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Effect of Rule Changes on Concussions in Youth Hockey

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ABSTRACT

Purpose: the purpose of this experiment is to determine the effect of USA Hockey rule changes implemented between 2014 and 2016 on concussion injuries in youth hockey during the periods of 2010 and 2023. Procedure: download National Electronic Injury Surveillance System data for hockey related injuries between the period of 2010-2023, filter for injuries with diagnosis of concussion and age range between 13 and 18, manually code data based on hospital notes. Adding coding for mechanism of injury (player to player, player to ice, player to board, result of a hit vs. fall). Create columns Checked, P2P (Player to Player), P2B (Player to Board), P2I (Player to Ice), count and graph the absolute number of concussions each year. Conclusion: prior to the implementation of USA Hockey Rule Changes, between January 1, 2010 and December 31, 2013, the mean concussions among youth hockey players between ages of 13-18 were 69.75 concussions/year. The rule changes were implemented between 2014 and 2016. After the implementation of these changes, for the period between January 1, 2017 and December 31, 2023 (excluding 2020 and 2021 due to COVID 19), the mean number of concussions declined to 43.8 concussions/year (P=.015).

Purpose

The purpose of this experiment is to determine the effect of USA Hockey Rule Changes implemented between 2014 and 2016 on Concussion Injuries in Youth Hockey. This is interesting because there is a high prevalence of concussion injuries in hockey and, as a result, a general concern among parents regarding safety of young players. While few rule changes against direct intentional hits, in particular to the head, have been implemented, the effectiveness of these rule changes are not well understood. A better understanding of effectiveness of rule changes already implemented will better inform opportunities for further rule changes to make the sport safer.

Hypothesis

If USA Hockey rule changes between the periods of 2014 and 2016 were analyzed, the incidence of concussions as reported by NEISS for the periods before 2014 will be significantly higher than incidence of concussion injuries in the period after 2016. This is because meaningful rule changes against blind side hits, boarding, checking, direct contact to head and neck areas were instituted during this period.

Variables/Essential Components

- Independent Variable: Change in number of concussions between 2010 and 2023 due to major rule changes adopted by Hockey USA between the periods of 2014 and 2016.
- Test subjects are youth hockey players ranging from 13 years to 18 years of age.

- Dependent Variable: Tally the absolute number of concussion each year. These will be reviewed retrospectively.
- Constants: Age range of 13-18; concussions reported in hospital settings only; geographic perimeter of USA.
- Comparison Group: Number of concussions before 2014 vs. number of concussions after 2016

Review of Literature

Hockey, by nature, is a highly physical sport. The physicality of the sport is intrinsic to its popularity, both among the player and the athletes. However, the speed and propensity for collisions, both incidental and intentional, make the game play particularly susceptible to concussion injuries. Concussion injuries can have a devastating impact on the life of the player moments after impact, and in a much greater number of cases the injury goes undetected causing adverse effects in the long term. Over time the medical community, and the broader athletic community, has made concerted efforts to increase awareness and have hypothesized several approaches to reduce the risk of concussion injuries in the sport. One such simple, yet novel, approach was the painting of an orange "look-up line" on the ice at the base of the boards. Hockey coaches teach players to look up, not look down on the puck, to brace themselves for the hit; therefore, the look-up line had the potential to provide an important warning to the player about to crash into the board (Vickers JN & Causer J. 2016). However, this idea, along with other similar approaches, were not able to be proved out in studies. On the other hand, factors such as rule changes targeting specific hits at highest risk of causing concussions have shown promise in professional leagues (Kuhn & Gary, 2015).

The purpose of this paper is to determine the effect of rule changes on concussion injuries in Youth Hockey. There is a high prevalence of concussion injuries in hockey and, as a result, a general concern among parents regarding safety of young players. While some rule changes against direct intentional hits, in particular to the head, have been implemented, the effectiveness of these rule changes are not well understood. A better understanding of effectiveness of rule changes already implemented will better inform opportunities for further rule changes to make the sport safer.

