2016

Evaluation of the Effect of Policy Change on Physical Contacts in Youth Ice Hockey Using Video Analysis

Krolikowski, Maciej

Krolikowski, M. (2016). Evaluation of the Effect of Policy Change on Physical Contacts in Youth Ice Hockey Using Video Analysis (Unpublished master's thesis). University of Calgary, Calgary, AB. doi:10.11575/PRISM/25993

<http://hdl.handle.net/11023/3421>

Downloaded from PRISM Repository, University of Calgary

UNIVERSITY OF CALGARY

Evaluation of the Effect of Policy Change on Physical Contacts in Youth Ice Hockey Using
Video Analysis

by

Maciej Piotr Krolikowski

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN KINESIOLOGY

CALGARY, ALBERTA

SEPTEMBER, 2016

© Maciej Piotr Krolikowski 2016

Abstract

Objective: To determine the association between body checking policy change and the frequency and intensity of physical contacts in Bantam ice hockey players (ages 13-14).

Methods: This is a cohort study design. Video-analysis data includes 13 non-elite (lowest 70% by division of play) Bantam (ages 13-14) ice hockey games videotaped in Calgary, Alberta, Canada (2014-15 where body checking was permitted) and Vancouver, British Columbia, Canada (2014-15 where body checking was not permitted). Primary outcome measures include high intensity physical contact (body checking), as well as hooking and slashing behaviours.

Results: Lower incidence rates of high intensity physical contact were observed in Bantam ice hockey players in a league where body checking was not permitted [IRR= 0.09 (95% CI; 0.05-0.15)]. Players in a league where body checking was not permitted had significantly higher incidence rates of hooking and slashing behaviours [IRR= 1.81 (95% CI; 1.33-2.47)].

Conclusions: There was a lower incidence of higher intensity physical contacts in Bantam ice hockey players in a league where body checking is not permitted, whereas the incidence of hooking and slashing behaviours were higher. This research will inform the mechanisms explaining injury and will have important national public health implications (reduction of injury) for policy decisions related to rule enforcement in youth ice hockey.

Acknowledgements

I would like to acknowledge the Hockey Canada for their support and assistance in facilitating this research.

I would like to thank my supervisor, Dr. Carolyn Emery, and my committee members Dr. Luz Palacios Derflinger, Dr. Brent Hagel, and Dr. Luc Nadeau for their mentorship, patience, encouragement, and support for this thesis.

Thank you to everyone in the Sport Injury Prevention Research Centre for your support. I would also like to acknowledge Amanda Black for her mentorship and infinite patience. As well, I would like to thank Nicole Romanow for her mentorship and assistance in making this project run as smoothly as possible.

Thank you to all of the research assistants who have spent many hours in cold arenas in the data collection process. I would also like to especially thank Leticia Janzen and German Martinez for their splendid work on this project.

Thank you to my parents Agnieszka and Jacek Krolikowski who supported me greatly throughout my degree.

Finally, I would like to acknowledge the funding support for this research project provided by: Alberta Innovates Health Solutions, Canadian Institutes for Health Research, Alberta Children's Hospital Research Institute (Alberta Children's Hospital Foundation).

Table of Contents

CHAPTER 1: BACKGROUND	1
1.1 PROBLEM STATEMENT	1
1.2 RESEARCH PURPOSE	1
1.3 BACKGROUND	2
1.3.1 Ice Hockey	2
1.3.2 Risk of Injury and Concussion in Youth Ice Hockey	2
1.3.3 Concussion	3
1.4 RESEARCH RATIONALE	7
1.5 RESEARCH QUESTION AND SPECIFIC OBJECTIVES	8
1.5.1 Research Question	8
1.6 RESEARCH SIGNIFICANCE	9
CHAPTER 2: The Effect of Policy Change on Sport Injury: A Review of the Literature	10
2.1 INTRODUCTION	10
2.2 EFFECTIVENESS OF POLICY CHANGE IN YOUTH ICE HOCKEY	10
2.3 HEAD CONTACT IN SPORT	16
2.4 DISCUSSION	20
2.4.1 Critical Appraisal of the Current Body of Knowledge	20
2.4.2 Recommendations for Future Research	21
CHAPTER 3: Methods	23
3.1 BACKGROUND	23
3.2 STUDY POPULATION	23
3.3 PROCEDURES	24
3.3.1 Data Collection	24
3.3.2 Outcome Measures	25
3.3.3 Exposure Variables	26
3.4 STATISTICAL METHODS	27
3.4.1 Primary Objective	28
3.4.2 Secondary Objective	29
3.4.3 Exploratory Objectives	30
3.4.4 Inter- and Intra-rater agreement	31
3.4.5 Regular and Playoff Season Games	32

3.5 ETHICAL CONSIDERATIONS	32
CHAPTER 4: Results	34
4.1 SUMMARY CHARACTERISTICS	34
4.2 PRIMARY OBJECTIVE	35
4.2.1 Differences between a league that allows body checking and a league that does not allow body checking	35
4.2.2 Assessing for provincial differences between elite Bantam ice hockey players with no difference in body checking regulation.....	36
4.2.3 Sensitivity analysis for differences between regular and early playoff games.....	36
4.2.4 Player and physical contact characteristics in a league that allows body checking and a league that does not allow body checking.....	37
4.3 SECONDARY OBJECTIVE.....	42
4.3.1 Differences between Bantam ice hockey players with differing body checking experience	42
4.4 EXPLORATORY OBJECTIVES	42
4.4.1 Differences in all levels of physical contact made with the trunk and all other physical contact in a league that allows body checking compared to a league that does not allow body checking	42
4.4.2 Differences in all levels of PC made with the trunk and other types of PC in ice hockey players with differing body checking experience.....	45
4.4.3 Direct and indirect head contact	47
4.5 SUMMARY OF RESULTS	51
CHAPTER 5: Discussion.....	53
5.1 DIFFERENCES BETWEEN A LEAGUE THAT ALLOWS BODY CHECKING AND A LEAGUE THAT DOES NOT ALLOW BODY CHECKING	53
5.1.1 High intensity physical contact made with the trunk and other types of physical contact in leagues with differing body checking regulation	53
5.1.2 Exploratory analysis of all levels of intensity and all other PC in leagues with differing body checking regulation.....	55
5.1.3 Game, player, and PC characteristics in league with differing body checking regulation	57
5.2 DIFFERENCES IN PC MADE WITH THE TRUNK AND OTHER TYPES OF PC IN LEAGUES WITH DIFFERING BODY CHECKING EXPERIENCE.....	60
5.3 HEAD CONTACT IN LEAGUES WITH DIFFERING BODY CHECKING REGULATION.....	61
5.4 STRENGTHS	63

5.5 LIMITATIONS	65
CHAPTER 6: Conclusion	70
6.1 SUMMARY OF FINDINGS	70
6.2 PUBLIC HEALTH IMPLICATIONS	72
6.3 FUTURE DIRECTIONS	72
REFERENCES	74
APPENDIX A: SAMPLE SIZE CALCULATION	81
APPENDIX B: INTER- AND INTRA-RATER AGREEMENT	84
APPENDIX C: MEASURE OF PHYSICAL CONTACTS	86
APPENDIX D: INFORMATION ABOUT THE STUDY	88
APPENDIX E: MEASURE OF PLAYING TIME.....	90

List of Tables and Figures

Table 3.3.1 Definition of physical contact made with the trunk.....	26
Illustration 3.3.1 Definition of zones on the playing surface.....	27
Table 4.2.1 Incidence rates and incidence rate ratios (per 100 player minutes) of high intensity physical contact made with the trunk (levels 4 and 5), and hooking/slashing behaviours in Bantam ice hockey players playing in non-elite leagues in Calgary and Vancouver	35
Table 4.2.2 Incidence rates (per 100 player minutes) and incidence rate ratios of high intensity physical contact made with the trunk (levels 4 and 5), and hooking/slashing behaviours in elite Bantam ice hockey players playing in Calgary and Vancouver.....	36
Table 4.2.3 Incidence rates and incidence rate ratios (per 100 player minutes) of physical contact made with the trunk and other PC in elite Bantam ice hockey players in regular and early playoff games	37
Table 4.2.4 Summary player and Player Contact (PC) characteristics in non-elite Bantam ice hockey players in Calgary (body checking allowed) and Vancouver (body checking not allowed).....	38
Table 4.2.5 Number and proportions of physical contact made with the trunk in each location on the ice in non-elite Bantam ice hockey player in Calgary (2014-15)	39
Table 4.2.6 Number and proportions of other types of physical contact in each location on the ice in non-elite Bantam ice hockey players in Calgary (2014-15).....	39
Table 4.2.7 Number and proportions of PC made with the trunk in each location on the ice in non-elite Bantam ice hockey player in Vancouver (2014-15).....	39
Table 4.2.8 Number and proportions of other types of PC in each location on the ice in non-elite Bantam ice hockey player in Calgary (2014-15)	40
Table 4.2.9 Number and proportions of physical contact made with the trunk by score differential in non-elite Bantam ice hockey players in Calgary (2014-15).....	41
Table 4.2.10 Number and proportions of physical contact made with the trunk by period in non-elite Bantam ice hockey players in Calgary and Vancouver (2014-15)	41
Table 4.3.1 Physical contact made with the trunk (level 1-5) and other physical contact in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons)	42
Figure 4.4.1 Physical contact rates made with the trunk (levels 1-5) in non-elite Bantam ice hockey players playing in Calgary and Vancouver in 2014-15	43

Figure 4.4.2 Other types of physical contact rates in non-elite Bantam ice hockey players playing in Vancouver and Calgary in 2014-15	44
Table 4.4.1. Physical contact rates made with the trunk and other physical contact rates in non-elite Bantam ice hockey players in Vancouver and Calgary (2014-15)	45
Figure 4.4.3 Physical contact rates made with the trunk in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons).....	46
Figure 4.4.4 Other contact rates made with the stick and limbs in Bantam ice hockey players playing in Calgary 2013-14 and 2014-15	47
Figure 4.4.5 Direct head contact rates and associated physical contact made with the trunk in non-elite Bantam ice hockey players in Calgary and Vancouver	48
Table 4.4.2 Incidence rates and incidence rate ratios of indirect head contact and associated physical contact made with the trunk in non-elite Bantam ice hockey players in Calgary and Vancouver	49
Figure 4.4.6 Direct head contact and associated physical contact made with the trunk in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons)	50
Figure 4.4.7 Indirect head contact and associated physical contact made with the trunk in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons)	50

CHAPTER 1: BACKGROUND

1.1 Problem Statement

Ice hockey is a popular winter sport in Canada, with over 570, 000 youth players registered in the Hockey Canada program.¹ Despite the various benefits to the sport (e.g. sportsmanship, exercise, team building, specific motor skill acquisition), it is associated with among the highest rates of injury among youth sports in Canada.^{2,3} Body checking has been identified as the single most consistent risk factor for injury in youth ice hockey players, and it has been shown that the removal of body checking significantly decreases the risk of injury in the sport.³⁻⁷

While the reduction of injuries can be attributed to the removal of body checking in youth ice hockey, the relationship between body checking regulation and the frequency and intensity of physical contacts is less well known. Leagues with higher rates of higher intensity physical contacts may result in a higher rate of injury.^{7,8} Previous research focused solely on Pee Wee (11-12 year old) players playing at elite levels.⁸ It is important to continue to study the multifactorial association between body checking regulation and injury, as well as how this regulation affects playing behaviours in games over time, to help inform future injury prevention strategies.

1.2 Research Purpose

The purpose of this study is to evaluate the effect of body checking policy change to disallow body checking on the type, incidence, and intensity of physical contacts in Bantam ice hockey players using video analysis. Additionally, the incidence rates and types of physical contacts that include direct and indirect head contact will be described.

1.3 Background

1.3.1 Ice Hockey

1.3.1.1 Participation

Internationally, ice hockey is a very popular sport. Canada (>700,000 registered players), the United States of America (>500,000 registered players), and the Czech Republic (>100,000 registered players) lead the world in participation.⁹ The youth participation is exceptionally high in Canada, with over 570, 000 youth players registered.¹⁰

1.3.2 Risk of Injury and Concussion in Youth Ice Hockey

Ice hockey is associated with among the highest rates of injury in youth sport.^{2,3} The injury rate for youth ice hockey players was found to be 4.13/1000 player hours (95% CI: 3.67, 4.62), with ligament sprains, contusions, concussions, and muscle strains accounting for the greatest proportions of injury types.³ Among the high risk of injury, concussion accounts for the greatest proportion (18%) of specific injury reported in the sport, however there is converging evidence that concussions are being under-reported across many sports.^{3,11-13}

The risk of injury in ice hockey varies due to different factors including age group, level of play, player position, as well as game play versus practice.³ In a systematic review identifying risk factors for injury in youth ice hockey players, the risk of injury has been found to increase with age.^{2,4,14,15} Additionally, the risk of injury for players playing in a game is higher when compared to injuries resulted in practice (risk ratios range from 2.64 to 6.32).^{2,14,16} There is also some evidence that higher level of play increases the risk of injury, especially in Pee Wee (ages 11-12) players.^{2,3,17} Finally, both

forwards and defencemen have been found to be at a higher risk of injury than the other in separate studies, however both are consistently at a higher risk than goalies.^{2,4,14}

1.3.3 Concussion

1.3.3.1 Definition

According to the 2012 International Consensus Statement on Concussion in Sport, concussion has been defined as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.”¹⁸ There are several common features that define the nature of a concussion incorporating clinical, pathologic, and biomechanical injury constructs, including:

1. *Concussion may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an “impulsive” force transmitted to the head.*
2. *Concussion typically results in the rapid onset of short- lived impairment of neurologic function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.*
3. *Concussion may result in neuropathologic changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury, and as such, no abnormality is seen on standard structural neuroimaging studies.*
4. *Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in some cases symptoms may be prolonged.*

1.3.3.2 Symptoms and Signs of Acute Concussion

The diagnosis of acute concussion usually involves the assessment of a range of domains including clinical symptoms, physical signs, cognitive impairment, neurobehavioural features, and sleep disturbance. Additionally, a concussion history should be included in the evaluation of the injured and pre-participation patients.¹⁸ Suspected concussions can be diagnosed using any one or more of the following clinical domains:

1. *Symptoms: somatic (eg, headache), cognitive (eg, feeling like in a fog), and/or emotional symptoms (eg, lability)*
2. *Physical signs (eg, loss of consciousness, amnesia)*
3. *Behavioral changes (eg, irritability)*
4. *Cognitive impairment (eg, slowed reaction times)*
5. *Sleep disturbance (eg, insomnia)*

1.3.3.3 Child and Adolescent Athletes

Children (<12 years) and adolescent (12-18 years) athletes are considered to be a “special population” that must be treated differently after sustaining a concussion. Child and adolescent brains are structurally different than an adult brain, and an injury to a developing brain may lead to further complications later in life.^{18,19} It is agreed upon that no return to sport or physical activity should occur before the child has been able to return to school successfully and until the patient is completely asymptomatic regardless of level of participation. Thus, while most concussions resolve within 7-10 days, the return to play period may be longer for children and adolescent athletes.¹⁸

1.3.3.4 Concussion and Injury Prevention Methods in Youth Ice Hockey Players

Relative to other sports, youth ice hockey players are among those at the highest risk of injury and concussion.^{20,21} To date, prevention is the most effective management tool for concussion.²² There are several proposed preventative measures to reduce the risk of concussion in youth ice hockey, including protective equipment (such as mouthguards and helmets) and rule changes; however, there is limited evidence for the effectiveness of these strategies and all require further investigation.^{18,23} Whereas the introduction of helmets has resulted in a decrease in catastrophic head injuries and mouthguards have an important role in preventing dental and orofacial injury, neither have been shown to be associated with a significant decrease in risk of concussion in youth ice hockey.^{18,24} Recently, in order to reduce the number of head injuries suffered in hockey games, Hockey Canada introduced a “Zero-tolerance for head contact” rule.²⁵ However, it has been found that the risk of concussion increased after the policy change, most likely due to increased awareness and reporting of concussion compared to previous study years.²⁶ Alternatively, there is significant and growing high-quality evidence indicating policy allowing body checking is the single most consistent risk factor for concussion in youth ice hockey.^{6,27}

