.56-0.74
Center	0.38	0.29-0.48
Goalie	0.12	0.07-0.18
Other		
Overall	1.17	1.09-1.24
Defense	1.10	0.98-1.22
Left Wing + Right Wing	0.99	0.88-1.10
Center	1.41	1.23-1.59
Goalie	0.47	0.36-0.59
Upper Body		
Overall	2.05	1.95-2.15
Defense	1.68	1.53-1.82
Left Wing + Right Wing	1.79	1.64-1.94
Center	1.49	1.35-1.63
Goalie	0.44	0.36-0.51
Lower Body		
Overall	2.02	1.92-2.12
Defense	2.10	1.93-2.26
Left Wing + Right Wing	1.84	1.69-1.99
Center	1.77	1.57-1.97
Goalie	0.93	0.76-1.09

IR=Incidence Rate; CI= Confidence Interval; IR was calculated by sum of injuries and divided by the sum of player-games, multiplied by 1000 x Athlete-Game Exposures (AGEs) and adjusted for number of regular and post-season games each year

in the upper extremity, oftentimes presenting with acromioclavicular sprains,[12] glenohumeral instability,[13] as well as minor injuries such as contusions[4] which likely reflects the majority of injuries among the shoulder/arm/elbow reported in the current study. In addition to centers, the finding that LW+RW players demonstrated a higher incidence of concussion compared to defense or goalies is consistent with previous NHL literature.[11,39] Offensive players sustain hits from defensemen that are on average larger in stature.[39] Furthermore, previous research has demonstrated that location of concussion event is more evenly distributed across all zones compared to defensemen and goalies. Forwards also incurred more concussions when 'on the rush' when the player is skating at a higher speed.[39] These variations of position stature, location, and nature of play may explain the current study findings of higher incidence of concussion among offensive players.

TEMPORAL TRENDS

Head/neck IP peaked in 2010-2011 season, followed by a drop beginning in 2013-2014 seasons. From 2010-2011 season to 2013-2014 season, modifications were made to rules

defining illegal checks to the head and subsequent penalties[17] following research on concussion incidence and screening protocols. This rule change likely contributed to the decreased incidence in head and neck injuries noted in our results.[14] Furthermore, the 2013-2014[18] season implemented a mandate requiring all players to wear a protective visor; players who wore a visor demonstrated more than a four-fold decreased risk of orbital or eye injuries.[9] Visor wear increased from 32% during the 2002-2003 season[9] to 97% during the 2018-2019 season,[18] likely contributing to the decrease in injuries in the body region category of 'head/neck' injuries seen after the 2013-2014 season in our findings. However, these studies were not based on individual visor wear and the impact of injury should be interpreted with caution. Specific to concussion, incidence decreased over time after the highest peak noted during the 2011-2012 season likely in part to improved concussion recognition and stricter protocols.[17,39] However, a spike in suspensions for illegal checks were demonstrated in 2013-2014 and 2018-2019 seasons which may in part contribute to the slight increase in overall or position specific (centers and RW+LW players) incidence, compared to the 2014-2015 to 2017-2018 seasons.[25] Notably, the slight increase in overall or position specific incidence of concussion during the 2013-2014 may have been impacted by the NHL player strike, resulting in a condensed season, and should be considered. Impact of regulation on body checks and association with lower head/neck and concussion rates have been established among youth ice hockey players.[39] These results suggest that rule implementation preventing body checks to the head and neck may also have a positive impact on lowering the incidence of head/neck and concussion injuries when rules are adequately followed and enforced in the NHL.