Overview of Contact Situations in Hockey

In hockey, there are numeral permutations and combinations of situations that can result in concussion. These contact situations can be divided into 6 categories according to their severity (Eskola & Piispanen, 2014):

1. Brush: A brush is a minor contact in the battle for the puck possession. This is the most common contact situation in hockey.
2. Bump: Similar to a brush, the bump is not intentional and only has the minor effect of pushing the opponent away from his or her direction of travel.
3. Body contact: This contact situation is defined as one that takes time and space from the opponent, but still isn't an offensive move towards the puck carrier. Rather, it is designed to interrupt the progress of the puck carrier, but not by going in the opposite direction to the player.
4. Body check: This is the first type of situation where the initiator of the check extends his or her body towards the opposing player.
5. Blow up hit: This is the most severe type of check, where the initiating player makes a hard concerted effort to throw his or her body into the hit, with the opposing player often not ready for the hit.
6. Incidental contact: These types of contacts are not intentional but can be quite severe and lead to injuries.

Main contact penalties, each of which are focus of this paper, that were the result of rule changes in youth hockey in the last decade are:

- Boarding: Player is pushed dangerously into the boards
- Checking from behind
- Direct/Indirect to the hit

One important note regarding contact is that, per rules set out by professional and youth hockey leagues, all contact must be made with the intention of puck possession, rather than to hurt the opposing player. This principle is critical to the rule framework and the penalties designated in the sport (Eskola & Piispanen, 2014).

Governing Bodies & Key Rule Changes in Youth Hockey

There are many governing bodies for hockey based on age and level of play. The key organizations relevant for this paper are:

- NHL: National Hockey League is the professional ice hockey league in North America comprising 32 teams, 25 in the USA and 7 in Canada (About the NHL).
- USA Hockey: USA Hockey is the main youth hockey organization that supports and develops grass-roots hockey programs amongst the youth of America. This organization was previously known as the Amateur Hockey Association and changed its name to USA Hockey in the early '90s (USA Hockey, 2023).
- NFHS: The National Federation of State High School Associations is the overarching body that manages rules of competition for most high school sports and activities in the United States. This body governs rules for all high school sports – for hockey, NFHS and USA Hockey rules are typically aligned.

The focus of rule changes of this study are those implemented by NFHS. The most impactful, and the subject of this study, rule changes that were implemented were as follows (NFHS Rules Changes Affecting Risk (1982-2023)):

- In 2014, specific language was added to penalize hits on players not in a position to defend themselves. These hits are often referred to as blind side hits. Multiple layers of penalties were added (i) first level penalty for Boarding and Checking from Behind were increased to a 5 minute Major penalty (ii) malicious hits could result in a Major & Misconduct penalty or a disqualification from the game.
- In the 2016-2017 timeframe, any direct contact to the head or neck area was determined to be a flagrant penalty and indirect contact to the same body area would also be penalized. “Direct contact occurs when the initial force of the contact occurs to the head or neck area. Indirect contact to the head or neck area shall be penalized. Indirect contact occurs when the initial force of the contact begins below the neck and progresses upward to the head or neck area. Revised language within required equipment for goalkeepers to reflect current vocabulary to increase effectiveness for all constituents. (NFHS Rules Changes Affecting Risk (1982-2023))”

Review of Previously Related Research

Studies conducted on the topic of concussion injuries related to hockey fall into one of the following categories (Kuhn & Gary, 2015):

- Incidence rate of concussion in the NHL (1986-2012): The incidence of concussion rates in NHL have varied between 2-3 concussions/100 games. While this paper is focused on incidence of concussion injuries in high school hockey, the NHL data does provide a good benchmark.