Body checking has been consistently associated with high rates of injury and concussion, accounting for 45-86% of injuries in youth ice hockey players.^{3,6,21,27} Hockey Canada defines body checking as “body contact primarily caused by the movement of the checker. That movement can be and often is, in a direction different than that of the puck carrier. The checker uses their body for the purpose of stopping the attacking progress of the puck carrier and/or to separate the carrier from the puck”.²⁸ Historically, there has been great debate over the age that body checking should be introduced in youth ice hockey. In Canada, body checking was

introduced at the Pee Wee (ages 11-12) level, with four provinces introducing the skill at the Atom (ages 9-10) level and one province (Quebec) introducing it at the Bantam (ages 13-14) level.²⁹ Body checking was delayed until the Bantam level due, in part, to evidence that showed penalties and aggressive play were more prevalent when allowing younger players to body check.³⁰ A historical cohort study found that introducing body checking in Atom players resulted in an odds ratio of 1.83 (95% CI: 1.60, 2.11) for checking-related injuries compared to Atom players where body checking is not allowed.⁶ As well, the odds ratio for concussion was slightly higher [OR: 1.42 (95% CI: 0.98, 2.05)]. Another prospective cohort study examining Pee Wee players conducted in Alberta (where body checking was allowed in this age group) and Quebec (where body checking is introduced at a later age) showed that body checking in this age group resulted in a greater than 3-fold risk of concussion [IRR: 3.88 (95% CI: 1.91-7.89)], injury [IRR: 3.26 (95% CI: 2.31-4.60)], severe concussion [IRR: 3.61 (95% CI: 1.16-11.23)], and severe injury [IRR: 3.30 (95% CI: 1.77-6.17)].²⁷

1.3.3.5 Analyzing Physical Contacts in Youth Ice Hockey Players Using Video Analysis

The policies allowing BC at the Pee Wee level in Alberta and the Bantam level in Québec provided a unique opportunity to examine whether the incidence, the intensity, and the type of physical contacts (PC) differ for Pee Wee ice hockey players in a league that permits body checking and a league that does not. Body checking (i.e. higher intensity PC) is defined as a tactic used to gain advantage on the opponent with the use of the body, often in a direction different than that of the puck carrier. The checker uses their body for the purpose of stopping the progress of the puck carrier and/or to separate the carrier from the puck.³¹ Lower intensity PC refers to body contact, i.e. incidental contact that occurs when two players are vying for control of the puck. A cohort study examining physical contacts in these players analyzed 10 games in

each city using a system with defined levels of trunk contact (1-5) with levels 4 and 5 corresponding to body checking as defined by Hockey Canada.⁸ The authors found more frequent PCs in Calgary than in Quebec [Incidence Rate Ratio (IRR): 1.39; 95% CI: 1.09, 1.88] and more frequent higher intensity physical contacts in Calgary as well (Level 4 IRR: 7.01; 95% CI: 3.43, 14.33, Level 5 RR: 12.72; 95% CI: 4.48, 36.14). While global rates of other contacts (hooking, slashing, hitting with the limbs or stick) did not differ between Calgary and Quebec City, differences were seen when the contacts were distributed by type (Hooking IRR: 0.89; 95% CI: 0.84, 0.95; Slashing with hockey stick IRR: 0.91; 95% CI: 0.85, 0.97). Hooking and slashing may be used to indirectly limit the progression of the opponent. The results suggest that a higher intensity in PC may be related to an increased risk of injury and concussion in Alberta compared with Québec, corresponding with previous research that found an increased rate of injuries and concussion in young Pee Wee ice hockey players who were playing with BC.^{6,7} The practical implications of this study and the methods used can be used by policy makers when making decisions in regards to the introduction of body checking, as well as for coaches to adapt their teaching of body checking accordingly in leagues with differing body checking regulation.

1.4 Research Rationale

Research in concussion in a youth sport population is an emerging field with many areas that still need further investigation. There are a number of preventative measures implemented to reduce the risk of concussion in youth ice hockey players, with rule changes (specifically banning body checking in Pee Wee ice hockey leagues) having a significant body of support in terms of effectiveness. Basing policy decisions on evidence-based research could mean fewer players are removed from the sport due to injury, which could translate into fewer hospital visits and admissions, less time and money spent on treatment within the healthcare system, and fewer

hours missed at school, work, sport, and other activities for youth who can then remain physically and mentally active. It is important to continue to study the multifactorial association between body checking regulation and injury, as well as how this regulation affects playing behaviours in games over time. Additionally, any changes in game play and techniques used to separate the player from the puck should be taken into account by the coaches..

1.5 Research Question and Specific Objectives

1.5.1 Research Question

What is the association between body checking policy change disallowing body checking and the frequency and intensity of physical contacts in Bantam ice hockey players?

Primary Objectives

- 1) To compare the incidence of higher intensity physical contact (levels 4 and 5) and other types of contact (specifically hooking and slashing) in Bantam ice hockey players playing in a league that allows body checking and in a league that does not allow body checking

Secondary Objective

- 2) To compare the incidence of higher intensity physical contact and other types of contact in Bantam ice hockey players with differing body checking experience

Exploratory Objectives

- 3) To compare each level of intensity of physical contact and other types of contact in Bantam ice hockey players playing in a league that allows body checking and in a league that does not allow body checking
- 4) To compare direct and indirect head contact in Bantam ice hockey players with

differing body checking regulation and in Bantam ice hockey players with differing body checking experience

1.6 Research Significance

This project will move sport injury prevention research forward in youth ice hockey by evaluating the effect of injury prevention strategies in this population. This will provide a unique look at the behaviours of the players and how they are affected by a nation-wide rule change. This research project will have important national public health implications (reduction of injury) for policy decisions related to rule enforcement in youth ice hockey. Additionally, the trends of player behaviour in response to new body checking rule enforcement will inform coaches and allow them to adapt their teaching accordingly.

CHAPTER 2: The Effect of Policy Change on Sport Injury: A Review of the Literature

2.1 Introduction

Relative to other sports, youth ice hockey players are among those at the highest risk of injury and concussion.^{20,21} To date, prevention is the most effective management tool for concussion.²² There are several proposed preventative measures to reduce the risk of concussion in youth ice hockey, including protective equipment (such as mouthguards and helmets), increase in neck strength, and rule changes; however, there is limited evidence for the effectiveness of these strategies and all require further investigation.^{18,22–24,32} Whereas the introduction of helmets has resulted in a decrease in catastrophic head injuries and mouthguards have an important role in preventing dental and orofacial injury, neither have been shown to be associated with a significant decrease in risk of concussion in youth ice hockey.^{18,24} Alternatively, there is significant and growing high-quality evidence indicating body checking is the single most consistent risk factor for concussion in youth ice hockey.^{3,6,21,27}

2.2 Effectiveness of Policy Change in Youth Ice Hockey

The rules of play in sport may have a significant and lasting impact on the prevention of injury and concussion, however new rules should be correctly enforced, adhered to by players and coaches, and subsequently assessed to determine effectiveness.^{22,33} “Fair play” rules and restricting the exposure to injurious contact have been shown to be effective in epidemiologic studies in ice hockey.^{34,35}

The “fair play” concept was developed in response to the perceived increase in violence in youth ice hockey where teams have points added to the season for staying under a pre-

established number of team penalties per game.^{34,35} Teams that used foul play during games may have points subtracted for committing too many penalties during the game. Individual players may be suspended if they exceeded a preset number of penalties in a game, as well coaches may be suspended for being regularly penalized for illegal play. In Quebec, the fair play rules have shown to successfully decrease the number of penalties in youth ice hockey players.³⁵ Notably, there was a substantial decrease in major penalties (such as roughing and fighting) and 50% fewer game suspensions when fair play was used.³⁵ In one ice hockey tournament, five randomly selected teams were followed to study the effects of fair play rules on injury.³⁴ Injury rates captured in the tournament were compared to National Collegiate Athletic Association college ice hockey game injury rates and Canadian Athletic Injury Reporting System injury rates. The authors found a ratio of regular-rules injury to fair-play rules injuries as 5:1, concluding that fair play rules are effective in reducing injuries due to infractions.³⁴

Body checking has been consistently identified as a risk factor for injury and concussion in ice hockey players, accounting for 45-86% of injuries.^{3,6,21,27} Proponents of body checking argue that lowering the age at which body checking is introduced will not change the risk of injury and concussion.³⁶ Additionally, there is a pervasive belief in the general public that introducing body checking at an earlier age may prevent injuries later on, however there is no evidence to support this belief.²¹ In one retrospective study evaluating emergency department visits due to body checking and non-body checking injuries over 10 seasons in Ontario, 52.2% of the injuries were attributable to body checking.³⁷ The same study evaluated the risk of injury due to body checking after a 5-year pilot program in Ontario that lowered the age allowed for body checking from Pee Wee (ages 11-12) to Atom (ages 9-10). The results showed an increase in the odds of body checking-related injury in Atom level players after the rule change (OR: 2.20, 95%

CI: 1.70-2.84).

These findings are consistent with another study evaluating body checking-related injuries in Ontario during this rule change and comparing the injury rates with Quebec, where body checking is delayed until the Bantam level (ages 13-14).⁶ Macpherson et al. also evaluated injuries that resulted in hospital visits and found that players ages 10-13 in leagues that allowed body checking were at a two-fold greater risk of injury (OR: 1.86, 95% CI: 1.60, 2.11) with some evidence they were also more likely to suffer a concussion (OR: 1.46, 95% CI: 0.98, 2.05).⁶ In older players, the odds of receiving a checking injury were slightly higher (OR: 1.90, 95% CI: 1.36, 2.66), suggesting no benefit to allowing players to body check at an earlier age.⁶ However, these studies used hospital-based data, which could lead to an underestimation of injuries that are perceived as less serious. More specifically, concussion is known to be a widely underreported injury in youth sports primarily due to athletes' inability to recognize concussive symptoms, as well as a lack of belief that the symptoms are serious enough to warrant medical attention.^{13,38} Macpherson et al. note that injuries were classified as "checking-related" only if checking was explicitly mentioned in the injury forms, which may have underestimated the number of checking-related injuries. Nonetheless, body checking is widely recognized as a risk factor for injury.

There is strong evidence that delaying body checking until the Bantam level (as opposed to introducing it earlier) has been found to be protective against concussion in Pee Wee players.²⁷ Emery et al. conducted a prospective cohort study following Pee Wee (ages 11-12) players in Alberta and Quebec during the 2007-08 hockey season, which allowed for a comparison between players in Alberta where policy allowed bodying check and players in Quebec where policy did

not allow body checking.²⁷ Using a previously validated injury surveillance system, the results of the study showed that playing in a league that allows body checking compared to a league that does not allow body checking resulted in a three-fold increased risk of all game-related injuries, concussions, severe injuries (>7 days time loss), and more severe concussions (>10 days time loss) among the players compared with a league that does not allow body checking.^{3,27}

Additionally, a study examining the effects of body checking policy change (i.e. removal of body checking in non-elite Pee Wee ice hockey players in Ontario in 2011) found a three-fold increased risk of injury and concussion [Injury IRR: 2.97 (95% CI: 1.33-6.61), Concussion IRR: 2.83 (95% CI: 1.09-7.31)].³⁹ The injury and concussion rates of elite Pee Wee ice hockey players (where body checking was allowed in both provinces) did not differ, suggesting no provincial effect in differences in injury and concussion.³⁹ Body checking experience in older players has also been assessed as injury rates may increase due to players learning a novel skill. A study comparing injury and concussion rates in Bantam ice hockey players with two years of body checking experience in Pee Wee players (Alberta) and Bantam ice hockey players with no body checking experience (Quebec) found no difference in the risk of all injury, concussion, and severe concussion in players that did not have any body checking experience.⁴⁰

The economic burden of allowing body checking in younger age groups has been examined. The results of a study examining the cost-effectiveness of removing body checking from Pee Wee ice hockey showed a 2.5 fold increase in injury-related healthcare cost in Pee Wee players allowed to body check in Alberta (\$473/1000 player hours, 95% CI: \$358, \$603) compared with players that were not allowed to body check in Quebec (\$184/1000 player hours, 95% CI \$120, \$257). The authors also projected the results onto Alberta players in the 2011-12 season if they were to ban body checking, and concluded that an estimated 1273 injuries and

\$213, 280 in healthcare costs would be avoided in one season.⁴¹

Although evidence exists that playing in a league that allows body checking increases the risk of injury and concussion, it is important to understand the relationship between body checking regulation and the frequency, intensity, and types of physical contacts (incidental body contact and body checking) that occur during play. Examining physical contacts in leagues with differing body checking rules can shed light on the difference in physical contact behaviours in response to their respective body checking rules. Malenfant et al. conducted a prospective cohort study where Pee Wee ice hockey games were recorded in Calgary (where body checking was allowed) and Quebec (where body checking was not allowed).⁸ Physical contact is performed with the trunk and is defined by 5 categories: Level 1 contact refers to very light physical contact in players not moving forward, Level 2 contact refers to light physical contact between players moving in the same direction, Level 3 contact refers to moderate physical contact between two players skating in the same direction, Level 4 contact refers to the application of a forceful physical extension of the body to an opposing player who is skating in an opposite direction, and Level 5 contact refers to a deliberate extension to the opposing player who is skating in an opposite direction in order to initiate contact with excessive force.⁸ Levels 4 and 5 reflect body checking as defined by Hockey Canada. As well, other physical contacts (such as hitting or using the stick) were analyzed. The main findings of the study included a higher rate of heavy intensity physical contacts in Alberta (Level 4 Rate Ratio [RR] = 7.01 [95% CI: 3.43, 14.33] and Level 5 RR = 12.72 (95% CI: 4.48, 36.14)). As the literature shows that playing in a league that allows body checking increases the risk of injury, these results suggest that a league with higher frequency and higher intensity of physical contact may be related to the increase in risk.⁸ Additionally, the players in Quebec may have been more likely to use hooking and slashing to

slow the progress of the puck carrier (Calgary: hooking RR= 0.89 [95% CI: 0.84–0.95], slashing RR = 0.91 [95% CI: 0.85–0.97]). Coaches in body checking and non-body checking leagues should recognize the differences in the players' behaviours in their respective leagues.

Video analysis has also been used to determine the effects of body checking experience in youth ice hockey players. Bantam ice hockey players with body checking experience at the Pee Wee level (Calgary) were observed to have committed more light intensity trunk contact [IRR_{Adjusted}: 1.38 (95% CI: 1.28-2.29)], as well as committing more holding [IRR_{Adjusted}: 1.04 (95% CI: 1.02-1.07)] and slashing [IRR_{Adjusted}: 1.38 (95% CI: 1.07-1.77)] behaviours.⁴² No significant difference was found between provinces in terms of higher-intensity contacts (levels 4 and 5). However, the higher incidence of PCs made on the puck carriers in Calgary may be indicative of more effective body checking, although the specific effectiveness of body checking was not assessed in this study.

Some limitations of studies using video analysis include the quality of the video, “blind spots” that the camera cannot physically film due to where the camera is positioned, and misclassifying the physical contacts. However, since the camera quality and the blind spots would not be different between leagues with differing body checking regulation, and since the level of agreement between testers was regularly reviewed, these limitations would not invalidate the study, rather they would bias the results towards the null. Additionally, there is no precise way to measure the levels of intensity of the PCs using this method, as well it is not possible to know the real intention of the player committing the physical contact. Despite these limitations however, video analysis can be a very useful tool in determining the effects of rule changes on the behaviours of the players (as well as their adherence to the rule).

2.3 Head Contact in Sport

According to the U.S Consumer Product Safety Commission (CPSC), there were an estimated 446, 788 sports- and exercise-related head injuries treated at emergency rooms in 2009 among children ages 14 and younger.⁴³ Due to the use of emergency room data the numbers are potentially higher. Regardless, the high number of head injuries in this age group is concerning. Rule changes aimed at reducing head injury incidence may be appropriate, especially where a definite mechanism can be identified and prevented in a particular sport.¹⁸ However, there is a paucity in the literature regarding the effectiveness of head contact policy changes on sport-related concussion.

Policy change aimed at limiting the exposure to head contact is shown to be effective when the diagnosis of the injury is clear. In American football, “spearing” is a method of tackling in which a player keeps their head out and arms by their side, essentially using their body as a spear, and often uses the top of the helmet as the initial point of contact. In response to the high rate of cervical spine injuries resulting from “spearing” (axial loading was identified as a mechanism of catastrophic cervical spine injuries in a review of game films), the National Collegiate Athletic Association banned “spearing” in 1976.⁴⁴ Similar changes were also put in place at the high-school level.⁴⁴ As a result of this rule change, subluxations and dislocations of the cervical spine decreased dramatically in the following decade (7.72/100,000 and 30.66/100,000 for high school and college athletes, respectively, in 1976, to 2.31/100,000 and 10.66/100,000, respectively, by 1987).⁴⁴ On the basis of these findings, it was concluded that the policy change resulted in a clear and definite reduction of injury. However, concussions were not a focus of the policy change or an objective of studies evaluating the effects of the policy change, therefore conclusions for this particular injury cannot be made.

