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An Economic Evaluation of Body Checking Policies in Bantam Ice Hockey

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An Economic Evaluation of Body Checking Policies in Bantam Ice Hockey

by

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Abstract

Sport-related injury is the leading cause of injury in youth and are costly to the healthcare system. Disallowing body checking in Pee Wee (ages 11-12) ice hockey has been found to be effective in reducing the risk of injuries and associated healthcare costs, however the impact on injury risk and costs in Bantam (ages 13-14) remains unknown. The objectives of this study are to compare injury rates and costs between non-elite (lower 70% divisions of play) Bantam players in leagues allowing body checking to where body checking is disallowed, and to project the overall change on the number of injuries and costs to the Alberta healthcare system if body checking were disallowed for all Bantam players over one season. The study found that disallowing body checking reduced injuries by 4.32/1000 player-hours and saved cost by $1,737/1000 player-hours in the public healthcare system. This policy change could potentially prevent 1,102 injuries that occur during games and save $331,522 in the public healthcare system over one season in Alberta. However, this study used injury rates adjusted only for exposure hours and team clustering, but not other covariates or repeated observations. Thus further analysis is required before policy recommendations can be made.

Keywords: Health Economics, Costs and Cost Analysis, Economic Evaluation, Cost-effectiveness Analysis, Prevention, Adolescents, Sports, Cohort Study, Athletic Injuries

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Table of Contents

List of Tables

List of Figures and Illustrations

Chapter 1 Introduction

In Canada, approximately 475,000 youth participate in hockey in 2015-2016 season[1]. Participating in a team sport has a range of benefits such as improving self-esteem, performance in academic studies, and mental health[2-4]. While sport participation is important and beneficial, concussions and musculoskeletal injuries are a risk in hockey[5]. A national study of admissions to the emergency department for sport-related injuries found that ice hockey accounted for the highest proportion of concussions and musculoskeletal injuries compared to other sports in Canadian youth between the ages 5-19 years[6]. This is concerning because these injuries can cause permanent, detrimental effects later in life such as osteoarthritis[7-9]. There is also growing literature in concussion showing that 13.7% of all children with concussions remain symptomatic longer than three months post-injury[10,11].

Injuries can lead to significant health care costs. In 2015, $97 million was spent in the healthcare system on sport-related injuries in Canada for all ages[12]. The cost of sport-specific injuries in youth is unknown as data on the current economic burden was collected under a broad sport category[12]. The overall cost estimate did not account for all sports nor for the chronic disease that result from musculoskeletal injuries and concussions. As such, the true cost burden of these injuries is currently underestimated.

In a systematic review evaluating risk factors for injury and severe injury in youth ice hockey, body checking was consistently identified as a significant risk factor for all hockey related injuries[13]. One of the studies in the systematic review reported that of all injuries occurring in hockey, 44.6% were due to body checking which was much higher than the second mechanism of injury which was incidental contact (16.6%)[14]. Studies published after the systematic review also found that body checking was the most common mechanism of injury in a cohort study over one season of play in 2011-2012[15,16]. When the following 2013-2014 season disallowed body checking, it was projected that 772 injuries and 581 concussions would have been prevented for 8,768 Pee Wee players registered in Alberta[15].

Body checking policy is regulated provincially or municipally and therefore differences allow natural comparisons, which can be evaluated within a cohort study[17-19]. A previous study conducted an economic evaluation of body checking policy in Pee Wee (age 11-12 years) hockey leagues[20]. In that study, injury rates were 2.84 times higher and healthcare costs were 2.96 times here when body checking was allowed during games. It was projected that 1,273 injuries could have been prevented and $213,280 (2009 CAD) saved over one season if body checking were disallowed in Alberta[20]. An economic evaluation has not been conducted at the Bantam (age 13-14 years) age group and it is unknown if similar results would be observed. A national policy change was implemented by Hockey Canada in 2013 to disallow body checking in games in Pee Wee and younger age groups[17]. Provincial or local hockey organizations can choose to restrict body checking even more conservatively without a national policy change for older age groups in local or provincial competitions. Some jurisdictions disallow body checking in non-elite Bantam and Midget age groups (age 15-17), but this is not national in scope. Differences in how jurisdictions make decisions may be due to a variety of factors such as concerns with injury risks, how it would affect skill development, and other consequences as a result of changing the body checking policy. Evidence is needed on the associated costs to families and the healthcare system as a result of differing rates of injury associated with body checking, to provide evidence to inform decisions about a body checking policy in other jurisdictions.

1.1 Research Question

What is the expected effect on injury rates and costs if body checking were disallowed for non-elite Bantam ice hockey players?

1.2 Objectives

1. To compare injury rates and costs between policies allowing and disallowing body checking in non-elite Bantam ice hockey players (lower 70% by division of play).
2. To estimate the overall change in the frequency of injury and costs in Alberta if body checking were disallowed for all non-elite Bantam ice hockey players over one season using a budget impact analysis.

The remainder of this thesis is organized as follows. The second chapter describes the ice hockey league structure in Canada and includes a literature review on the epidemiology of hockey injuries, the cost burden of hockey injuries, current economic evaluations on injury prevention strategies in hockey, and rationale for the study. The third chapter describes the research methods consisting of the cohort design, the design of the economic evaluation which addresses objective one, and the design of the budget impact analysis which addresses objective two. The fourth chapter contains the results from the cost-effectiveness analysis and the budget impact analysis. The fifth chapter provides the discussion of the results from this thesis, comparing previous literature, and lastly the strengths and limitations of this study.