- Additionally, NHL implemented a major rule change (Rule 48), intended to eliminate hits to the head. This is somewhat equivalent to the NFHS rule changes of 2014-2016 for High School hockey. The long-term impact of Rule 48 on incidence of concussions in NHL are not clear.
- Incidence rate of concussion by position in the NHL: Several studies conclude that forwards are almost twice as likely to be concussed as their defensemen counterparts. Concussions in goalies are far lesser.
- Incidence rate of concussion by mechanism in the NHL: These studies tried to delineate the mechanism of the concussion, including puck possession at the time of contact, open ice vs. perimeter, collision between players, head contact with the board.
- Equipment & other considerations for concussion in the NHL: These studies analyzed the difference in equipment such as visor (device attached to the front of a helmet to reduce potential of injury to the face)
- Rink Size: Studies have been able to utilize the difference in sizes between rinks for NHL, Winter Olympics and World Junior Championships to show that larger rink sizes can significantly reduce collisions and risk of injuries.

Research Methodology for Measuring Impact of NFHS Rule Changes

This paper will analyze the impact of NFHS rule changes between the periods of 2014-2016 on concussion injuries in high school hockey. The primary data source for all analysis will be National Electronic Injury Surveillance System (NEISS). “The primary purpose of NEISS is to collect data on consumer product-related injuries occurring in the United States. NEISS is based on a nationally representative probability sample of hospitals in the U.S. and its territories. Each participating NEISS hospital reports patient information for every emergency department visit associated with a consumer product or a poisoning to a child younger than five years of age. (National Electronic Injury Surveillance System (NEISS)”.

NEISS provides several important attributes around a given case of concussing, including date of treatment, age of player, sex, race, body part involved and diagnosis. Additionally, for each case, the data source includes descriptive case notes that provide insights into the mechanism of the injury. One such example of the narrative for an actual case is “16YOM, GOT CHECKED IN THE CHEST PLAYING ICE HOCKEY " KNOCKING THE WIND OUT OF ME" THEN LATER DEVELOPED HEADACHE AND PHOTOPHOBIA, DX: CONTUSION OF CHEST WALL; CONCUSSION WITHOUT LOSS OF CONSCIOUSNESS". One of the key limitations of the data from NEISS is that it only includes data reported in hospital settings. Many hockey concussions are not reported by the team management, and even fewer result in a hospital visit. However, this data should still provide insights into trends for the most serious of the concussion injuries in hockey and findings can be extrapolated to less severe injuries that may not be reported to the hospital (NEISS).

Methods

1. Download National Electronic Injury Surveillance System data for hockey related injuries between the period of 2010-2023
2. Filter for injuries with diagnosis of concussion and age range between 13 and 18.
3. Manually code data based on hospital notes. These notes are not structured - an example is: “16YOM, GOT CHECKED IN THE CHEST PLAYING ICE HOCKEY " KNOCKING THE WIND OUT OF ME" THEN LATER DEVELOPED HEADACHE AND PHOTOPHOBIA, DX: CONTUSION OF CHEST WALL; CONCUSSION WITHOUT LOSS OF CONSCIOUSNESS". Manual clean up of data would involve adding coding for mechanism of injury (player to player, player to ice, player to board, result of a hit vs. fall). Create columns for the following - Checked, P2P (Player to Player), P2B (Player to Board), P2I (Player to Ice);

4. For Checked Column, filter on the criteria of - “checked”, “hit”, “body slammed” (cannot contain “hit the ice”)
5. For P2B Column, filter on the criteria of “boards”
6. For P2P, filter on the criteria of “collided with another player”
7. For P2I, filter on the criteria of “fell on the ice”, “ice” (but cannot have “ice hockey”)
8. Count the absolute number of concussions each year.
9. Graph the number of concussions above by intentional hit, checking was involved, and by mechanism of the injury (player to player, player to ice etc.) .

Statistical Analysis

Statistical analysis was performed using the using Data Analysis module of Analysis Toolpak Add-In for MS Excel 365. Analyses performed included mean concussions and unpaired Student t tests. Statistical significance was set at $P < .05$. In addition, to control for the transition process, the years 2014, 2015 and 2016 were removed from analysis when comparing trends pre- and post-implementation of the rule. Years 2020 and 2021 were also removed to control for COVID-19 related disruption in game play.