In male professional soccer, stricter interpretations were put in place to lower the incidents of arm-to-head contact (high elbows) during heading duels in order to further lower injury rates due to foul play.⁴⁵ Infractions would result in an automatic red card, which would result in an ejection of the player from the game. Using video analysis of tournament games one year before and after the stricter policy enforcement, Bjorneboe et al. found a reduction (RR=0.72, 95% CI: 0.54, 0.97) in the incidence of arm-to-head incidents.⁴⁵ While the most common cause of head injuries include head-to-head or arm-to-head contact in professional soccer, this study did not have sufficient power to detect a decrease in head injuries due to the reduction of arm-to-head contact. However, the authors do note that they believe incidents serve as a surrogate measure of injury risk as the incidents represent events with a propensity for injury.^{45,46} Though, the authors did not specifically examine the risk of concussion. Also, issues specific to playing in a professional league may bias the injury reporting in professional players, although there is no reason to believe this would differ in the same league one year apart.

More stringent penalties for head contact in ice hockey has recently been introduced in ice hockey and there is a paucity of research examining the effectiveness of limiting head contact in hockey. In the 2010-11 season, the National Hockey League (NHL) banned all blind-side hits to the head, with a modification to the rule in the 2011-12 season that penalized all hits to the head.⁴⁷ To determine the effects this rule change has on the incidence of concussion, Donaldson et al. retrospectively collected concussion data on NHL players from the 2009-10 to 2011-12 seasons.⁴⁸ As well, concussion data was collected from the Ontario Hockey League (OHL) in the same seasons where hits to the head were banned since 2006-07 to compare the NHL data to a league where no major interventions were put in place during the data collection period. The authors found that the risk of concussion did not decrease after the introduction of the rule

change (1-way ANOVA: $F_{2,467}=0.87$, $p.>0.05$) as blindsided hits were found to be an uncommon cause of concussions in the NHL.⁴⁸ These results suggest that banning hits to the head may not be effective on its own as a strategy to reduce concussion incidence. However, there are certain pertinent limitations to this study. Namely, the authors did not have access to the medical records for final player diagnosis. Rather, all of the injury data was gathered from publicly available sources. This provides many challenges for gathering injury data from professional leagues as some teams might not want to make an injury publicly available due to fear of having that area targeted by opposing players.⁴⁸ As well, publicly available injury data may dissuade fans from appearing to games if their favourite player is not present, leading to financial concerns. These considerations, along with the elite level of play, must be made before attempting to generalize these results to other age groups within the sport, especially to youth players. Additionally, to determine objective incidence rates of head contact more objective tools are needed (such as video analysis and head telemetry).^{8,49}

Head Impact Telemetry (HIT) has been previously used to measure head impact magnitude in youth ice hockey players (13 years of age) and in conjunction with game footage in male and female collegiate ice hockey players.^{50,51} In the younger players, 14.2% of head impacts were sustained to the top of the head, with the impact magnitude being significantly higher than those to the other areas of the head.⁵⁰ This led the authors to believe that these findings reinforces the need to instruct youth ice hockey players to keep their heads up and be aware of their surroundings, as well that an impact to the top of the head results in greater head linear acceleration than players that kept their heads up. However, due to the small sample of players ($n=14$), only one concussion was clinically diagnosed. Therefore, further investigation is needed to identify the specific biomechanical factors associated with concussion in a sport

population.

In collegiate ice hockey players, HIT has been used in conjunction with video footage to determine the mechanisms of head impacts in this population.⁵¹ The predominant mechanism that resulted in head contact was contact with another player for both men (50.4% of head contacts) and women (50% of head contacts). The second-highest leading cause of head contact for both men and women was contact with the boards or glass (31.3% and 17.3%, respectively). The peak rotational acceleration of the head impacts were greater for men, which is attributed to the fact that body checking is permissible in men's hockey and not in women's hockey.⁵¹ However, even though checking is not allowed in women's collegiate ice hockey, the results show that women are still subject to frequent and high magnitude head contact. This may be attributed to the fact that many female ice hockey players are not taught checking skills and may be less prepared to absorb impacts due to not expecting the contact.⁵¹ Similarly to the HIT research done on younger ice hockey players, concussions were not a focus of the study, therefore conclusions cannot be made on the frequency and magnitude of head impacts and the risk of concussion.

In 2011, Hockey Canada introduced a “zero-tolerance for head contact” rule in an effort to reduce head injuries in ice hockey. This rule enforcement would penalize all intentional and unintentional contact to the head across all age groups. A historical cohort study using injury and exposure data from Pee Wee (ages 11-12) and Bantam (ages 13-14) players found an increase in the incidence of concussion after the rule was put in place compared to players playing in similar divisions before the rule was implemented [Pee Wee IRR = 1.89 (95% CI: 1.20-2.97), Bantam IRR = 2.29 (95% CI: 1.05-5.01)].²⁶ These results suggest that players are at a higher risk of

sustaining a concussion after a rule was put in place to limit the exposure to head contact in the game. However, the findings in this study reflect a trend of increasing concussion incidence in sport.⁵²⁻⁵⁴ Proposed explanations include the plausibility that youth ice hockey players are becoming bigger, stronger, and faster, however a more likely explanation is that the observed increased risk of concussion is related to an increased awareness and sensitivity in concussion diagnosis.⁵²⁻⁵⁶ Similar increases in the incidence of concussion has been observed in pediatric athletes' emergency room visits in the United States (100% in athletes ages 8-13, 200% in athletes ages 14-19 over a 10-year period).⁵⁶ Additionally, an increase in concussion incidence has been observed in at least two studies surveying sport-related injuries in high school sports.^{54,57} As such, further research is needed to evaluate the effect of head contact rules on limiting head contact and on their desired effects on the risk of concussion.

2.4 Discussion

2.4.1 Critical Appraisal of the Current Body of Knowledge

The major strength of the studies reviewed in assessing policy changes in youth ice hockey is the study design. The two studies conducted by Emery et al. are large prospective cohort studies which clearly indicate the temporal sequence between exposure and outcome.^{27,40,58} Another study clearly shows a higher injury risk with early introduction of body checking, however this data relies on hospital data.⁶ Therefore, injuries and concussions that did not result in a hospital visit were not included, which could lead to an underestimation of injuries that are perceived as less serious. It is evident that body checking is a strong risk factor for concussion in the pediatric population.

Studies of the effectiveness in limiting head contact to reduce head injury are sparse in

the literature. When the injury has a clear and definite diagnosis (such as catastrophic cervical spine injuries), the evidence is clear that limiting head contact reduces the risk of certain types of injury.⁴⁴ However, other studies examining head contact policy changes found mixed results in injury risk after they were put in place. The study examining the effectiveness of limiting arm-to-head contact in soccer players found a decrease in arm-to-head incidents, however the authors did not have sufficient power in seeing a reduction in head injury after the policy change was put in place, therefore sound conclusions cannot yet be made.⁴⁵ A study performed on NHL players after a head contact policy change found no change in the risk of concussion, however data was extracted from publicly available sources which may not represent the true number of concussion incidence in this population.⁴⁸ Additionally, as this study was performed on elite professional players, the generalizability to younger cohorts of varying levels of play is severely limited. A study that aimed to examine the effects of the “Zero Tolerance for Head Contact” rule enforcement change brought forward by Hockey Canada found an increase in concussion risk in youth ice hockey players after the rule change was put in place.²⁶ Although the data was collected prospectively and with consistent methodology across all years (2008-2012), it is likely that the increase in concussion incidence is related to an increase in awareness of concussion. This bias severely affects any conclusions that can be made from assessing the effectiveness of the policy change. Finally, using Head Impact Telemetry, studies have shown the risk of head impacts in youth and collegiate ice hockey players and their associated mechanisms.^{50,51} However, a definite link between head impact magnitude and concussion has not yet been made.

2.4.2 Recommendations for Future Research

While there is strong evidence for the effectiveness of delaying body checking, there is a paucity of research examining the types and intensities of physical contacts associated with

differing body checking regulations in youth. Using video analysis and a validated surveillance system, physical contacts have been objectively measured in hockey games, however the analysis was restricted to upper-level Pee Wee (ages 11-12) players.⁸ More research is needed for other age groups and levels of play, as well as the measurement of the effects of differing body checking experience in the years following the removal of body checking. Additionally, evidence for the effectiveness of solely limiting head contact in sport to reduce head injuries is sparse and yields mixed results in reducing concussion risk. More objective measures need to be used in assessing the mechanisms through which head contact occurs in a youth ice hockey population and if solely limiting head contact is an effective strategy in reducing sports related concussion. Additionally, longitudinal prospective cohort studies including validated injury surveillance would have the potential to inform short- and long-term effects of future rule changes and trends in concussion identification in youth ice hockey players.

CHAPTER 3: Methods

3.1 Background

A prospective cohort design was used. Games were filmed throughout one season for each cohort.

3.2 Study Population

Bantam (ages 13-14) ice hockey players playing in Calgary (2013-14 and 2014-15 seasons) and Vancouver (2014-15 season) were the target population for this study. Thirteen games were videotaped in each level of play in Calgary in the 2013-14 season, in Calgary in the 2014-15 season, and in Vancouver in the 2014-15 season. With the available number of recorded games, we had 80% power to detect a clinically/practically meaningful incidence rate ratio (IRR) of 2.2 for higher intensity physical contacts (levels 4 and 5) in a body checking league, as well as a 0.2 IRR for other contacts that were more common in a non-body checking league (hooking and slashing).⁸ Given that there was no literature regarding PC incidence rates for Bantam ice hockey players, the incidence rates used in the sample size calculation were based on results found in Pee Wee ice hockey players playing in Alberta (where body checking was allowed) and Quebec (where body checking was not allowed) in the 2007-08 season. Given that there was no previous research on the effects of body checking experience on physical contacts in this age group, the comparison between players in Calgary in 2013-14 and 2014-15 will use 26 games (13 for each level of play). For full sample size calculations, see Appendix A.

Inclusion criteria for games to be videotaped were:

1. Bantam teams registered with Hockey Calgary (2013-14 and 2014-15 seasons) where body checking is allowed, and The Pacific Coast Amateur Hockey association (2014-15 season) where body checking is not allowed

Exclusion criteria for games to be videotaped were:

1. Any all-girl hockey teams
2. Recreational teams

Elite Calgary teams were defined as those playing in divisions AA and tier 1 (upper 30% by division of play). Non-elite Calgary teams were defined as those playing in tiers 2-7 (lower 70% by division of play). Elite level Vancouver teams were defined as those playing in level A (assumed to be equivalent to the upper 30% by division of play in Calgary). Non-elite Vancouver teams were defined as those playing in Vancouver House League (assumed to be equivalent to the lower 70% by division of play in Calgary).

3.3 Procedures

3.3.1 Data Collection

Trained research assistants videotaped Bantam ice hockey games were videotaped in hockey arenas in Calgary and Vancouver. A schedule of all of the games in the city was reviewed by the study research coordinator and the games were videotaped in accordance with the research assistants' schedules. As such, the selection of games within each level of play represents a convenience sample. Research assistants were instructed to follow the play when filming (i.e. the puck carrier), as well as filling out game exposure sheets where each player ice-time is recorded on paper (Appendix E). Those filming the game were instructed to position the camera by center ice as high as possible in the stands to cover as much of the ice as possible. If there was no room in the stands or if there was a thick protection net, the camera was positioned in one of the corners of the ice and zoomed in if the play was happening on the other end of the rink. This was done to minimize "blind spots" on the ice where it is difficult to see and analyze the physical contacts being made due to the view being obstructed by the boards. During breaks

in the game (e.g. after a referee whistle), those filming the game were instructed to film the time remaining in the period. To record exposure for each player, two research assistants recorded the line changes during the game (one research assistant per team) and at what time they happened.

3.3.2 Outcome Measures

The primary outcome variable of interest was whether there was a PC made. The outcome measures of interest were the type, frequency, and intensity level of physical contact (as described in Table 3.3.1), as well as head contact.⁸

Each contact has been described using the following characteristics: whether it was done by an offensive player (their team had control of the puck) or defensive player (the opposing team had control over the puck), whether the player that received the contact was a puck carrier, whether the physical contact was observed to be deliberate, whether the contact was operational (has been influenced by the play or influenced the play), whether there was a penalty called by the referee, what the score difference was at the time of the contact, and where on the playing surface the contact was made (Appendix C). The ice surface is divided into 5 zones, as shown in Illustration 3.3.1.⁸ Player positions (forward or defenseman) were identified by examining their positions during face-offs. Contacts that consist of only skate-to-skate, stick-to-stick, or stick-to-skate were not included as they do not fit any of the definitions of physical contact or other physical contacts made with the stick or limb. Any contacts made by the goaltender or on a goaltender were not included in the analysis.

Undergraduate research assistants and a supervising graduate student performed the video analysis. The video analysis was done using the computer software Dartfish (Dartfish, Fribourg, Switzerland, 2014). Dartfish is a sophisticated software that allows for analyzing and tagging specific events in uploaded videos. While Dartfish Software can have various uses in sport (by

therapists, coaches, athletes, and researchers), only the tagging (bookmarking) feature was used in this study.

3.3.3 Exposure Variables

The exposure variable for the primary comparison is whether the players were in a body checking league or in a non-body checking league.

The exposure variable for the secondary comparison is based on body checking experience in Bantam ice hockey players following the removal of body checking at the Pee Wee level at the beginning of the 2013-14 season. An assumption was made that half of the Bantam players playing in Calgary in the 2013-14 season had 4 years of body checking experience and half had 3 years of body checking experience, whereas in the 2014-15 season half of the players had 4 years of body checking experience and half of the players had 2 years of body checking experience.

Table 3.3.1 Definition of physical contact made with the trunk

Physical Contact	Definition
Level 1	Very light physical contact between players who are not moving forward
Level 2	Light physical contact between two players skating in the same direction
Level 3	Moderate physical contact between two players skating in the same direction
Level 4	Occurs when a player applies a forceful physical extension of the body to an opposing player, who is usually skating in the opposite direction. This corresponds to a heavy intensity physical contact
Level 5	Occurs when a player deliberately extends toward an opposing player, who is usually skating in the opposite direction, in order to initiate contact and hit with excessive force. The intention is more than simply to impede the progress of the opponent, who is totally affected by the contact.

Illustration 3.3.1 Definition of zones on the playing surface

3.4 Statistical Methods

All statistical analyses were carried out using STATA 13 (Statacorp, College Station, TX). Descriptive statistics have been used to illustrate the characteristics of the physical contacts in each cohort. This includes the number and proportions of PCs made with the trunk and other types of PC, whether the player was in a defensive or offensive position, if the physical contact was deliberate, if the physical contact included the puck carrier, and if the contact was operational to the play.

The multiple Poisson regression model has been used for individual players (alpha level set *a priori* at 0.05) to calculate incidence rate ratios (IRRs) for the primary, secondary, and exploratory objectives. The multiple Poisson regression model is used to model count data. This model assumes that that logarithm of the disease rate changes linearly with equal increment increases in the exposure variable, that the observations are independent from one another, and that the variance is equal to the mean. The multiple Poisson regression model for players (per 100 player minutes) was offset by player minutes and clustered by team. 95% confidence

intervals will be presented with the IRRs of the physical contacts made with the trunk and other types of physical contacts. Player position was included in the adjusted ratio ratios ($IRR_{Adjusted}$) as a potential covariate as it has been previously identified as a risk factor for injury in youth ice hockey.^{2,7}

Proportions were calculated to examine the relationship between PC and score differential, period of play, and location on the ice (Figure 3.3.1). The numbers and proportions of PCs made with the trunk was observed when the team was winning/losing by 1 point, winning/losing by 2 points, or when the score was tied.

In the case of missing exposure time, the mean of player minutes (stratified by player position) was imputed using exposure time from games of the same length, in the same city, and in the same year as the game with missing exposure data. In the case of missing film due to the research assistants arriving late, only the contacts after the first instance of seeing the game clock were recorded, and the player/game time was truncated to match the game time recorded. In the case of missing film due to camera malfunction, only the contacts recorded up to the last time the game clock was recorded were analyzed, and the exposure time was adjusted accordingly. If the rest of the game was recorded after the malfunction, only the contacts after the game clock was seen for the first time were analyzed.

In order to minimize the risk of bias in terms of over- or underestimating the main outcomes based on knowledge of whether players were allowed to body check or not, the coders were blinded to the level of play in each city.