Among the most injured body region, the groin/hip/thigh and knee injuries demonstrated declines over the study time frame, although ambiguous labels including 'Lower Body' injuries demonstrated an increase over time. Therefore, the current study may reflect an underrepresentation of injury incidence across multiple body regions including the lower extremity. The NHL is required to disclose to the public a player's injury status[39]; however, teams are not required to disclose the specific nature of the player's injury, such as pathology.[39] Many teams have opted to use the terms 'lower body' injury which may explain the increase in incidence of injury labeled 'lower body' over time compared to hip/groin/thigh.[39,40] This decreased transparency in injury reporting is in contrast to other leagues such as the National Basketball Association, who are required to disclose the specific nature of the player's injury.[39] Furthermore, decreased transparency of publicly available injury data and hesitancy to disclose epidemiological data to researchers[3] is likely reflected in the substantially less injury surveillance research among NHL players compared to other professional leagues.[41] Decreased transparency in data reporting and access impacts volume and quality of studies that can improve player injury outcomes and appropriate resource allocation.[3,41] Concussion was the specific diagnosis that the current study was able to report beyond the Orchard Injury Classification System body region labels. This increased transparency of reporting specific to this diagnosis likely aided in informing rule changes, injury recognition, and implementation of stricter protocols which likely contributed to the decreased incidence rate over time.[17,40] This application of transparency may be applicable to other diagnoses of upper and lower body injuries for improved quality of injury surveillance data across the NHL to ensure appropriate injury mitigation programs and effective resource allocation implementation.

LIMITATIONS

Only NHL players were assessed, decreasing generalizability of the results to other professional ice hockey leagues, amateur ice hockey players, or female ice hockey players. Further, the public data set does not allow for missing data to be quantified, which may impact the precision of these results. However, external data validation was performed with other publicly available data to increase the interpretability of these results. Due to ambiguous terms such as 'lower body' the injury incidence by specific body region may be underreported or misclassified.[40] Furthermore, these ambiguous terms may impact the ability to differentiate by body region for subsequent injuries (i.e., initial injury reported as 'knee injury' if reinjured could be reported as a 'lower body injury'). This data was not reported by a clinician or other medical practitioner, which may also influence misclassification. Additionally, an estimated athlete-game exposures (AGEs) value was used to calculate IR based on typical games played each season. Although this approach has been previously performed to estimate player-game exposures,[1,20,21,42] athletes by position may have different exposure to sport, and residual confounding is possible, impacting the clinical interpretability of these findings. In future studies examining effects of policy or intervention effects, AGEs may be suitable to use as a denominator, though exposure that captures both practice and game exposures may be more applicable to discern individual treatment effects. Furthermore, research varies in how athlete exposure is measured (i.e. 1000 athlete exposures versus 10000 athlete game), impacting comparability of the results. Finally, some injuries were reported to the nearest anatomical body part or nonspecific labels such as 'lower body' with specific injury classification (e.g., knee injury versus lateral meniscal tear of the right knee) not possible, decreasing the clinical interpretability of these findings.

CONCLUSION

Centers demonstrated the highest overall combined injury and illness incidence, were more likely to report multiple injuries, and more likely to report a subsequent injury compared other positions. The groin/hip/thigh, knee, and head/neck were the most commonly injured body regions for centers, defense, and goalies similar to previous literature; however, LW+RW players demonstrated higher incidence for groin/hip/thigh, trunk/back/buttock, shoulder/arm/el-

bow, and concussion. Head/neck injuries peaked in the 2010-2011 season but demonstrated a substantial decrease in the following seasons. These findings inform clinicians on specific injury incidence that may reflect positional variability, which may inform injury mitigation programs that address these position specific variations. Further, the current findings provide initial insight into injury trends that occur during periods of rule changes for illegal checking and visor wear for those who entered the league after 2013. Future literature is needed to investigate effects of rule or equipment changes to further confirm their effectiveness. Clinicians should be aware that although injury incidence decreased for groin/hip/thigh and knee, 'lower body' injuries demonstrated an increase over time, indicating that these injuries are likely underreported, citing a need for greater transparency of reporting injury.

CONFLICTS OF INTEREST

The authors report no conflicts of interest

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REFERENCES

1. McKay CD, Tufts RJ, Shaffer B, Meeuwisse WH. The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. *Br J Sports Med*. 2014;48(1):57-62. doi:10.1136/bjsports-2013-092860

2. Ornon G, Ziltener JL, Fritschy D, Menetrey J. Epidemiology of injuries in professional ice hockey: a prospective study over seven years. *J Exp Ortop*. 2020;7(1):87. doi:10.1186/s40634-020-00300-3

3. Izraelski J. Concussions in the NHL: A narrative review of the literature. *J Can Chiropr Assoc*. 2014;58(4):346-352.

4. Mosenthal W, Kim M, Holzshu R, Hanypsiak B, Athiviraham A. Common ice hockey injuries and treatment: A current concepts review. *Curr Sports Med Rep*. 2017;16(5):357-362. doi:10.1249/jsr.0000000000000402