Results

Prior to the implementation of USA Hockey Rule Changes, between January 1, 2010 and December 31, 2013, the mean concussions among youth hockey players between ages of 13-18 were 69.75 concussions/year. The rule changes were implemented between 2014 and 2016. After the implementation of these changes, for the period between January 1, 2017 and December 31, 2023 (excluding 2020 and 2021 due to COVID 19), the mean number of concussions declined to 43.8 concussions/year (P=.015).

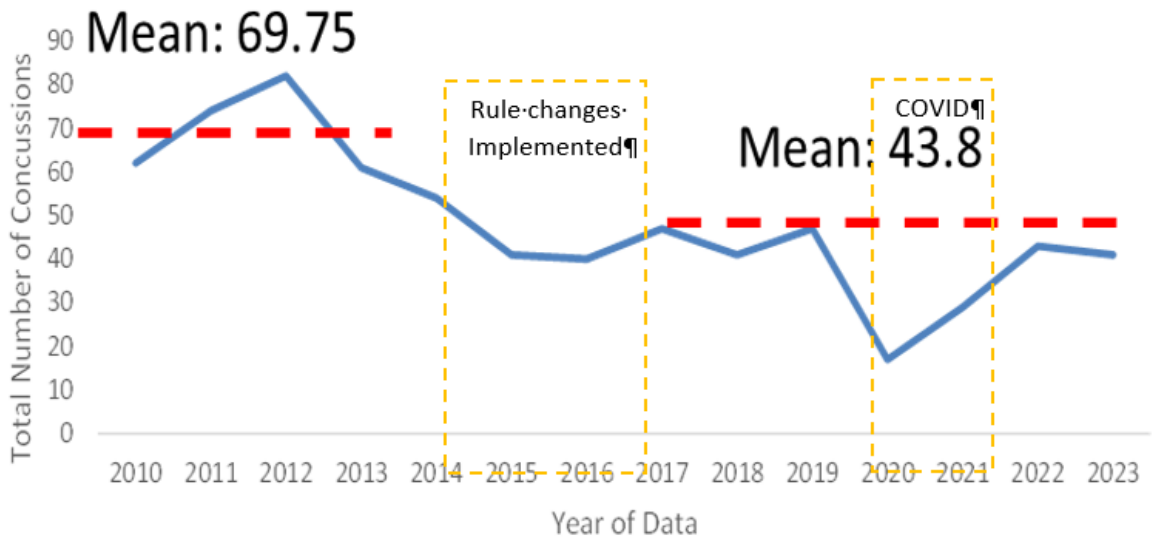

Figure 1. Total Number of Concussions vs. Year of Data

Table 1. Concussion Injuries in Youth Hockey, By Cause of Injury, By Year

	'10	'11	'12	'13	'10-'13 Avg	'14	'15	'16	'17	2018	2019	'22	'21	'22	'23
All Concussions	**62**	**74**	**82**	**61**	70	54	41	40	47	**41**	**47**	17	29	**43**	**41**
% Change vs. '10-'13 avg.										***(32.6%)***	***(41.2%)***			***(58.4%)***	***(38.4%)***
Concussions From Intentional Checks	**30**	**33**	**33**	**25**	30	28	21	23	25	**19**	**24**	14	19	**29**	**11**
% Change vs. '10-'13 avg.										***(17.4%)***	***(37.2%)***			***(37.2%)***	***(4.1%)***
Concussions From Accidental Falls	**41**	**49**	**36**	40	26	20	17	22	**22**	**23**	3	10	**14**	**30**	**41**
% Change vs. '10-'13 avg.										***(44.3%)***	***(44.3%)***			***(74.7%)***	***(64.6%)***