3.4.1 Primary Objective

- 1) The primary comparison of the incidence of higher intensity PC (levels 4 and 5) and other PC (hooking and slashing) was made between Calgary (body checking) and

Vancouver (non-body checking) Bantam ice hockey players at the lower levels of play in the 2014-15 season. Player position (forward/defenceman) was added as a covariate in the adjusted model.

- a. Descriptive statistics have been used to illustrate the characteristics of the physical contacts in each cohort. This includes the number and proportions of PCs made with the trunk and other types of PC, whether the player was in a defensive or offensive position, if the physical contact was deliberate, if the physical contact included the puck carrier, and if the contact was operational to the play. Proportions were calculated to examine the relationship between PC and score differential (team was winning/losing by 1 point, winning/losing by 2 points, or when the score was tied), period of play, and location on the ice (Figure 3.3.1).
- b. A sub-analysis will include the comparison of elite level incidence rates (where both provinces allow body checking at the Bantam level) to assess for provincial differences.
- c. A sub-analysis will include the comparison of elite level incidence rates (where both provinces allow body checking at the Bantam level) to assess for differences between regular and early playoff season games within Calgary and within Vancouver.

3.4.2 Secondary Objective

- 2) The secondary comparison was made between ice hockey players playing in Calgary in the 2013-14 season (half of the players playing in the 2014-15 season were assumed to have 4 years of body checking experience and half were assumed to have

3 years of body checking experience) and ice hockey players playing in the 2014-15 season (half of the players playing in the 2014-15 season were assumed to have 4 years of body checking experience and half were assumed to have 2 years of body checking experience) at all levels of play. The comparison included the incidence rates and rate ratios of higher intensity PC (levels 4 and 5) and other PC (hooking and slashing). Player position (forward/defenceman) will be a covariate in the adjusted model.

3.4.3 Exploratory Objectives

- 3) A multiple Poisson regression model was used to compare each level of PCs made with the trunk (levels 1-5), and other types of PC (pushing with the stick/limbs, hitting with the stick/limbs, hooking with the stick, holding with the limb/stick) between Calgary (body checking) and Vancouver (non-body checking) at the lower levels of play in the 2014-15 season. Player position (forward/defenceman) was added as a covariate in the adjusted model.
- 4) A multiple Poisson regression model was used to compare each level of PCs made with the trunk (levels 1-5), and other types of PC (pushing with the stick/limbs, hitting with the stick/limbs, hooking with the stick, holding with the limb/stick) between Calgary in the 2013-14 season (half of the players have 4 years of body checking experience, half of the players have 3 years of body checking experience) and Calgary in the 2014-15 season (half of the players have 4 years of body checking experience, half of the players have 2 years of body checking experience). Player position (forward/defenceman) was added as a covariate in the adjusted model.

- 5) A multiple Poisson regression model was used to compare head contact (direct and indirect) and their associated physical contacts (levels 1-5) in players with differing body checking regulation (non-elite Bantam ice hockey players in Calgary and Vancouver in the 2014-15 season) and in players with differing body checking experience (Bantam ice hockey players in Calgary in the 2013-14 and 2014-15 seasons).
- 6) In order to make comparisons with previous literature that expresses incidence rates as number of PCs per team-game, estimates have been calculated to facilitate comparisons between lower level players in Vancouver and Calgary.

3.4.4 Inter- and Intra-rater agreement

Inter-rater agreement was assessed by choosing 46 video clips of contacts of variable intensity approximately 5 seconds in duration and comparing the raters' decisions with the supervising graduate student. 9 variables were judged by each of the research assistants [whether the contact was on an offensive/defensive player, level of physical contact (1-5), if the contact was deliberate/non-deliberate, what zone it was made in, if there was another contact made using limbs or object, what type of other contact (if there was an "other" contact), if the contact was operational/non-operational to the play, and if there was head contact involved]. Using these decisions a percentage of agreement was assessed and a kappa statistic was used between raters. The kappa statistic was weighted for location, intensity level, and type of other PC. Discrepancies between decisions on describing the contacts resulted in reviewing the descriptions of the variables. This was done monthly (using the same video clips) to ensure that the inter-rater reliability was high, and to allow for intra-rater reliability. Intra-rater agreement

was assessed by rating the same contacts after a month and comparing the decisions made by each rater using a percentage of agreement and a kappa statistic (Appendix B).

3.4.5 Regular and Playoff Season Games

Due to scheduling difficulties and short timelines, not all games in Vancouver could be videotaped in the regular season, which resulted in games being videotaped during the early playoff season. Therefore, an equivalent number of upper-level games were videotaped in Calgary and included in the analysis for the primary objective. A sensitivity analysis using multiple Poisson regression (offset by player minutes and clustered by team) for PCs made with the trunk and other types of PC was performed comparing elite regular and playoff games within Calgary and within Vancouver to assess for any differences between regular and playoff season games.

3.5 Ethical Considerations

The Conjoint Health Research Ethics Board at the University of Calgary (E-20252) has approved this study. This study is an extension of an original approval for a project examining the risk of injury associated with body checking among youth ice hockey players (Ethics ID#: 20252, Title: The Risk of Injury Associated with Body Checking among Pediatric Ice Hockey Players).

This study did not inflict or increase the risk of harm to any players. During the filming, the players, coaches, managers, and parents were not disrupted at any point. The filming did not interrupt the regular game process. The information recorded will stay in the hands of the research team and will not be made available to any other parties. The players stayed anonymous throughout the filming and analysis process; therefore, informed consent was not collected. Only the team names and the jersey numbers are known about the team and the players. The videos

were transferred to a secure server accessible only to approved research assistants/coordinators/students at the Sport Injury Prevention Research Centre. All research assistants have signed a confidentiality agreement prior to beginning the video filming and video analysis.

If spectators in the crowd during hockey games asked questions about the study, the recording crew supplied the spectators with information regarding the study. This information is provided in Appendix D.

CHAPTER 4: Results

4.1 Summary Characteristics

In total, 84 Bantam games were videotaped in Calgary in the 2013-14 and 2014-15 seasons, and in Vancouver in the 2014-15 season. Three games were excluded as they were in the girl's Bantam hockey league. An additional three games were also excluded due to significant technical issues with the filming process. This resulted in the inclusion of 78 Bantam ice hockey games and 22800 physical contacts recorded. Thirteen non-elite games were videotaped in Calgary in the 2014-15 season where body checking was allowed [mean player minutes: 15:45 (95% CI; 15:19-16:07); mean game minutes: 43:48 (95% CI; 42:00-45:03)] and thirteen non-elite games were filmed in Vancouver in the 2014-15 season where body checking was not allowed [mean player minutes: 17:44 (95% CI; 17:10-18:18); mean game minutes: 46:08 (95% CI; 43:44-48:28)]. Eighteen elite games were videotaped in Calgary in the 2014-15 season where body checking was allowed (mean player minutes: 15:48 (95% C; 15:24-16:10); game minutes: 49:37 (95% CI; 46:19-52:54)] and twelve elite games were videotaped in Vancouver where body checking was also allowed (mean player minutes 16:47 (95% CI; 16:15-17:19); mean game minutes [50:24 (95% CI; 47:16-53:31)]). Twenty-two elite and non-elite games were videotaped in Calgary in the 2013-14 season (where all players were assumed to have 4 years of body checking experience) [mean player minutes: 16:06 (95% CI; 15:46-16:25); mean game minutes: 47:24 (95% CI; 45:39 – 49:48)].

4.2 Primary Objective

4.2.1 Differences between a league that allows body checking and a league that does not allow body checking

A total of 3883 physical contacts (PCs) made with the trunk and 3271 PCs made with the stick or limbs were observed in Calgary and Vancouver at the lower levels of play. Three-hundred and one high intensity PCs (levels 4 and 5) and 406 hooking and slashing contacts were observed. As presented in table 4.2.1, significant differences between provinces were observed in the incidence rates of high intensity PCs and other types of PC (hooking and slashing) per 100 player minutes. There was an lower rate of observed high intensity PC (level 4 and 5 body checking contact) in Vancouver (body checking is not allowed) compared to Calgary (body checking is allowed) [IRR_{Adjusted}: 0.09 (95% CI; 0.05-0.15)]. Hooking and slashing behaviours were significantly higher in Vancouver non-elite ice hockey players compared to Calgary non-elite ice hockey players [IRR_{Adjusted}: 1.81 (95% CI; 1.33- 2.47)].

Table 4.2.1 Incidence rates and incidence rate ratios (per 100 player minutes) of high intensity physical contact made with the trunk (levels 4 and 5), and hooking/slashing behaviours in Bantam ice hockey players playing in non-elite leagues in Calgary and Vancouver

PC Behaviour	Calgary	Vancouver	IRR* (95% CI)	IRR _{Adjusted} ** (95% CI)
Levels 4 and 5	4.92 (4.02-6.01)	0.43 (0.26-0.73)	0.09 (0.05-0.15)	0.09 (0.05-0.15)
Hooking and Slashing	2.55 (2.01-3.22)	4.61 (3.75-5.67)	1.80 (1.32-2.46)	1.81 (1.33-2.47)

*Poisson regression cluster by team, offset by player minutes

** Adjusted for player position

4.2.2 Assessing for provincial differences between elite Bantam ice hockey players with no difference in body checking regulation

Table 4.2.2 describes the incidence rates and IRRs of high intensity contacts and hooking and slashing behaviours in elite ice hockey players in Vancouver and Calgary. There was no difference in the incidence of high intensity PCs made with the trunk (levels 4 and 5) in Calgary elite Bantam ice hockey players when compared to elite players playing in Vancouver where body checking is allowed in both cities [IRR_{Adjusted} 1.15 (95% CI; 0.97-1.36)]. There was no difference in the incidence of hooking and slashing between the two provinces [IRR_{Adjusted}: 1.07 (95% CI: 0.78-1.47)].

Table 4.2.2 Incidence rates (per 100 player minutes) and incidence rate ratios of high intensity physical contact made with the trunk (levels 4 and 5), and hooking/slashing behaviours in elite Bantam ice hockey players playing in Calgary and Vancouver

PC Behaviour	Calgary	Vancouver	IRR* (95% CI)	IRR _{Adjusted} ** (95% CI)
Levels 4 and 5	6.76 (6.05-7.56)	7.81 (6.87-8.87)	1.16 (0.98-1.36)	1.15 (0.97-1.36)
Hooking and Slashing	4.50 (3.52-5.76)	4.85 (3.98-5.91)	1.07 (0.78-1.47)	1.07 (0.78-1.47)

*Poisson regression cluster by team, offset by player minutes

** Adjusted for player position

4.2.3 Sensitivity analysis for differences between regular and early playoff games

The comparisons between elite early playoff and regular season games within each city (Calgary and Vancouver) are presented in tables 4.2.3. There were no differences in the incidence of high intensity PC made with the trunk [IRR_{Adjusted}: 1.00 (95% CI; 0.77-1.29)] and hooking and slashing behaviours [IRR_{Adjusted}: 0.81 (95% CI; 0.54-1.21)] between regular and early playoff games in Vancouver. There are no differences in the incidence of high intensity PC

made with the trunk [IRR_{Adjusted}: 1.20 (95% CI; 0.94-1.56)] and hooking and slashing behaviours [IRR_{Adjusted}: 1.38 (95% CI; 0.90-2.17)] between regular and early playoff games in Calgary.

Table 4.2.3 Incidence rates and incidence rate ratios (per 100 player minutes) of physical contact made with the trunk and other PC in elite Bantam ice hockey players in regular and early playoff games

City	PC Behaviour	Regular season	Playoff season	IRR* (95% CI)	IRR _{Adjusted} ** (95% CI)
Vancouver	Levels 4/5	7.80 (6.52-9.33)	7.82 (6.49-9.42)	1.00 (0.77-1.29)	1.00 (0.77-1.29)
	Hooking/Slashing	4.30 (3.07-5.91)	5.29 (4.16-6.73)	0.81 (0.54-1.21)	0.81 (0.54-1.21)
Calgary	Levels 4/ 5	7.12 (6.27-8.09)	5.90 (4.73-7.36)	1.20 (0.94-1.56)	1.20 (0.94-1.56)
	Hooking/Slashing	4.91 (3.63-6.65)	3.51 (2.54-4.86)	1.38 (0.90-2.17)	1.38 (0.90-2.17)

*Poisson regression cluster by team, offset by player minutes

** Adjusted for player position

4.2.4 Player and physical contact characteristics in a league that allows body checking and a league that does not allow body checking

There were no observable differences in the proportions of player and PC characteristics between non-elite Bantam ice hockey players playing in Calgary and Vancouver (Table 4.2.4). In Calgary and Vancouver, more PCs were made with the trunk by defensive players (85.22% and 85.81%, respectively) compared to offensive players, as well as more PCs were made on the puck carrier (69.24% and 73.50% respectively) compared to the non-puck carrier. There were more deliberate PCs made with the trunk than non-deliberate PC in both cities (96.12% in Calgary and 96.55% in Vancouver). There were more PCs made with the trunk that were operational (influenced or were influenced by the play) than non-operational in Calgary and Vancouver (99.74% and 99.67%, respectively).

Table 4.2.4 Summary player and Player Contact (PC) characteristics in non-elite Bantam ice hockey players in Calgary (body checking allowed) and Vancouver (body checking not allowed)

	Calgary 2014-15 Body checking	Vancouver 2014-15 Non-body checking
Player Position		
Total (n)	340	321
Forward, n (%)	218 (64.12)	209 (65.11)
Defenceman, n (%)	122 (35.88)	112 (34.89)
PC with the trunk made, n	2347	1536
Offensive/Defensive		
By an offensive player, n (%)	347 (14.78)	218 (14.19)
By a defensive player, n (%)	2000 (85.22)	1318 (85.81)
Puck carrier/non-puck carrier		
On a puck carrier, n (%)	1625 (69.24)	1129 (73.50)
On a non-puck carrier, n (%)	722 (30.76)	407 (26.50)
Deliberate/Non-Deliberate		
Deliberate, n (%)	2256 (96.12)	1483 (96.55)
Non-deliberate, n (%)	91 (3.88)	53 (3.45)
Operational/Non-operational		
Operational, n (%)	2341 (99.74)	1531 (99.67)
Non-Operational, n (%)	6 (0.26)	5 (0.33)
Other types of PC, n	1905	1366

Tables 4.2.5 - 4.2.8 describe the number and proportions of PCs made with the trunk and other types of PC observed in each zone on the ice (as described in Illustration 3.3.1). The highest proportions of PCs made with the trunk were observed in zone 3 in Calgary and Vancouver (29.52% and 31.96% respectively). In both Calgary and Vancouver, the proportion of level 1 contacts and pushing with the stick was observed in front of the net (zone 5) and along the boards (zones 1, 2, and 4). The highest proportion of higher intensity PCs (levels 4 and 5) was made along the boards (zones 1, 2, and 4 in Calgary), however more high intensity PCs were observed in zone 3 in Vancouver. Hitting and hooking contacts were observed to occur more often in zone 3 in Calgary and in Vancouver.