5. Anderson GR, Melugin HP, Stuart MJ. Epidemiology of injuries in ice hockey. *Sports Health*. 2019;11(6):514-519. doi:10.1177/1941738119849105

6. Kuhn AW, Noonan BC, Kelly BT, Larson CM, Bedi A. The hip in ice hockey: A current concepts review. *Arthroscopy*. 2016;32(9):1928-1938. doi:10.1016/j.arthro.2016.04.029

7. Tuominen M, Stuart MJ, Aubry M, Kannus P, Parkkari J. 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(1):30-36. doi:10.1136/bjsports-2014-093688

8. Donaldson L, Li B, Cusimano MD. Economic burden of time lost due to injury in NHL hockey players. *Inj Prev*. 2014;20(5):347-349. doi:10.1136/injuryprev-2013-041016

9. Micieli JA, Zurakowski D, Ahmed II. Impact of visors on eye and orbital injuries in the National Hockey League. *Can J Ophthalmol*. 2014;49(3):243-248. doi:10.1016/j.jcjo.2014.03.008

10. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med*. 1992;14(2):82-99. doi:10.2165/00007256-199214020-00002

11. Adams R, Li AY, Dai JB, et al. Modifying factors for concussion incidence and severity in the 2013-2017 National Hockey League Seasons. *Cureus*. 2018;10(10):e3530. doi:10.7759/cureus.3530

12. White LM, Ehmann J, Bleakney RR, Griffin AM, Theodoropoulos J. Acromioclavicular joint injuries in professional ice hockey players: Epidemiologic and MRI findings and association with return to play. *Orthop J Sports Med*. 2020;8(11):2325967120964474. doi:10.1177/2325967120964474

13. Swindell HW, McCormick KL, Tedesco LJ, et al. Shoulder instability, performance, and return to play in National Hockey League players. *J Shld Elbow Surg*. 2020;4(4):786-791. doi:10.1016/j.jseint.2020.08.008

14. 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

15. Emery CA, Meeuwisse WH, Powell JW. Groin and abdominal strain injuries in the National Hockey League. *Clin J Sport Med*. 1999;9(3):151-156. doi:10.1097/00042752-199907000-00006

16. Knowles SB, Marshall SW, Guskiewicz KM. Issues in estimating risks and rates in sports injury research. *J Athl Train*. 2006;41(2):207-215.

17. Checking (Ice Hockey). Accessed September 1, 2021. https://en.wikipedia.org/wiki/Checking_(ice_hockey)

18. Serravalli F. Who will be the Craig MacTavish of visors? Published 2019. Accessed September 25, 2021. https://www.tsn.ca/who-will-be-the-craig-mactavish-of-nhl-visors-1.1386373

19. Blond BN, Blond JB, Loscalzo PJ. Game spacing and density in relation to the risk of injuries in the National Hockey League. *Orthop J Sports Med*. 2021;9(4):2325967121999401. doi:10.1177/2325967121999401

20. Bullock GS, Ferguson T, Vaughan J, Gillespie D, Collins G, Kluzek S. Temporal trends and severity in injury and illness incidence in the National Basketball Association over 11 seasons. *Orthop J Sports Med*. 2021;9(6):23259671211004094. doi:10.1177/23259671211004094

21. Bullock GS, Murray E, Vaughan J, Kluzek S. Temporal trends in incidence of time-loss injuries in four male professional North American sports over 13 seasons. *Sci Rep*. 2021;11(1):8278. doi:10.1038/s41598-021-87920-6

22. Newman K. Go public! Using publicly available data to understand the foreclosure crisis. *J Am Planning Assoc*. 2010;76(2):160-171. doi:10.1080/01944360903586738

23. Oki NO, Nelms MD, Bell SM, Mortensen HM, Edwards SW. Accelerating adverse outcome pathway development using publicly available data sources. *Curr Environ Health Rep*. 2016;3(1):53-63. doi:10.1007/s40572-016-0079-y

24. Bullock GS, Ward P, Peters S, et al. Call for open science in sports medicine. *Br J Sports Med*. 2022;56(20):1143-1144. doi:10.1136/bjsports-2022-105719

25. Wilkinson MD, Dumontier M, Aalbersberg IJ, et al. The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data*. 2016;3(1):1-9. doi:10.1038/sdata.2016.18

26. Hayes J, Orchard J. Using the World Wide Web to conduct epidemiological research: an example using the National Basketball Association. *Int Sport Med J*. 2001;2(2):1-15.