Table 2. Statistical t-Test comparing concussions from 2010-2013 vs. 2017-2023

	Concussions in 2010-2013	***Concussions between 2017-2023 (excluding 2020 and 2021)***
Mean	69.75	43.8
Variance	101.5833333	9.2
Observations	4	5
Hypothesized Mean Difference	0	
df	3	
t Stat	4.972411111	
P(T<=t) one-tail	0.007813783	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.015627565	
t Critical two-tail	3.182446305	

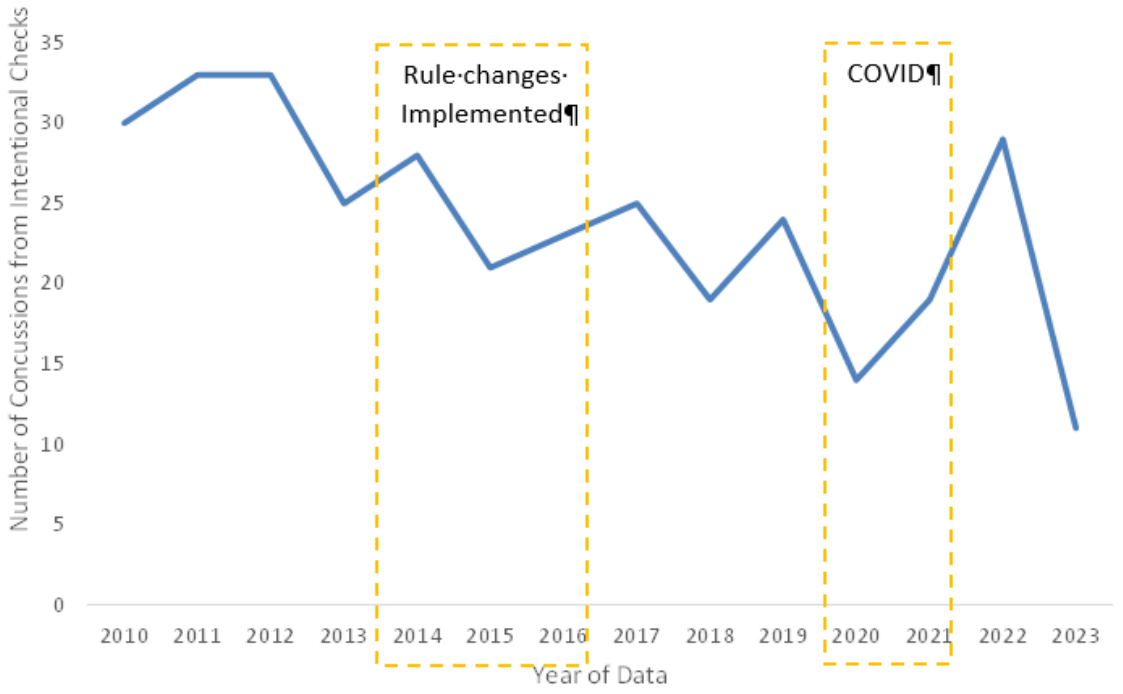

Figure 2. Concussions Resulting from Intentional Checks vs. Year of Data

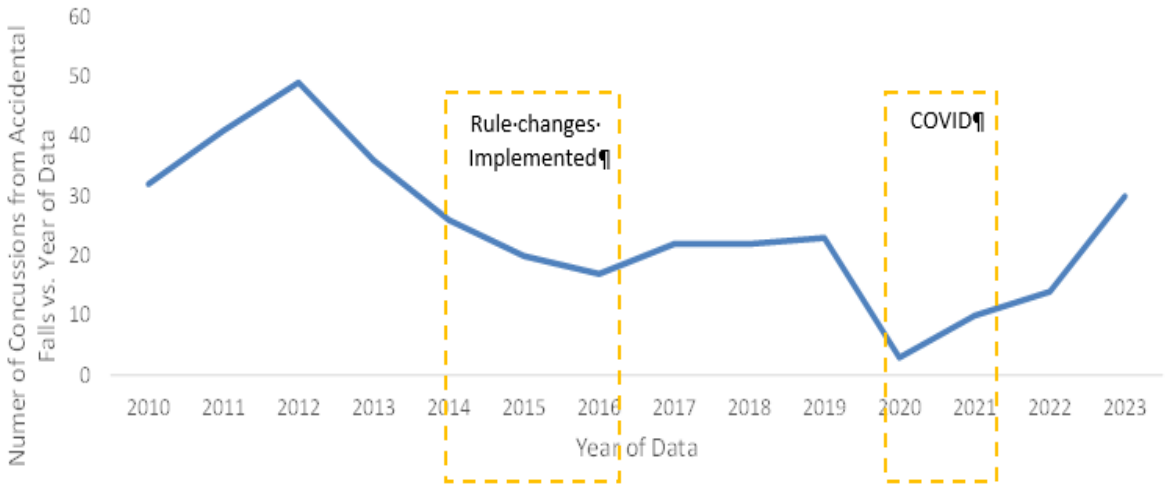

Figure 3. Concussions Resulting from Accidental Falls & Collisions vs. Year of Data

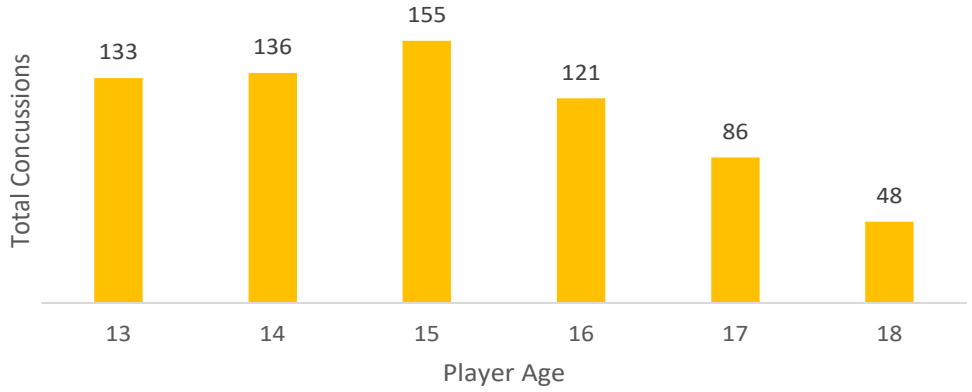

Figure 4. Total Concussions by Player Age (2010-2023)

Discussion

Observations

In addition to measuring total concussions, significant effort was made to attempt to distinguish between accidental injuries versus intentional hits. As rule changes are directed only at intentional hits, these would be important to discern. The determination of an accidental vs. intentional hit is somewhat subjective. The doctor's narrative included in NEISS data was used to make this determination. The following algorithm was used to make the determination:

- Each concussion injury was broken down into the following mechanism: Player To Player (P2P), Player To Ice (P2I), Player To Board (P2B), Direct Hit (DH)
- The narrative was scanned to determine whether player was "checked" or "boarded' or other indications of being hit; then remaining narrative was examined to classify the mechanism of injury to one of 4 types (P2P, P2I, P2B, DH)
- Any indication of "checking", "boarding" or other forms of hit were classified as hits
- P2I, P2P, P2B injuries without evidence of intentional hits were classified as accidents

Analysis

Years 2010-2013 were used as a baseline years - concussions after rule changes were compared with the average number of concussions between 2010-2013. Since rule changes were brought into effect between 2014 and 2016, it is assumed that 2017 was used to streamline enforcement among youth hockey programs. 2020 and 2021 data appears to be impacted by COVID with concussions down significantly relative to prior years - as a result these years were excluded from the key analysis. Since the most impactful rule changes occurred between the period of 2014 and 2016, the number of concussions before 2014 and after 2018 (adding 2 years of buffer for rule changes to be enforced consistently) were evaluated. The number of concussions, especially those due to intentional hits (checking), after 2018 should be lower than before 2014. 2018, 2019, 2022 and 2023 years are used as post rule change years to measure impact on concussions; in each of these four years total concussions declined meaningfully compared to the baseline average of 2010-2013. Concussions from accidental collisions declined more than those from intentional checks – this finding was surprising as rule changes were

targeted at intentional checking, so greater reduction was expected here. The anomaly could be explained by the treating physician inexperience with hockey or due to error in interpreting physician narrative.