Table 4.2.5 Number and proportions of physical contact made with the trunk in each location on the ice in non-elite Bantam ice hockey player in Calgary (2014-15)

	Intensity of PC made with the trunk					
	All	1	2	3	4	5
Total, n	2347	431	1445	195	249	27
Location						
1, n (%)	452 (19.26)	113 (26.21)	233 (16.12)	31 (15.89)	69 (27.71)	6 (22.22)
2, n (%)	527 (22.45)	106 (24.59)	320 (22.14)	46 (23.58)	50 (20.08)	5 (18.51)
3, n (%)	693 (29.52)	30 (6.96)	492 (34.04)	71 (36.41)	89 (35.74)	11 (40.74)
4, n (%)	128 (5.45)	30 (6.96)	65 (4.49)	17 (8.71)	14 (5.62)	2 (7.40)
5, n (%)	547 (23.30)	152 (35.26)	335 (23.18)	30 (15.38)	27 (10.84)	3 (11.11)

Table 4.2.6 Number and proportions of other types of physical contact in each location on the ice in non-elite Bantam ice hockey players in Calgary (2014-15)

	Other PC						
	Limbs			Stick			
	Hitting	Pushing	Holding	Hitting	Pushing	Hooking	Holding
Total, n	207	336	5	117	143	26	21
Location							
1, n (%)	35 (16.74)	71 (21.13)	0	3 (2.56)	18 (12.58)	1 (3.84)	1 (4.54)
2, n (%)	35 (16.74)	58 (17.26)	1 (20.00)	20 (17.09)	36 (25.17)	6 (23.07)	2 (9.09)
3, n (%)	73 (34.92)	91 (27.08)	3 (60.00)	65 (55.55)	22 (15.38)	14 (53.84)	9 (40.90)
4, n (%)	12 (5.74)	15 (4.46)	1 (20.00)	1 (0.85)	3 (2.09)	0	0
5, n (%)	54 (25.83)	101 (30.05)	0	28 (23.93)	64 (44.75)	5 (19.23)	10 (45.45)

Table 4.2.7 Number and proportions of PC made with the trunk in each location on the ice in non-elite Bantam ice hockey player in Vancouver (2014-15)

	Intensity of PC made with the trunk				
	All	1	2	3	4
Total, n	1536	365	1004	104	25
Location					
1, n (%)	272 (17.70)	79 (21.64)	172 (17.13)	19 (18.26)	2 (8.00)
2, n (%)	325 (21.15)	84 (23.01)	219 (21.81)	17 (16.34)	5 (20.00)
3, n (%)	491 (31.96)	64 (17.53)	351 (34.96)	63 (60.57)	13 (52.00)
4, n (%)	94 (6.11)	31 (8.49)	53 (5.27)	1 (0.96)	1 (4.00)
5, n (%)	354 (23.04)	107 (29.31)	209 (20.81)	4 (3.84)	4 (16.00)

Table 4.2.8 Number and proportions of other types of PC in each location on the ice in non-elite Bantam ice hockey player in Calgary (2014-15)

Other PC							
Limbs				Stick			
	Hitting	Pushing	Holding	Hitting	Pushing	Hooking	Holding
Total, n	83	143	12	212	135	51	19
Location							
1, n (%)	8 (9.63)	19 (13.28)	0	14 (6.60)	18 (13.33)	3 (5.88)	1 (5.26)
2, n (%)	14 (16.86)	30 (20.97)	3 (25.00)	34 (16.03)	28 (20.74)	9 (17.64)	4 (21.05)
3, n (%)	27 (32.53)	35 (24.47)	4 (33.33)	113 (53.30)	30 (22.55)	27 (52.94)	8 (42.10)
4, n (%)	0	4 (2.79)	1 (8.33)	7 (3.30)	3 (2.22)	2 (3.92)	1 (5.26)
5, n (%)	34 (40.96)	55 (38.46)	4 (33.33)	44 (20.75)	56 (41.48)	10 (19.60)	5 (26.31)

Table 4.2.9 describes the number and proportions of PC made with the trunk when teams were winning/losing by 2 points, winning/losing by 1 point, and when the score was tied in non-elite Bantam ice hockey players in Calgary and Vancouver. The proportion of level 4 contacts appeared to increase when the score was not tied in both cities, regardless of whether the team was winning or losing by 1 point or by more than 2 points. The proportion of level 3 contacts in Vancouver was highest when players were winning by 1 point (15.63%) compared to all other score differentials.

Table 4.2.9 Number and proportions of physical contact made with the trunk by score differential in non-elite Bantam ice hockey players in Calgary (2014-15)

City	Trunk Contacts	Score Difference				
		Losing by 2 or more	Losing by 1	Tied	Winning by 1	Winning by 2 or more
Calgary	Total, n	419	304	916	312	396
	Level 1, n (%)	65 (15.51)	46 (15.13)	209 (22.81)	45 (14.42)	66 (16.66)
	Level 2, n (%)	265 (63.24)	196 (64.47)	534 (58.29)	198 (63.46)	252 (63.63)
	Level 3, n (%)	35 (8.35)	20 (6.57)	82 (8.95)	25 (8.01)	33 (8.33)
	Level 4, n (%)	50 (11.93)	36 (11.84)	81 (8.84)	38 (12.17)	44 (11.11)
	Level 5, n (%)	4 (0.95)	6 (1.97)	10 (1.09)	6 (1.92)	1 (0.25)
Vancouver	Total, n	474	224	254	211	373
	Level 1, n (%)	107 (22.57)	66 (29.46)	50 (19.68)	51 (24.17)	91 (24.39)
	Level 2, n (%)	309 (65.18)	141 (62.94)	187 (73.62)	126 (59.71)	241 (64.61)
	Level 3, n (%)	47 (9.91)	15 (6.69)	15 (8.95)	33 (15.63)	32 (8.57)
	Level 4, n (%)	11 (2.32)	2 (0.89)	2 (0.78)	1 (0.47)	9 (2.41)
	Level 5, n (%)	0	0	0	0	0

Table 4.2.10 describes the number and proportions of PCs made with the trunk during each period. In Calgary, the proportion of level 5 contacts was highest in period 3 (1.55%) compared to period 2 (0.08%) and period 1 (1.01%). In Vancouver, the proportion of level 4 contacts appears to be highest in period 3 (2.79%) compared to period 2 (1.41%) and period 1 (0.84%).

Table 4.2.10 Number and proportions of physical contact made with the trunk by period in non-elite Bantam ice hockey players in Calgary and Vancouver (2014-15)

	Period (Calgary)			Period (Vancouver)		
	1	2	3	1	2	3
Total PC made with the trunk, n	792	782	773	473	634	429
Intensity						
1, n (%)	148 (18.68)	154 (19.69)	129 (16.68)	120 (25.36)	160 (25.23)	85 (19.81)
2, n (%)	492 (62.12)	479 (61.25)	474 (61.31)	308 (65.11)	403 (63.56)	293 (68.29)
3, n (%)	65 (8.20)	61 (7.80)	69 (8.92)	41 (8.66)	62 (9.77)	39 (9.09)
4, n (%)	79 (9.97)	81 (10.35)	89 (11.51)	4 (0.84)	9 (1.41)	12 (2.79)
5, n (%)	8 (1.01)	7 (0.08)	12 (1.55)	0	0	0

4.3 Secondary Objective

4.3.1 Differences between Bantam ice hockey players with differing body checking experience

A total of 11338 physical contacts made with the trunk and 5102 contacts made with the stick or limb were observed in Calgary (2013-14 and 2014-15 seasons) at all levels of play. One thousand five-hundred and forty-three high intensity contacts (levels 4 and 5) and 913 hooking and slashing contacts were observed. Less body checking experience had no significant effect on the incidence of high intensity PC made with the trunk [IRR_{Adjusted}: 0.88 (95% CI: 0.74-1.05)] and hooking and slashing behaviours [IRR_{Adjusted}: 0.97 (95% CI: 0.71-1.32)].

Table 4.3.1 Physical contact made with the trunk (level 1-5) and other physical contact in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons)

PC Behaviour	Calgary 2013-14	Calgary 2014-15	IRR* (95% CI)	IRR _{Adjusted} ** (95% CI)
Levels 4 and 5	6.80 (5.94-7.78)	6.02 (5.43-6.69)	0.88 (0.74-1.05)	0.88 (0.74-1.05)
Hooking and Slashing	3.80 (3.01-4.80)	3.72 (3.04-4.55)	0.97 (0.72-1.32)	0.97 (0.71-1.32)

*Poisson regression cluster by team, offset by player minutes

** Adjusted for player position

4.4 Exploratory Objectives

4.4.1 Differences in all levels of physical contact made with the trunk and all other physical contact in a league that allows body checking compared to a league that does not allow body checking

Figures 4.4.1 and 4.4.2 show the IRRs_{Adjusted} (cluster by team and offset by player minutes) for each level of intensity in PC made with the trunk and other PCs in non-elite Bantam ice hockey players playing in Vancouver and Calgary in 2014-15. In a league where ice hockey players are not allowed to body check (Vancouver), there is a decreased incidence of total types of PC made with the trunk [IRR_{Adjusted}: 0.64 (95% CI; 0.55-0.74)], light and moderate intensity contacts [Level 2 IRR_{Adjusted}: 0.68 (95% CI; 0.60-0.78), level 3 IRR_{Adjusted}: 0.71 (95% CI; 0.55-0.93)], and high intensity physical contacts [Level 4 IRR_{Adjusted}: 0.09 (95% CI; 0.05-0.17)]. There

were no level 5 contacts recorded in non-elite Vancouver games, therefore a formal comparison could not be made.

The incidence of the total of other PCs was lower in Vancouver [IRR_{Adjusted}: 0.75 (95% CI; 0.60-0.93)]. The incidence of hitting with the limbs [IRR_{Adjusted}: 0.39 (95% CI; 0.29-0.51)] and pushing with the limbs [IRR_{Adjusted}: 0.41 (95% CI; 0.29-0.59)] were lower in Vancouver. The incidence of hitting and hooking behaviours was higher in Vancouver compared to Calgary [Hitting IRR_{Adjusted}: 1.78 (95% CI; 1.30-2.46), Hooking IRR_{Adjusted}: 1.93 (95% CI; 1.08-2.57)].

Figure 4.4.1 Physical contact rates made with the trunk (levels 1-5) in non-elite Bantam ice hockey players playing in Calgary and Vancouver in 2014-15

*Poisson regression cluster by team, offset by player minutes, adjusted for player position

Figure 4.4.2 Other types of physical contact rates in non-elite Bantam ice hockey players playing in Vancouver and Calgary in 2014-15

*Poisson regression cluster by team, offset by player minutes, adjusted for player position

Results presented in table 4.4.1 shows the point estimates of the rate of PCs made with the trunk (levels 1-5) and other PCs per team-game. There appears to be a higher incidence rate of total PCs made with the trunk in a league that allows body checking (Calgary) compared to a league that does not allow body checking (Vancouver). The incidence rates of light, moderate, and high intensity PC made with the trunk appears to be higher in Calgary compared to Vancouver. Pushing with the limb appears to be more common in Calgary, whereas hitting and hooking with the hockey stick is usually more common in Vancouver.

Table 4.4.1. Physical contact rates made with the trunk and other physical contact rates in non-elite Bantam ice hockey players in Vancouver and Calgary (2014-15)

	Vancouver 2014-15 (N/Team-Game)	Calgary 2014-15 (N/Team-Game)
Intensity of PC with the trunk		
All Contacts	59.07	90.26
1	14.03	16.57
2	38.61	55.57
3	5.46	7.50
4	0.96	9.57
5	0	1.03
Other PC		
All	15.61	18.42
Pushing with limb	5.50	12.92
Hooking with stick	1.96	1.00
Slashing with stick	8.15	4.50

4.4.2 Differences in all levels of PC made with the trunk and other types of PC in ice hockey players with differing body checking experience

Figures 4.4.3 and 4.4.4 show the $IRR_{Adjusted}$ (cluster by team and offset by player minutes) for each level of intensity in PC made with the trunk and other PCs in Bantam ice hockey players in Calgary in the 2013-14 season (half of the players assumed to have 4 years of body checking experience, half assumed to have 3 years) and in the 2014-15 season (half of the players assumed to have 4 years of body checking experience, half assumed to have 2 years of body checking experience). Differing body checking experience does not have a significant effect on the intensity of PC made with the trunk. There was a lower incidence of pushing with the limbs in players with less body checking experience (2014-15 season) [$IRR_{Adjusted}$: 0.70 (95%

CI; 0.57-0.85)]. There was a higher incidence of holding with the stick in players with less body checking experience [IRR_{Adjusted} 2.19 (95% CI; 1.25-3.82)].

Figure 4.4.3 Physical contact rates made with the trunk in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons)

*Poisson regression cluster by team, offset by player minutes, adjusted for player position

Figure 4.4.4 Other contact rates made with the stick and limbs in Bantam ice hockey players playing in Calgary 2013-14 and 2014-15

*Poisson regression cluster by team, offset by player minutes, adjusted for player position

4.4.3 Direct and indirect head contact

Overall, there was a lower incidence of direct head contact due to all PCs made with the trunk in Vancouver where body checking is not allowed [IRR_{Adjusted}: 0.33 (95% CI; 0.17-0.65)], as shown in Figure 4.4.5. There were no significant differences in direct head contact in lower-intensity PCs (levels 1-3), however there was a decreased incidence of head contact associated with higher-intensity hits [Level 4 IRR_{Adjusted}: 0.33 (95% CI; 0.17-0.65)] in Vancouver. There were no level 5 contacts recorded in Vancouver, therefore a comparison could not be made. The highest incidence of direct head contact resulted from level 4 contacts in Calgary [0.35 (95% CI; 0.22-0.56)] and Vancouver [0.10 (95% CI; 0.00-0.12)].

Overall, there was a lower incidence of indirect head contact (head contact with the environment as a result of a PC made with the trunk) in Vancouver where body checking is not allowed [IRR_{Adjusted}: 0.08 (95% CI; 0.01-0.62)], as presented in table 4.4.1. There were no differences in incidence rates found in indirect head contact resulting from lower intensity PCs (levels 1 & 3), and comparisons could not be made in indirect head contact associated with level 2 contacts due to instances recorded in Vancouver (level 2). Indirect head contact due to high intensity (levels 4-5) hits were also recorded only in Calgary.

Figure 4.4.5 Direct head contact rates and associated physical contact made with the trunk in non-elite Bantam ice hockey players in Calgary and Vancouver

*Poisson regression cluster by team, offset by player minutes, adjusted for player position

Table 4.4.2 Incidence rates and incidence rate ratios of indirect head contact and associated physical contact made with the trunk in non-elite Bantam ice hockey players in Calgary and Vancouver

	Vancouver 2014-15	Calgary 2014-15	IRR (95% CI)*	ARR (95% CI)**
Indirect Head Contact				
All	0.03 (0.00-0.25)	0.44 (0.28-0.70)	0.08 (0.01-0.62)	0.08 (0.01-0.62)
Level 1	0.01 (0.00-0.12)	0.03 (0.00-0.25)	0.52 (0.03-8.36)	0.52 (0.03-8.25)
Level 2	0	0.08 (0.03-0.23)	NA	NA
Level 3	0.01 (0.00-0.12)	0.05 (0.01-0.15)	0.32 (0.03-3.12)	0.32 (0.03-3.12)
Level 4	0	0.23 (0.13-0.40)	NA	NA
Level 5	0	0.03 (0.00-0.13)	NA	NA

*Poisson regression cluster by team, offset by player minutes

** Adjusted for player position

The incidence rates and IRRs of direct and indirect head contact in players with differing body checking experience are presented in figures 4.4.6 and 4.4.7. Overall, there was a lower incidence of direct head contact in players with less body checking experience [IRR_{Adjusted}: 0.69 (95% CI: 0.52-0.91)]. However, no differences were found in head contact associated with each individual level of intensity between the two years except in level 1 contacts [IRR_{Adjusted}: 0.46 (95% CI: 0.23-0.92)]. There were no differences in the risk of indirect head contact due to PC made with the trunk between the two years [IRR_{Adjusted}: 0.77 (95% CI: 0.45-1.32)].

Figure 4.4.6 Direct head contact and associated physical contact made with the trunk in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons)

*Poisson regression cluster by team, offset by player minutes, adjusted for player position

Figure 4.4.7 Indirect head contact and associated physical contact made with the trunk in Bantam ice hockey players at all levels of play in Calgary (2013-14 and 2014-15 seasons)

*Poisson regression cluster by team, offset by player minutes, adjusted for player position

4.5 Summary of results

The comparisons of PC made with the trunk and other types of PC between cohorts was assessed using Poisson regression modelling. Univariate analyses (cluster by team and offset by player minutes) suggests that there is lower incidence of higher intensity contacts (level 4 and 5 body checking) in a league that does not allow body checking compared to a league that allows body checking. Hooking and slashing behaviours were more common in a non-body checking league. There were no differences in the incidence of higher intensity contacts, hooking, and slashing behaviours in Bantam ice hockey players with differing body checking experience.

Multiple Poisson regression found that there was no difference in the incidence of high intensity PCs made with the trunk and hooking and slashing behaviours between elite Vancouver games compared to elite Calgary games. The incidence of high intensity PCs and hooking/slashing behaviours did not differ between regular and early playoff games in elite Bantam ice hockey players within cities (Calgary and Vancouver). Multiple Poisson regression modelling using player position as a covariate did not differ from the univariate regression in all analyses.

Exploratory analyses using multiple Poisson regression modelling found a lower rate of all levels of PC made with the trunk, as well as a lower rates of PC levels 2, 3, 4, and 5 in Vancouver. The incidence of hitting and pushing with the limbs was higher in a body checking league compared to a non-body checking league, whereas the incidence of hitting and hooking with a stick was higher in a non-body checking league. There was no difference in rate of PCs made with the trunk in players with differing body checking experience, however players playing in Calgary in the 2014-15 season had a decreased rate of observed pushing with the limb

compared to players playing in the 2013-14 season, as well as a higher rate of holding with the stick.