27. Landers RN, Brusso RC, Cavanaugh KJ, Collmus AB. A primer on theory-driven web scraping: Automatic extraction of big data from the Internet for use in psychological research. *Psych Methods*. 2016;21(4):475-492. doi:10.1037/met0000081

28. Landers RN, Brusso RC, Cavanaugh KJ, Collmus AB. A primer on theory-driven web scraping: Automatic extraction of big data from the Internet for use in psychological research. *Psych Methods*. 2016;21(4):475-492. doi:10.1037/met0000081

29. Bahr R, Clarsen B, Derman W, et al. International Olympic Committee Consensus Statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (Including the STROBE Extension for Sports Injury and Illness Surveillance (STROBE-SIIS)). *Orthop J Sports Med*. 2020;8(2):2325967120902908.

30. Orchard J et al. Revision, uptake and coding issues related to the open access Orchard Sports Injury Classification System (OSICS) versions 8, 9 and 10.1. *Open Access J Sports Med*. 2010;1:207. doi:10.2147/oajsm.s7715

31. Finch CF, Cook J. Categorising sports injuries in epidemiological studies: the subsequent injury categorisation (SIC) model to address multiple, recurrent and exacerbation of injuries. *Br J Sports Med*. 2014;48(17):1276-1280. doi:10.1136/bjsports-2012-091729

32. 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.

33. Brunner R, Bizzini M, Niedermann K, Maffiuletti NA. Epidemiology of Traumatic and Overuse Injuries in Swiss Professional Male Ice Hockey Players. *Orthop J Sports Med*. 2020;8(10):2325967120964720. doi:10.1177/2325967120964720

34. Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. *Am J Sports Med*. 2005;33(2):183-189. doi:10.1177/0363546504267349

35. Morrissette C, Park PJ, Lehman RA, Popkin CA. Cervical spine injuries in the ice hockey player: Current concepts in epidemiology, management and prevention. *Global Spine J*. 2020;11(8):1299-1306. doi:10.1177/2192568220970549

36. Epstein DM, McHugh M, Yorio M, Neri B. Intra-articular hip injuries in National Hockey League Players: A descriptive epidemiological study. *Am J Sports Med*. 2013;41(2):343-348. doi:10.1177/0363546512467612

37. Asplund C, Bettcher S, Borchers J. Facial protection and head injuries in ice hockey: a systematic review. *Br J Sports Med*. 2009;43(13):993-999. doi:10.1136/bjsm.2009.060152

38. Simmons MM, Swedler DI, Kerr ZY. Injury surveillance of head, neck, and facial injuries in collegiate ice hockey players, 2009-2010 through 2013-2014 academic years. *J Athl Train*. 2017;52(8):776-784. doi:10.4085/1062-6050-52.4.03

39. Hutchison MG, Comper P, Meeuwisse WH, et al. A systematic video analysis of National Hockey League (NHL) concussions, part II: How concussions occur in the NHL. *Br J Sports Med*. 2015;49:552-555.

40. Rush C, Khurshudyan. Some NHL teams hide information, but it might be hurting players. Published 2018. Accessed September 1, 2021. https://www.washingtonpost.com/sports/some-nhl-teams-hide-injury-information-but-it-might-be-hurting-players/2018/01/17/373a98f0-fb07-11e7-ad8c-ecbb62019393_story.html

41. Makhni EC, Buza JA, Byram I, Ahmad CS. Sports Reporting: A Comprehensive review of the medical literature regarding North American professional sports. *Phys Sportsmed*. 2014;42(2):154-162. doi:10.3810/psm.2014.05.2067

42. Boltz AJ, Nedimyer AK, Chandran A, Robison HJ, Collins CL, Morris SN. Epidemiology of injuries in National Collegiate Athletic Association men's ice hockey: 2014–2015 through 2018–2019. *J Athl Train*. 2021;56(7):703-710. doi:10.4085/1062-6050-611-20

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