It was also noted that the number of concussions declined with age. In the period between 2010 and 2023, 18 year olds experienced 60% less concussions than 13 year olds. The number of concussions increases between ages 13 and 15 and then declines as the player gets older. This decline can likely be attributed to player experience; though increasing body mass and intensity of the game would suggest greater severity of the injury. Also, the steep drop at 18 may be due to students moving to college level hockey, where concussion injuries are recorded differently.

Conclusion

The purpose of this experiment was to determine the effect of USA Hockey Rule Changes on Concussion Injuries in Youth Hockey. While few rule changes against direct intentional hits, in particular to the head, have been implemented, the effectiveness of these rule changes are not well understood. A better understanding of effectiveness of rule changes already implemented will better inform opportunities for further rule changes to make the sport safer.

The NEISS data supports the hypothesis that if USA Hockey rule changes between the periods of 2014 and 2016 were analyzed, the incidence of concussions as reported by NEISS for the periods before 2014 will be significantly higher than incidence of concussion injuries in the period after 2016. Total concussions after implementation of rule changes declined (41.2%), (32.6%), (38.4%) and (41.2%) in 2018, 2019, 2022 and 2023 respectively when compared against the average of baseline years of 2010-2013. Intentional injuries declined (37.2%), (20.7%), (4.1%) and (63.6%) in 2018, 2019, 2022 and 2023 respectively when compared against the average of baseline years of 2010-2013. Many hockey fans, student athletes and even parents believe that the rule changes such as “boarding” “penalties against direct hit” go against the spirit of the game and do not really prevent injuries. The data in this paper shows conclusive evidence that rule changes have a clear impact on reducing concussion injuries.

The interpretation of medical narrative is critical in evaluating whether an injury was preventable (due to intentional hit) or not. Medical staff not familiar with hockey can leave out detail regarding an intentional hit and characterize the mechanism as a simple fall, resulting in misclassification and erroneous data. This error could be further managed by matching patients’ records with rink records. This would require more geographically focused studies and would also require rinks to share data.

Concussion injuries can be devastating – they are a constant source of worry for parents, athletes and medical practitioners. Recovery and post concussion management is taxing on student health and academics and in certain cases has difficult prognosis. In the long-term, concussions can lead to neurological deficits such as memory loss, depression and Alzheimers. In more severe cases, hospital management can also be a financial strain. Preventative measures explored in this paper provide a low cost and low impact way of reducing the incidence of these injuries, making the game safer for student athletes.

This paper examines the impact of the last major batch of rule changes in youth hockey on concussions; however, significant other areas of investigation remain. In the stands, there continue to be many debates on additional rule changes such as making penalties for direct hits more severe and removing checking altogether. Rules can potentially also be tiered by age, sex and level of play. Rink size also offers the promise of reducing injuries. International sized rinks are wider than NHL rinks and afford players an extra 3,000 square feet of ice to skate through. Some preliminary studies suggest that there were significantly fewer collisions, checks and other impacts in the international sized rinks (Kuhn & Gary, 2015). Factors such as rink size and other rule changes should be investigated to determine their potential in preventative concussions in youth hockey.

Limitations

One of the key limitations of the data from NEISS is that it only includes data reported in hospital settings. Many hockey concussions are not reported by the team management, and even fewer result in a hospital visit. However, this data should still provide insights into trends for the most serious of the concussion injuries in hockey and findings can be extrapolated to less severe injuries that may not be reported to the hospital (NEISS).

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