The incidence of direct (player-player) head contact as a result of high intensity PC made with the trunk was found to be lower in a league where body checking was not allowed. There was a lower incidence of direct and indirect (player-environment) head contact resulting from PC made with the trunk in a league where body checking was not allowed. The incidence of direct head contact due to PC made with the trunk was lower in players with less body checking experience, however indirect head contact did not differ in players with less body checking experience.

CHAPTER 5: Discussion

This is the first study of its kind to compare the intensity and frequency of physical contacts (PC) made with the trunk, and other types of contacts (e.g. hooking, slashing, head contact), in Bantam (ages 13-14) youth ice hockey players playing in a body checking (BC) league and a non-body checking league through video analyses. Additionally, this is the first study to examine the intensity and frequency of physical contacts and other types of contacts in Bantam ice hockey players with differing body checking experience after the removal of body checking at the Pee Wee level.

5.1 Differences between a league that allows body checking and a league that does not allow body checking

5.1.1 High intensity physical contact made with the trunk and other types of physical contact in leagues with differing body checking regulation

Video analysis data from 26 non-elite Bantam (ages 13-14) ice hockey games were included in the primary analysis for this study. Using a previously validated video analysis methodology system, 7154 physical contacts (PC) made with the trunk and other types of PC made with the limbs and stick were recorded in non-elite games in Calgary (2014-15 season, BC allowed) and Vancouver (2014-15 season, BC not allowed).⁸ There were no observable differences in the proportions of forwards and defencemen between cities and seasons. Mean player minutes and game length did not appear to differ between cities. The proportions of defensive, deliberate, and operational PCs made with the trunk did not differ between cities. The proportions of PCs made with the trunk on the puck carrier did not differ between cities.

The results of the multiple Poisson regression, adjusted for player position, has shown that the rate of PC made with the trunk and other types of PC was different in a league where body checking was allowed (Calgary) compared to a league where body checking was not

allowed (Vancouver). There is a significantly lower incidence of body checking PC in Vancouver compared to Calgary [IRR_{Adjusted}: 0.09 (95% CI; 0.05-0.15)]. The incidence of hooking and slashing behaviours was higher in Vancouver compared to Calgary [IRR_{Adjusted}: 1.81 (95% CI; 1.33- 2.47)]. These results are consistent with previous research where Pee Wee (ages 11-12) players were found to be at a higher risk of higher intensity PCs in a body checking league compared to a non-body checking league. Additionally, hooking and slashing behaviours were more commonly observed in a non-body checking league in Pee Wee players.⁸ A comparison of PCs made with the trunk and other types of PCs among elite players in Calgary and Vancouver (where players are allowed to body check in both cities) yielded no difference in incidence rates, signifying no provincial effect among the non-elite players.

Due to issues with feasibility, all of the Vancouver non-elite games were videotaped in the early playoff season. Therefore, a comparison was done within Calgary and within Vancouver between elite playoff and regular season games. This yielded no significant differences in risk of PC made with the trunk and hooking and slashing behaviours, therefore a comparison between the non-elite ice hockey players could be made.

There is compelling evidence that playing in a body checking league results in an increased risk of concussion and injury, with the act of body checking an opponent being the most consistent risk factor for concussion and injury in youth ice hockey players.^{6,27,59} Therefore, our results suggest that a league in which higher rates of higher-intensity in PC occurs may be related to an increased risk of concussion and injury. However, injury rates were not collected for this study, therefore causation between PC and injury cannot be formally examined.

5.1.2 Exploratory analysis of all levels of intensity and all other PC in leagues with differing body checking regulation

Exploratory analyses using multiple Poisson regression revealed that the incidence of the total levels of PC made with the trunk was lower in Vancouver where body checking is not allowed. Additionally, the incidence of low to moderate intensity PCs (levels 2-3) and high intensity PCs (levels 4-5) was significantly lower in Vancouver. The incidence of all other PC, hitting with the limbs, and pushing with the limbs was higher in Calgary. Conversely, the incidence of hooking and slashing behaviours was observed to be higher in Vancouver. The higher incidence of global rates of PC and other types of PC, PCs of low to high intensity (levels 2-5), and pushing with the limbs observed in this study are consistent with previous research comparing the frequency and intensity of PC in Pee Wee (ages 11-12) ice hockey players playing in Alberta (where body checking was allowed) and Quebec (where body checking was not allowed).⁸ This higher incidence of most levels of intensity suggest that players playing in a body checking league tend to play a more physical game than players in a league where body checking is not allowed.

Exploratory analyses also yielded different incidence rates of other types of PC between Vancouver and Calgary. In Vancouver, hooking and slashing behaviours were more common. Both of these tactics have been previously reported to occur more commonly in a non-body checking league to limit the progression of the opponent.⁸ Bantam ice hockey players in Calgary preferred to use more aggressive types of other PC (i.e. pushing and hitting with the limbs). The significantly higher rate of using the limbs to hit and push other players in a body checking league may be due to higher intensity PC made with the trunk that missed the opponent (with the

offending player using their limbs to affect the opposing player instead as a result), or it may be a result of more intensive and competitive attitudes in the players. Emery et al. found significantly more positive responses concerning the willingness to inflict harm on an opponent in players playing in a body checking league (ages 11-16) when compared with players playing in a non-body checking league.⁶⁰ The same study also found that player playing in a body checking league demonstrate significantly higher aggression, however this difference was found only in Midget (ages 15-16) players.⁶⁰ It is therefore possible that hitting and pushing with the limbs found in the present study, as well as the higher rate of level 5 PCs (which differ from level 4 PCs solely by the excessive force used to deliberately contact the play), may be a reflection of more intensive and competitive attitudes in players playing in a body checking league.

For the purposes of facilitating comparison with the literature (where rates of PC have been presented per team-game), rates of PC and other types of PC found in this study were presented in a similar manner (Table 4.4.1). There appears to be large differences between the rates of PC made with the trunk in Bantam players and historical rates in Pee Wee players.⁸ Bantam players in a body checking league (Calgary) have been observed to commit higher rates of all types of PC made with the trunk compared to Pee Wee players in Calgary (where body checking was permitted) in 2007-08. However, the rates of all PC made with the trunk is similar between Bantam (Vancouver) and Pee Wee (Quebec) players in leagues where body checking was not permitted. The rates of level 1 contacts were higher in Pee Wee players compared to Bantam players regardless of body checking policy, suggesting a difference in style of play in younger age groups (i.e. more battling over the puck in Pee Wee players in face offs or along the boards). Much higher incidence rates of level 2 contacts have been observed in Bantam players regardless of body checking policy. This is most likely due to a faster and more physical game in

Bantam players resulting in a higher incidence rate of physical contact between players, however this difference may also be explained by improvements in camera quality and improved software used to analyze contacts which may not have been captured previously. The incidence rates of level 4 and 5 contacts are relatively consistent between Pee Wee and Bantam players in respect to body checking policy, however no level 5 contacts were observed in Bantam players in a league that does not allow body checking. The total rates of pushing with the limbs, and hooking/slashing with the hockey stick, were similar between Bantam and Pee Wee players regardless of policy change. However, incidence rates of hooking with the hockey stick were higher in Pee Wee players, and slashing with the hockey stick was observed to be higher in Bantam players.⁸

5.1.3 Game, player, and PC characteristics in league with differing body checking regulation

There was a higher proportion of PCs made with the trunk observed in open ice (zone 3) in Calgary (29.52%) and Vancouver (31.96%) than all other individual zones, however more PCs made with the trunk were observed along the boards (zones 1, 2, and 4) in both Calgary and Vancouver (Figure 3.3.1). The highest proportion of high-intensity PCs (levels 4 and 5) were observed along the boards in Calgary, however the highest proportion of high-intensity PCs were in zone 3 in Vancouver, suggesting that players in Calgary regularly use the boards when engaging in high intensity contacts (level 4 and 5 body checking) whereas players in Vancouver commit higher intensity contacts in open ice. This may be a point of interest as players tend to skate faster in open ice, which may result in more injurious contacts. A study using the Head Impact Telemetry (HIT) system in 14 year-old ice hockey players found that open-ice collisions resulted in greater head linear and rotational accelerations compared with collisions along the playing boards.⁶¹ Additionally, players playing in a body checking league may anticipate

collisions better than players playing in a league where body checking is not allowed and therefore not necessarily expected. The same study using the HIT system found that anticipated collisions tended to result in less-severe head impacts than unanticipated collisions.⁶¹ It is not possible to know if this is the case in the present study (as anticipation was not measured using video analysis), however it is important that coaches teach their players to always anticipate contacts and body checks, even if body checking is not allowed in their respective league.

Differences between the two leagues were also observed in the proportion of pushing with the limbs. The proportion of pushing with the limbs was higher along the boards in Calgary (body checking allowed) but more common in zone 5 (i.e. when protecting the front of the net) in Vancouver. The highest proportion of level 1 contacts were observed in zone 5 where players aimed to protect the front of the goal and battle for the puck after face-offs, and along the boards where players often battle for the puck. Pushing with the shaft of the stick was also a common tactic when defending the front of the net in zone 5 in both Calgary and Vancouver. The highest observed proportion of slashing and hooking behaviours were observed in zone 3 in Calgary and Vancouver where players have more room to skate. This may be due to attempts to try to limit the puck carrier's movement as they create plays before entering the opponent's defensive zones or due to attempts at limiting the progression of the puck carrier after stealing the puck and attempting to breakaway across the open ice. Coaches must know PC made with the trunk and other types of PC differ in frequency and intensity depending on the location, therefore their teaching must be adapted accordingly. Additionally, future research should attempt to capture the rates of physical contacts observed in each zone for a more in-depth understanding of the relation between PC and location on the ice.

The proportions of observed individual levels of PCs made with the trunk appeared to differ due to the score difference (whether the players were losing/winning by more than 2 points, losing/winning by 1 point, or if the score was tied). In Calgary, teams that were winning or losing by 1 or more points were observed to have engaged in a higher proportion of high-intensity PCs made with the trunk compared to when the score was tied. Similarly, the proportion of level 4 contacts was highest when teams were winning/losing by 2 or more points in Vancouver. Reasons for these differences may be due to teams using more intensive tactics as an advantage to win, as well as teams that are losing may be becoming exasperated and may start using higher intensity PCs to attempt winning the game. This is in contrast to a previous study examining behaviours in collegiate ice hockey players using video observation which found a higher number of intensive acts when the score differential was lower (<2 points) compared to large score differentials (<3 points).⁶² However, the sample size of games was relatively small in the aforementioned study (4 teams playing 3 games over 2 days), and no exposure time was collected. Our study is limited by the use of proportions instead of rates as the amount of time that each player spent on the ice during the times their team was winning, losing, or were tied was not recorded. For example, games may take a longer amount of time until a goal is scored, therefore the number of contacts made during this time would be higher if the exposure time is not separated by score differential. While the use of aggressive PC may be influenced by score differential, further research is required to explore the association between score differential and frequency/intensity of PCs.

The proportion of higher intensity contacts appeared to have increased in both Calgary and Vancouver players later in the game. Players may be resorting to higher intensity contacts in order to win the game. This may be concerning as players would be more tired

nearing the end of the game and therefore may not be able to anticipate the high intensity contacts. Further research is needed to examine the rates of contacts made per period, and to examine the influence of score difference and period on physical contacts.

5.2 Differences in PC made with the trunk and other types of PC in leagues with differing body checking experience

The results of the multiple Poisson regression (adjusted for player position and offset by player minutes) demonstrates that the incidence of PC made with the trunk and other types of PC did not differ between a league where all Bantam ice hockey players have 4 years of body checking experience (2013-14 season) and a league where half of the players have 4 years of body checking experience and half of the players have 3 years of body checking experience (2014-15 season). This difference between cohorts is due to a policy change put forward in the 2013-14 season to ban body checking at the Pee Wee (ages 11-12) level. While this study was not powered to detect a difference between body checking experience, the results suggest that the incidence of high intensity physical contacts and hooking and slashing behaviours does not differ for ice hockey players with less body checking experience.

Observing no difference in the incidence in PCs made with the trunk and other types of PC is not surprising. A study examining the risk of injury and concussion between Bantam ice hockey players with two years body checking experience in Pee Wee compared to Bantam ice hockey players with no body checking experience in Pee Wee (Quebec) found no difference in the risk of overall injury, concussion, and severe concussion (resulting in >10 days time loss) with the exception of a 33% reduction in the risk of injury resulting in 7 days time loss among Bantam ice hockey players with two years of body checking experience in Pee Wee.⁴⁰ These results suggest that consistent rates of PC made with the trunk and other types of PC may be

associated with relatively no difference in injury risk. However, it is worth noting that the comparison of body checking experience in the aforementioned study is not identical to that in the present study.

A study examining Bantam ice hockey players with differing body checking experience in 2009 (Bantam players in Calgary had 2 years of body checking experience at the Pee Wee level whereas players in Quebec had none at the Pee Wee level) found no differences in the incidence of PCs made with the trunk between the two cohorts (with the exception of players in Calgary committing more level 1 contacts).⁴² Although the differences in body checking experience were more pronounced, these results are consistent with the ones found in this study. Goulet et al. also note an increase in the incidence of slashing and holding in the Calgary cohort. We did not find differences in slashing, hooking, and holding behaviours, however this may be due to the fact that the difference in body checking experience in our study was not as large, or it could be a provincial effect (as Goulet et al. did not assess for this). Future research should assess the changes in PC and other types of PC in the proceeding seasons following the disallowing of body checking at the Pee Wee level, and should therefore be continually assessed to examine how the frequencies and intensities of PC made with the trunk and other types of PC change over time.

5.3 Head contact in leagues with differing body checking regulation

There was a lower incidence of observed direct head contact in Bantam ice hockey players in a league where body checking was not allowed (Vancouver) compared to a league where body checking was allowed (Calgary) [IRR_{Adjusted}: 0.31 (95% CI: 0.16-0.61)]. Direct head contact due to level 4 contacts was lower in players playing in Vancouver compared to players playing in Calgary [IRR_{Adjusted}: (95% CI: 0.10-0.85)]. No level 5 contacts were recorded in

Vancouver therefore a formal comparison could not be made between the two provinces.

Additionally, the incidence of indirect head contact (i.e. head contact with the environment as a result of a PC) was observed to be lower in Vancouver [IRR_{Adjusted}: 0.08 (95% CI; 0.01-0.62)].

This is not surprising as non-elite players in Vancouver tend to commit higher intensity contacts on open ice rather than by the boards.

In 2011, Hockey Canada introduced non-evidence based rule enforcement change where hits to the head would be penalized in order to reduce head injuries in ice hockey players.²⁵ A study comparing the incidence rates of concussion and severe concussion (concussion resulting in >10 days time loss) in Pee Wee and Bantam ice hockey players before and after the rule change found an increase in the risk of concussion and severe concussion after the rule enforcement change was put in place.²⁶ Similar increases in concussion incidence during this time has been found in other sports and ages.⁵²⁻⁵⁶ The most likely cause of this increase in risk is related to an increased awareness of concussion and stricter return to play management of concussed players (a longer return to play protocol would increase the rates of severe concussion based on the time loss definition). Objectively assessing the difference in incidence of head contact before and after the rule change has therefore proven to be difficult, however video analysis can be used to measure the observed incidence rates of head impact. Although contact to the head is illegal, the results of this study suggest that the risk of head contact still exists in youth ice hockey.

The results of this study demonstrate that a league that does not permit body checking limits direct contact to the head, especially those sustained in high intensity contact. The removal of body checking to limit head impact is further supported by comparing the incidence rates of head contact in ice hockey players playing in Calgary in the 2013-14 and 2014-15 seasons as

there has not been any observed change in high intensity impacts between the two seasons. Therefore, these results suggest that an effective strategy for reducing the incidence of head impacts is disallowing body checking (limiting the exposure to high intensity PCs made with the trunk) which appears to be strongly associated with direct head contact. Additionally, the highest incidence of direct head contact in each cohort were associated with high intensity impact. As previously mentioned, this presents a unique risk for players playing in a non-body checking league as they may not be anticipating the collision (especially as they occur more frequently in open ice). However, it is also important to note that directly contacting the head is not necessary to receive a concussion as a concussion may also be caused by a blow elsewhere on the body with an impulsive force transmitted to the head.¹⁸

Unfortunately, no games were videotaped prior to the rule enforcement change, therefore an objective measure of the difference in head contact incidence as a result of the rule change could not be made. Additionally, as this study was not powered to investigate the incidence of head contact, future studies should examine the risk of head contact with a sufficient sample size. Head telemetry would also be of interest to measure biomechanical forces of head impacts and how they would relate to PCs of varying intensity.^{50,51,61}

5.4 Strengths

To the best of our knowledge, this is the first study to examine the differences in intensity and type of physical contact in Bantam (ages 13-14) ice hockey players with differing body checking regulation using video analysis. Additionally, this is the first study to examine differences in intensity and type of physical contacts in Bantam ice hockey players with 4 years of body checking experience and in players one year after body checking was removed from the Pee Wee level. Previous literature has solely examined the effect in differing body checking

regulation on physical contacts in Pee Wee (ages 11-12) ice hockey players. Previous studies using the same video analysis surveillance system used an incidence rate with team-game as the exposure. This present study used player minutes as the exposure variable where appropriate. The use of playing time was considered a more precise measurement when comparing cohorts as game time may vary based on the ice rink schedules. Additionally, using individual playing time is appropriate as some athletes may be injured and leave the game prematurely, and it also accounts for differing playing time for defencemen and forwards.

As this was a prospective cohort study, the study population for the primary outcome was classified based on their exposure to body checking. House League ice hockey players in Vancouver (where body checking was not allowed) were considered to be equivalent to lower level ice hockey players in Calgary based on participation rates (Bantam levels 2-7). The main advantage of this study being a prospective cohort study is that the results can bring clarity over questions of temporality (i.e., differences in PCs in a body checking and non-body checking league). However, as injury rates were not collected in this study, causation between frequency and intensity of PC and injury cannot be made directly. The cohort study design also allows for the calculation of the incidence of the PCs in the study population. Additionally, multiple outcomes for future studies may be assessed using this type of study design (e.g. physical contact as well as player performance).

All research assistants were trained by a co-author of the study that previously validated the video analysis surveillance system.⁸ The raters have all been assessed on a monthly basis, with percent agreement being high (>90%) within and between testers. As well, an inter-and intra-rater agreement was assessed using the Kappa statistic to determine consistency among raters. Agreement ranged from moderate to substantial agreement within and between testers,

with the exception of examining the types of other contact (Appendix B).⁶³ This may be due to the small number of contacts chosen that did not include the trunk, as well as the similarity between hooking/slashing/pushing behaviours. However, differential misclassification for all other PC decisions was minimized. Non-differential misclassification may still exist (which may bias the results towards the null). Nonetheless, significant differences were found in the primary outcome.

An exploratory analysis was conducted between non-elite games in Calgary and Vancouver to assess all individual levels of PC made with the trunk and other types of PC. This provided additional information on the differences between the two cohorts that may be of interest in future studies.

All research assistants were blinded to the level of play of the hockey games until after the games were done being coded. This method was put in place to minimize any bias towards coding particular PCs due to prior knowledge of the level of play of the particular game. For example, more body checking PCs (levels 4 and 5) may be coded in Calgary at the lower level of play due to the expectation that there will be a higher incidence rate of body checking contacts in a league where body checking is permissible.

5.5 Limitations

Despite the fact that all efforts were made to create a well-designed study, limitations still exist. Although all research assistants were directed to position the camera at centre ice as high as possible to see the ice as clearly as possible, some ice rinks did not have sufficient room in the stands to be able to capture all of the contacts when filming. Depending on the rink, this may have reduced the number of observed physical contacts, especially along the boards closest to the camera, resulting in a misclassification bias of the outcome. However, there is no reason to

believe that ice rinks would be systematically different in Calgary and Vancouver, therefore this bias would be non-differential in nature.

The research assistant filming the game was instructed to constantly keep the puck in the field of view of the camera. Therefore, any contacts occurring outside of the field of view could not be observed and included in the analysis. For this reason, the proportion of PCs that were operational and committed on the puck carrier may be overestimated. As well, any contacts made on the puck carrier immediately after they got rid of the puck would not be recorded. This introduces a measurement bias on contacts made on the puck carrier which would result in an overestimation of the frequency of contacts made on the puck carrier, as well as influence the incidence of type of PC observed (i.e. different types of PC may be committed on the puck carrier as opposed to a non-puck carrier not shown on video). However, this bias would be non-differential in nature as there is no reason to believe the contacts that were not observed would occur more often in a body checking league compared to a non-body checking league.

Although all raters were similarly trained in observing PCs using a previously validated system, difficulties in describing PCs would arise as not all contacts would fit the definition provided in table 3.3.1. Additionally, some contacts are difficult to observe on the camera (including head contact). However, inter- and intra-rater agreement has been assessed using a percentage of agreement (as used in previous studies using the same video analysis technique), as well as a kappa statistic (Appendix B).^{8,42} The kappa agreement was statistic was generally high, however it was low for other types of PC. This is possibly due to the low number of other types of PC chosen for the inter- and intra-rater tests. This would result in non-differential measurement bias if difficulties in describing PCs would arise as there is no reason to believe

these differences would occur more in a body checking league compared to a non-body checking league.

Due to time constraints, all of the non-elite Vancouver ice hockey games were videotaped in the early playoff season, whereas the ice hockey games in Calgary were videotaped in the regular season. Additionally, six elite ice hockey games that were videotaped in Vancouver were playoff games. This may affect the frequency and intensity of the PCs as players may play differently in a playoff game (where the importance of winning the game are higher) compared to playing in a regular season game. For example, it is reasonable to assume that there would be a higher incidence of high intensity contacts in a playoff game compared to a regular season game. Therefore, six additional elite ice hockey games were videotaped in Calgary to examine any potential differences in incidence rates of PCs made with the trunk and other types of PC in playoff and regular season games within each city. No differences were found in high intensity PC (levels 4 and 5) and hooking and slashing behaviours between playoff and regular season games. Therefore, the comparison between non-elite ice hockey players in Vancouver and Calgary is valid.

The characteristics of PCs made with the trunk when the score was tied or when the team was losing or winning, as well as which period they were observed in, were described using proportions. This limits the true understanding of the behaviours of the players as the proportions of the levels of intensity are relative to one another. Incidence rates would have provided a better understanding of the differences within each score differential, however the time spent when team was tied, winning, and/or losing was not recorded, therefore there was no time variable possible for the incidence rate. Using total game time or the time players spent on the ice as an

exposure variable would have overestimated the incidence rate of contacts when the game was tied and underestimated the rate of contacts in all other instances as most time was spent playing when the game is tied. Game time would also be an important exposure variable for examining the PCs made in each period as games may be truncated at the end to accommodate the ice rink schedule for other games.

This study was limited by its lack of covariates to assess for potential confounders. Confounding is a distortion in the magnitude of the true effect of a study exposure on a study outcome due to mixing of effects between the exposure and extraneous factors. All information is unknown about the players observed in this study (injury history, attitude towards body checking, etc.), with the exception of whether they were forwards or defencemen. Therefore, other factors that were not assessed for may influence the effects between exposure (body checking regulation) and outcome (physical contact). Body checking attitude would be a particular confounder of interest, as players in a body checking league may have a more positive body checking attitude compared to players playing in a league that does not allow body checking. This would have overestimated the incidence of higher intensity contacts in the players playing in a body checking league.

There is potential of survivor bias in this study, as some youth ice hockey players may not want to play in a body checking league due to the high injury rate, or they themselves have been injured and did not play in the seasons that were included in this study. This may result in higher incidence rates and intensity of PC observed in a body checking league if the stronger, more intensive players remain playing in the body checking league. Therefore, the rate ratios comparing high intensity PC made with the trunk between Calgary and Vancouver may be

underestimated.

The sample size calculation was performed solely for the primary objective [i.e. comparing higher intensity level 4 and 5 PCs (body checking) and other contacts (i.e. hooking and slashing) between a body checking league and a non-body checking league]. Therefore, the comparison between Bantam ice hockey players with differing body checking experience was a secondary analysis as rates of PC in leagues with differing body checking experience was not known prior to the commencement of this study. Additionally, the sample size calculation for the primary objective used rates of PC of Pee Wee players from a previous study as rates of PC in Bantam ice hockey players were unknown (Appendix A).⁸ We observed a higher IRR in high intensity contacts and hooking and slashing behaviours than expected. This may be due to differences in play in Pee Wee and Bantam ice hockey players, as well as improvements in camera quality and video analysis software used in the present study.

The generalizability of this study must also be considered. This study sample consisted of ice hockey players, therefore these results may not be relevant to other sports. As well, these results may not be generalizable to ice hockey players in different age groups. Players may play differently as they get older, therefore future studies of other age groups should assess those players separately. However, this video analysis methodology as presented in this study can be used in other age groups to inform a greater understanding of PC mechanisms in youth ice hockey in all age groups.

CHAPTER 6: Conclusion

6.1 Summary of findings

To the best of our knowledge, this is the first study to examine the differences in the rates and intensity in PC made with the trunk and other types of PC in Bantam ice hockey players playing in a league that allows body checking and in a league that does not allow body checking. Additionally, this is the first study to examine the differences in PC made with the trunk and other types of PC in Bantam ice hockey players with differing body checking experience as a result of the removal of body checking in Pee Wee players at the beginning of the 2013-14 season. Finally, this is the first study to examine the risk of direct and indirect head contact in Bantam ice hockey players.

Examination of the unadjusted and adjusted incidence rate ratios found that ice hockey players playing in a league that does not allow body checking (Vancouver) have a lower incidence of high intensity contacts made with the trunk compared to players playing in a body checking league (Calgary). However, players in a non-body checking league were observed to commit higher rates of hooking and slashing behaviours. The potential of provincial differences between Calgary and Vancouver were assessed by comparing the rates of high intensity PC and hooking and slashing behaviours in elite Bantam ice hockey players, however no significant differences were observed. Therefore, these results suggest that playing in a non-body checking league is associated with lower rates of high intensity physical contact (body checking).

Additionally, players playing in a league where body checking is not allowed use other methods (hooking and slashing with the stick) to limit the progression of the opponent. While injury rates were not captured in this study, these results suggest that the lower incidence of observed high

intensity contact may be associated with the reduction in injury found in ice hockey leagues where body checking is not allowed.

An exploratory analysis examining the differences in all levels of contact and other types of PC found a lower incidence rate of total PCs made with the trunk in Vancouver (where body checking is not allowed), as well as a lower incidence of levels light, moderate, and higher intensity PCs. The incidence rate of pushing and hitting with the limbs was also higher in Calgary, whereas hooking and slashing was higher in Vancouver. These results suggest that disallowing body checking has a protective effect against virtually all levels of physical contact made with the trunk. These results also suggest that players playing in a league where body checking is not allowed use their stick to restrict the progress of their opponent, whereas players playing in a league where body checking is allowed use more aggressive forms of other types of contact. An exploratory analysis found a lower incidence of direct and indirect head contact due to all types of PCs made with the trunk and higher intensity PCs players playing in Vancouver compared to players in Calgary.

Examination of the unadjusted and adjusted incidence rate ratios shows that ice hockey players with more body checking experience (Calgary, 2013-14 season) do not differ in high intensity PC and hooking and slashing behaviours compared to players with less body checking experience (Calgary, 2014-15 season). An exploratory analysis examining the differences in all levels of contact and other types of PC found no difference in the individual levels of intensity of PC made with the trunk, however pushing with the limbs was more common in players with more body checking experience. The incidence of direct and indirect head contact did not differ between the two seasons.

6.2 Public health implications

This project will move sport injury prevention research forward in youth ice hockey by objectively evaluating the effect of injury prevention strategies in this population using video analysis. This project has provided a unique look at the behaviours of the players in response to a rule change disallowing body checking. This research project will have important national public health implications for policy decisions related to rule enforcement in youth ice hockey. Coaches must know that body checking may lead to higher rates of injury due to higher rates and intensities of physical contacts and must adapt their teaching accordingly. Additionally, coaches should recognize that players use different strategies in limiting the progress of their opponent in body checking leagues compared to non-body checking leagues. Translating and disseminating knowledge about the effects of removal body checking in youth ice hockey will also be important in reducing injury incidence through awareness.

6.3 Future directions

Future investigations of the comparison of physical contacts using video analysis should continue to assess how the frequency and intensity of PC differ following rule changes aimed at reducing injury in youth ice hockey. Additionally, the inclusion of head telemetry with video analysis would be of interest for future research. If possible, other covariates (i.e. the rates of physical contacts in relation to score differential, ice location, and period) should be identified in players and teams and included in future analyses. The secondary objective of this study examined the effects of body checking experience in Bantam players one year following the removal of body checking at the Pee Wee level. Therefore, PCs should be continually analyzed over time as player behaviour may further change in the following years. Head contact should be further analyzed in-depth, possibly with the use of Head Impact Telemetry. Examining body

checking policy in other age groups is imperative as players may play differently depending on their age group. The enforcement of the rules by the referees should be assessed using video analysis and other surveillance systems, especially the enforcement of body checking policy and Hockey Canada's head contact rule.

REFERENCES

1. Hockey Canada. *Hockey Canada Annual Report 2013.*; 2013.
2. Emery CA, Hagel B, Decloe M, Carly M. Risk factors for injury and severe injury in youth ice hockey: a systematic review of the literature. *Inj Prev.* 2010;16:113–118. doi:10.1136/ip.2009.022764.
3. Emery CA, Meeuwisse WH. Injury rates, risk factors, and mechanisms of injury in minor hockey. *Am J Sports Med.* 2006;34(12):1960–9. doi:10.1177/0363546506290061.
4. Roberts WO, Brust JD, Leonard B. Youth ice hockey tournament injuries: rates and patterns compared to season play. *Med Sci Sports Exerc.* 1999;31(1):46–51. doi:10.1097/00005768-199901000-00009.
5. Kelly KD, Lissel HL, Rowe BH, Vincenten J a, Voaklander DC. Sport and recreation-related head injuries treated in the emergency department. *Clin J Sport Med.* 2001;11(2):77–81. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11403118>.
6. Macpherson A, Rothman L, Howard A. Body-checking rules and childhood injuries in ice hockey. *Pediatrics.* 2006;117(2):e143–7. doi:10.1542/peds.2005-1163.
7. Emery CA, Kang J, Shrier I, et al. Risk of injury associated with body checking among youth ice hockey players. *JAMA.* 2010;303(22):2265–72. doi:10.1001/jama.2010.755.
8. Malenfant S, Goulet C, Nadeau L, Hamel D, Emery C a. The incidence of behaviours associated with body checking among youth ice hockey players. *J Sci Med Sport.* 2012;15(5):463–7. doi:10.1016/j.jsams.2012.03.003.
9. IIHF. Survey of Players (2015). 2015. Available at: <http://www.iihf.com/iihf-home/the-iihf/survey-of-players/>. Accessed February 21, 2016.
10. Hockey Canada. *2013 Annual Report.*; 2013.
11. Williamson IJS, Goodman D. Converging evidence for the under-reporting of concussions in youth ice hockey. *Br J Sports Med.* 2006;40(2):128–32; discussion 128–32.

doi:10.1136/bjsm.2005.021832.

12. Meehan WP, Taylor AM, Proctor M. The pediatric athlete: younger athletes with sport-related concussion. *Clin Sports Med*. 2011;30(1):133–44, x. doi:10.1016/j.csm.2010.08.004.
13. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported Concussion in High School Football Players. *Clin J Sport Med*. 2004;14(1):13–17. doi:10.1097/00042752-200401000-00003.
14. Stuart MJ, Smith AM, Nieva JJ, Rock MG. Injuries in youth ice hockey: a pilot surveillance strategy. *Mayo Clin Proc*. 1995;70(4):350–356. doi:10.1016/s0025-6196(11)63415-0.
15. Brust JD. Children’s Ice Hockey Injuries. *Arch Pediatr Adolesc Med*. 1992;146(6):741. doi:10.1001/archpedi.1992.02160180101026.
16. Smith AM, Stuart MJ, Wiese-Bjornstal DM, Gunnon C. Predictors of injury in ice hockey players: A multivariate, multidisciplinary approach. *Am J Sports Med*. 1997;25:500–507. doi:10.1177/036354659702500413.
17. Wattie N, Cobley S, Macpherson A, Howard A, Montelpare WJ, Baker J. Injuries in Canadian youth ice hockey: the influence of relative age. *Pediatrics*. 2007;120(1):142–8. doi:10.1542/peds.2006-2672.
18. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport, Zurich, November 2012. *J Athl Train*. 2013;48(4):554–75. doi:10.4085/1062-6050-48.4.05.
19. Karlin AM. Concussion in the pediatric and adolescent population: “different population, different concerns”. *PM R*. 2011;3(10 Suppl 2):S369–79. doi:10.1016/j.pmrj.2011.07.015.
20. Emery CA. Risk factors for injury in child and adolescent sport: a systematic review of the literature. *Clin J Sport Med*. 2003;13(4):256–68. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12855930>.
21. Marchie A, Cusimano MD. Bodychecking and concussions in ice hockey: Should our youth pay the price? *CMAJ*. 2003;169(2):124–8. Available at:

<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=164979&tool=pmcentrez&rendertype=abstract>.

22. Benson BW, McIntosh AS, Maddocks D, Herring S a, Raftery M, Dvorák J. What are the most effective risk-reduction strategies in sport concussion? *Br J Sports Med*. 2013;47(5):321–6. doi:10.1136/bjsports-2013-092216.
23. Provvidenza C, Engebretsen L, Tator C, et al. From consensus to action: knowledge transfer, education and influencing policy on sports concussion. *Br J Sports Med*. 2013;47(5):332–8. doi:10.1136/bjsports-2012-092099.
24. Daneshvar DH, Baugh CM, Nowinski CJ, McKee AC, Stern R a, Cantu RC. Helmets and mouth guards: the role of personal equipment in preventing sport-related concussions. *Clin Sports Med*. 2011;30(1):145–63, x. doi:10.1016/j.csm.2010.09.006.
25. Hockey Canada. Hockey Canada’s New Head Contact Rule. 2011:1. Available at: <http://www.hockeycanada.ca/en-ca/news/2011-gn-018-en>.
26. Krolkowski M, Black A, Kang J, Emery C. Did Rules and Regulations Aimed at Reducing Head Contact in Ice Hockey Change the Risk of Concussion and Injury in Youth Hockey Players in Alberta ? *J Undergraduate Res Alberta*. 2014;4:6–7.
27. Emery CA, Kang J, Shrier I, et al. Risk of injury associated with body checking among youth ice hockey players. *JAMA*. 2010;303(22):2265–72. doi:10.1001/jama.2010.755.
28. Hockey Canada. Teaching checking: A progressive approach. Available at: <http://www.hockeycanada.ca/en-ca/Hockey-Programs/Coaching/Checking>. Accessed February 24, 2016.
29. Houghton KM, Emery CA. Bodychecking in youth ice hockey. *Paediatr Child Heal*. 2012;17(9):1–6.
30. Regnier G, Boileau R, Marcotte G, et al. Effects of body-checking in the Pee Wee (12 and 13-years-old) division in the Province of Quebec. In: *Safety in Ice Hockey*.; 1989.
31. Hockey Canada. Checking Skills. Available at: <http://www.hockeycanada.ca/en-ca/Hockey-Programs/Coaching/Checking>.

32. Mihalik JP, Guskiewicz KM, Marshall SW, Greenwald RM, Blackburn JT, Cantu RC. Does Cervical Muscle Strength in Youth Ice Hockey Players Affect Head Impact Biomechanics? *Clin J Sport Med*. 2011;21(5):416–421. doi:10.1097/JSM.0B013E31822C8A5C.
33. Rivara FP. *Sports-Related Concussions in Youth*.; 2013. doi:10.1001/jama.2013.282985.
34. Roberts WO, Brust JD, Leonard B, Hebert B. Fair-Play Rules and Injury Reduction in Ice Hockey. *Arch Pediatr Adolesc Med*. 1996;150(2):140. doi:10.1001/archpedi.1996.02170270022003.
35. Marcotte G, Simard D. Fair-Play : An Approach to Hockey for the 1990s. *ASTM Spec Tech Publ*. 1993;(1212):103–108.
36. Montelpare W. Final report to the Ontario Hockey Federation and the Canadian Hockey Association: measuring the effects of initiating body checking at the Atom age level. 2001. Available at: <https://books.google.ca/books?hl=en&lr=&id=LuKir84OOtIC&oi=fnd&pg=PA70&dq=Montelpare++final+report+to+the+ontario+hockey%5C&ots=X8cAoyo8zF&sig=OYbK8Fqm0FGLiax1M5-qHoO8hSY#v=onepage&q=Montelpare+final+report+to+the+ontario+hockey%5C&f=false>
37. Cusimano MD, Taback N a, McFaull SR, Hodgins R, Bekele TM, Elfeki N. Effect of bodychecking on rate of injuries among minor hockey players. *Open Med*. 2011;5(1):e57–64. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3205817&tool=pmcentrez&rendertype=abstract>.
38. Smith AM, Stuart MJ, Greenwald RM, et al. Proceedings from the ice hockey summit on concussion: a call to action. *Clin J Sport Med*. 2011;21(4):281–7. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21847809>.
39. Black AM, Macpherson AK, Hagel BE, et al. Policy change eliminating body checking in non-elite ice hockey leads to a threefold reduction in injury and concussion risk in 11- and 12-year-old players. *Br J Sports Med*. 2016;50(1):55–61. doi:10.1136/bjsports-2015-095103.
40. Emery C, Kang J, Shrier I, et al. Risk of injury associated with bodychecking experience among youth hockey players. *CMAJ*. 2011;183(11):1249–56. doi:10.1503/cmaj.101540.

41. Lacny S, Marshall D a, Currie G, et al. Reality check: the cost-effectiveness of removing body checking from youth ice hockey. *Br J Sports Med*. 2014;48(17):1299–305. doi:10.1136/bjsports-2014-093493.
42. Goulet C, Roy T-O, Nadeau L, Hamel D, Fortier K, Emery C. The Incidence and Types of Physical Contact Associated with Body Checking Regulation Experience in 13–14 Year Old Ice Hockey Players. *Int J Environ Res Public Health*. 2016;13(7):668. doi:10.3390/ijerph13070668.
43. American Association of Neurological Surgeons. Sports Related Head Injury. Available at: [http://www.aans.org/patient information/conditions and treatments/sports-related head injury.aspx](http://www.aans.org/patient%20information/conditions%20and%20treatments/sports-related%20head%20injury.aspx).
44. Torg JS, Guille JT, Jaffe S. Injuries to the Cervical Spine in American Football Players. *J Bone & Jt Surg*. 2002;84(1):112–122. Available at: <http://jbjs.org/content/84/1/112.abstract>.
45. Bjørneboe J, Bahr R, Dvorak J, Andersen TE. Lower incidence of arm-to-head contact incidents with stricter interpretation of the Laws of the Game in Norwegian male professional football. *Br J Sports Med*. 2013;47(8):508–14. doi:10.1136/bjsports-2012-091522.
46. Andersen TE. Mechanisms of head injuries in elite football. *Br J Sport Med*. 2004;38:690–696. doi:10.1136/bjsm.2003.009357.
47. National Hockey League. Official Rules 2014-2015 ©. 2014. Available at: <http://www.nhl.com/nhl/en/v3/ext/rules/2014-2015-rulebook.pdf>.
48. Donaldson L, Asbridge M, Cusimano MD. Bodychecking rules and concussion in elite hockey. Caylà JA, ed. *PLoS One*. 2013;8(7):e69122. doi:10.1371/journal.pone.0069122.
49. Broglio SP, Schnebel B, Sosnoff JJ, et al. Biomechanical Properties of Concussions in High School Football. *Med Sci Sport Exerc*. 2010;42(11):2064–2071. doi:10.1249/MSS.0b013e3181dd9156.
50. Mihalik JP, Guskiewicz KM, Jeffries JA, Greenwald RM, Marshall SW. Characteristics of head impacts sustained by youth ice hockey players. *Proc Inst Mech Eng Part P J Sport*

Eng Technol. 2008;222(1):45–52. doi:10.1243/17543371JSET4.

51. Wilcox BJ, Machan JT, Beckwith JG, Greenwald RM, Burmeister E, Crisco JJ. Head-impact mechanisms in men's and women's collegiate ice hockey. *J Athl Train.* 2014;49(4):514–520. doi:10.4085/1062-6050-49.3.19.
52. Daneshvar DH, Nowinski CJ, McKee AC, Cantu RC. The epidemiology of sport-related concussion. *Clin Sports Med.* 2011;30(1):1–17, vii. doi:10.1016/j.csm.2010.08.006.
53. Guerriero RM, Proctor MR, Mannix R, Meehan WP. Epidemiology, trends, assessment and management of sport-related concussion in United States high schools. *Curr Opin Pediatr.* 2012;24(6):696–701. doi:10.1097/MOP.0b013e3283595175.
54. Lincoln AE, Caswell S V, Almquist JL, Dunn RE, Norris JB, Hinton RY. Trends in concussion incidence in high school sports: a prospective 11-year study. *Am J Sports Med.* 2011;39(5):958–63. doi:10.1177/0363546510392326.
55. Echlin PS, Tator CH, Cusimano MD, et al. A prospective study of physician-observed concussions during junior ice hockey: implications for incidence rates. *Neurosurg Focus.* 2010;29(5):E4. doi:10.3171/2010.9.FOCUS10186.
56. Bakhos LL, Lockhart GR, Myers R, Linakis JG. Emergency department visits for concussion in young child athletes. *Pediatrics.* 2010;126(3):e550–6. doi:10.1542/peds.2009-3101.
57. Rosenthal JA, Foraker RE, Collins CL, Comstock RD. National High School Athlete Concussion Rates From 2005-2006 to 2011-2012. *Am J Sports Med.* 2014;42(7):1710–1715. doi:10.1177/0363546514530091.
58. Emery C, Black A, Macpherson A, et al. Evaluation of a body checking policy change as an injury prevention strategy for non-elite youth ice hockey players. *Br J Sports Med.* 2014;48(7):591. doi:10.1136/bjsports-2014-093494.85.
59. Black AM, Macpherson AK, Hagel BE, et al. Policy change eliminating body checking in non-elite ice hockey leads to a threefold reduction in injury and concussion risk in 11- and 12-year-old players. 2016:55–61. doi:10.1136/bjsports-2015-095103.
60. Emery CA, McKay CD, Campbell TS, Peters AN. Examining attitudes toward body

- checking, levels of emotional empathy, and levels of aggression in body checking and non-body checking youth hockey leagues. *Clin J Sport Med*. 2009;19(3):207–215. doi:10.1097/JSM.0b013e31819d658e.
61. Mihalik JP, Blackburn JT, Greenwald RM, Cantu RC, Marshall SW, Guskiewicz KM. Collision Type and Player Anticipation Affect Head Impact Severity Among Youth Ice Hockey Players. *Pediatrics*. 2010;125(6):e1394–e1401. doi:10.1542/peds.2009-2849.
 62. Gee C, Sullivan P. Using A Direct Observation Approach To Study Aggressive Behaviour In Hockey : Some Preliminary Findings. 2006;8(1):16–31.
 63. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159–174. doi:10.2307/2529310.

APPENDIX A: SAMPLE SIZE CALCULATION

Sample size calculation for video analysis on Physical Contact rate (levels 4 and 5) and other contact rate (hooking and slashing), respectively.

$\alpha = 0.05$ = acceptable type I error (using a two tailed test)

$\beta = 0.20$ = acceptable type II error

λ_0 = PC rate /game in the non body checking league

λ_1 = PC rate /game in the body checking league.

The following assumptions were made:

Average of 16 players per team

All players played same amount of time

Table 1. Calculation based on Alberta rates in 2007-2008.

Summary of team game information	Physical contact (levels 4 and 5) (AB – all divisions)	Other contact (hooking and slashing) (AB – all divisions)
Average number of players per team-game	16	16
Total number of players team-game	20*16=320	20*16=320
Total number of contacts	235	66
Overall contact rates (per player team-game)	0.734	0.206
Var of rates (per player team-game)	0.193	0.04979

$$c = 1 + (z_{\alpha/2} + z_{\beta})^2 \left[\frac{(\lambda_0 + \lambda_1)/y + k^2(\lambda_0^2 + \lambda_1^2)}{(\lambda_0 - \lambda_1)^2} \right] = \text{clusters per group.}$$

Cohorts	Physical Contact (levels 4 and 5) (based on AB– all divisions)	Other contact (hooking and slashing) (based on AB– all divisions)	
Y (average # players per team-game)	16	16	
D (empirical var of player team-game rates)	0.193	0.04979	
E (overall contact rate - player team-game)	0.734	0.206	
$F = Av(1/y_j)$	1/16	1/16	
$K = \sqrt{D - E \times F} / E$	0.522	0.933	
λ_0 (rate in control-player)	0.3336	1.03	
λ_{AB} (rate in body check league-player)	0.734	0.206	
$IRR = \lambda_1/\lambda_0$	2.2	0.2	
Sample size c (# of teams per province)	13	13	

APPENDIX B: INTER- AND INTRA-RATER AGREEMENT

Table 1. Intra-rater and inter-rater agreement using kappa statistic

Decisions	Intra-Rater			Inter-Rater	
	Rater 1	Rater 2	Rater 3	Test 1	Test 2
Defensive/Offensive	0.97	0.59	0.73	0.89	0.88
Location (1-5)*	0.94	0.77	0.77	0.94	0.95
Deliberate/Non-deliberate	0.97	0.74	1	0.97	0.95
Intensity (1-5)*	0.95	0.73	0.72	0.93	0.91
Other Contact (Limbs/Object)	1	0.82	0.8	0.75	0.91
Type of Other contact (Hooking, holding, hitting, pushing)*	0.7	0.2	0.63	0.58	0.66
Puck carrier	0.89	0.74	0.72	0.83	0.86
Operational	1	0.89	0.8	0.97	1
Head contact (Direct, indirect, no head contact)	0.84	0.54	0.49	0.93	0.84

*Weighted kappa

APPENDIX C: MEASURE OF PHYSICAL CONTACTS

Date _____

PeeWee () Bantam ()

Level: 1 () 2 () 3 () 4 () 5 () 6 () 7 () 8 () 9 ()

Color jerseys

Name _____

[illegible]

_____ 287.1

APPENDIX D: INFORMATION ABOUT THE STUDY

Sport Injury Prevention
Research Centre
UNIVERSITY OF CALGARY

The Risk of Injury Associated with Body Checking among Pediatric Ice Hockey Players

Principal Investigators: Dr. Carolyn Emery, Dr. Kathryn Schnelder (University of Calgary)

Co-Investigators: Dr. Brent Hagel, Dr. Willem Meeuwisse, Dr. Jian Kang, Dr. Alberto Nettel-Aguirre, Dr. Carly McKay, Dr. Gillian Currie, Dr. Deborah Marshall (all University of Calgary), Dr. Claude Goulet (Université Laval), Dr. Don Voaklander, Dr. Martin Mrazik (University of Alberta), Dr. Shalina Babul (University of British Columbia), Dr. Alison Macpherson (York University).

Funding: Alberta Innovates Health Solutions CRIO, Alberta Children's Hospital Research Institute, Canadian Institutes for Health Research, International Olympic Committee, Max Bell Foundation

Ethics: The Conjoint Health Research Ethics Board at the University of Calgary (E-20252) has approved this study.

Why do this research?

The recent policy change to ban body checking among Pee Wee players provides a unique context to evaluate the impact of this policy on the types of physical contacts executed during games, and on the offensive performance of players, according to their body checking experience.

What are the goals?

- 1) To compare physical contacts of Pee Wee players in Calgary playing with body checking (2007-2008 season historical cohort) and without body checking (2013-2014 season).
- 2) To compare physical contacts of Pee Wee players from Calgary and Québec City, both playing without body checking (2013-2014 season), however teams in Alberta include kids in 2nd year with previous body checking experience.
- 3) To compare physical contacts of Bantam players from Calgary exposed to body checking with body checking experience at Pee Wee level (2013-2014 season) to players from Calgary, also exposed to body checking, but some (1st year players) without body checking experience at Pee Wee level (2014-2015 season - pending).

How will it be done?

In Calgary and Québec City, we will videotape 26 Pee Wee games from February 2014 until the end of the regular season. In Calgary, we will also videotape 26 Bantam games during this time frame. Half of the games recorded will be from the top 30% level of play.

Two or three researchers will attend the games. They will set up a small video camera on a tripod, out of the way of the players, officials and the bench. Players, coaches, managers and parents will not be disrupted at any point. The filming will not interrupt the regular game process. The information recorded will stay in the hands of the research team and will not be made available to any other parties.

**The videos will be anonymous. Players will not be able to be identified in the recording.
Video footage will not be linked to team rosters or any other data.**

Contact us

If you have any questions or concerns contact the research team at 403-220-6336 or hockey@ucalgary.ca

APPENDIX E: MEASURE OF PLAYING TIME

Ice hockey research project 2014
Measure of playing time

Observed team _____ **Date & Time** _____ **Arena** _____

PeeWee () Bantam ()

Level : 1 () 2 () 3 () 4 () 5 () 6 () 7 () 8 () 9 () 10 () 11 () 12 ()

Your name _____ **Jersey colour** _____

Numbers on jerseys

Time	LD	RD	LW	C	RW