Chapter 2 Background and Literature Review

The second chapter describes the literature on ice hockey injury epidemiology in youth, feasible interventions to prevent injuries, and the current state of health economics research in injury prevention. The context of the public health issue of injury in youth ice hockey will be described. This chapter is organized as follows: Section 2.1 provides background information on the hockey league structure in Canada. It also describes the current literature on the epidemiology of hockey injuries and risk factors associated with injuries in ice hockey. Section 2.2 describes the steps required for an economic evaluation and what the possible scenarios are that can result from the analysis. Section 2.3 describes the current literature on the cost burden of hockey injuries, current economic evaluation guidelines in Canada, and gaps in current research and in policy.

2.1 Background and Literature Review on Ice Hockey Injuries

2.1.1 Hockey League Structure in Canada.

There were 467,360 Canadian youth and children registered in hockey in 2016-2017[21]. The age categories in youth ice hockey in Canada are: Initiation (under 7 years of age), Novice (7-8 years), Atom (9-10 years), Pee Wee (11-12 years), Bantam (13-14 years), and Midget (age 15-17)[1]. There were 8,539 Bantam players registered in 2016-2017 up from 8,231 that were registered 2015-2016 in Alberta[1,21]. There are divisions within minor ice hockey that are categorized based on competitive and non-competitive leagues defined by proportions of divisions of play (e.g. non-elite Bantam is at the lower 70% divisions of play). Every province has their own competitive league structure but generally follow the ‘AA’ league model provided by Hockey Canada[22]. Players try out for teams and are then allocated by independent evaluators to teams based on their divisions of play. Competitive divisions are divided based on skill level where AAA (also known as rep for representative hockey) is the most competitive and recreational leagues are the least competitive (E.g. Calgary Bantam: AAA being most competitive, then AA, A, 1, 2, 3, etc)). Recreational divisions do not require try outs to make the team at the start of the season.

Body checking (BC) has not been allowed in Pee Wee or younger age groups across Canada since the national policy change in 2013. BC can be introduced in Bantam or older according to municipal or provincial organization's (i.e. Hockey Calgary vs. Hockey Edmonton) policy[17]. Thus, body checking policy differs across Canada. In Ontario, Alberta, Quebec, and Saskatchewan, body checking in non-elite divisions of play is disallowed up to Midget for most of their major municipal bodies as of 2017[18,23]. In Alberta, Hockey Calgary disallowed body checking in non-elite Bantam (lower 70% by division of play) in the 2015-2016 season[24]. Hockey Edmonton disallowed body checking in the following season in the 2016-2017 season[24]. In British Columbia, hockey organizations were early adopters of disallowing body checking up to Midget ice hockey in the lower 70% divisions of play in 2013[25].

2.1.2 Injury in Hockey.

Musculoskeletal injuries are the most common injuries behind concussions in youth ice-hockey[14]. Of all general musculoskeletal injuries that occur during games, knee injuries (13.5%), acromioclavicular joint injuries (8.9%), upper leg contusions (6.2%), and pelvis strains (4.5%), and hip muscle strains (4.5%) were among the most common[26,27]. While it is not very common, severe knee injuries such as anterior cruciate ligament tears that occur in hockey can lead to osteoarthritis[28,29]. Repetitive musculoskeletal injuries are common in the sport and, while they can heal well for acute events, repeated partial tears and total ruptures can lead to ongoing disability[30]. One type of disability is post-traumatic osteoarthritis that most commonly affects the knee joint which may occur 3 to 10 years following a severe sport-related knee injury[31]. Those who were affected by post-traumatic osteoarthritis felt more pain, a lower quality of life, and believed that their injury affected their daily living and their ability to participate in sport/recreation[31]. Youth with post-traumatic osteoarthritis were also more likely to be overweight or obese due to their injuries which can further exacerbate their symptoms and quality of life[31].

Another concern with ice hockey is the risk of concussions. Ice hockey has the second highest proportion of concussions for both males and females between the age 5-19 among sport and recreation activities in Canada[6]. It has also been recently reported that 18-66% of all injuries causing time loss from sport in youth hockey are concussions[15].While research is still ongoing to identify the full extent of the consequences, concussions can lead to neurocognitive and memory deficiencies during recovery. A recent systematic review on the potential long-term effects of sport-related concussion showed multiple prior concussions in former athletes were associated with depression and cognitive deficits later in life[32]. A retrospective chart review also observed that 65% of hockey players with a history of concussions admitted to the emergency department suffered from long-term post-concussion symptoms and were recommended to stop participating in sports[33]. In most children, post-concussion symptoms resolve within ten days[34]. However, this is not the case for all children with concussions. It was found that among those who suffered a concussion, 13.7 to 29.3% remained symptomatic after 3 months[10,11], and 2.3% of cases remained symptomatic beyond one year[11].

2.1.3 Epidemiology of Injuries.

2.1.3.1 Severe Injuries.

There is no standard definition for severe musculoskeletal injuries that is agreed upon in current literature. Different definitions of severe musculoskeletal injuries are currently used including either ten consecutive days lost from sport, or as a result of specific injury types such as fractures, dislocations, concussions, or any injuries that require hospitalization or emergency medical attention[35]. Severe injury was examined as a separate outcome in 11 studies to examine unique risk factors that are associated with injuries that either required hospitalization or took time away from sport[35]. For concussions, ten days are also used to differentiate between mild concussions and more severe concussions based on the recent sport-related concussion consensus statement[34]. Age and body checking were identified as consistent risk factors for severe injury and concussions[35].

2.1.3.2 Risk Factors of Injury in Hockey.

2.1.3.2.1 Body Checking

There are two main mechanisms of injury that occur in hockey: intentional and unintentional contact[36]. Intentional contact includes body checking which is defined as "*an individual defensive tactic designed to legally separate the puck carrier from the puck. The action of the defensive player is deliberate and forceful in an opposite direction to which the offensive player is moving*"[37]. Unintentional contact is when contact occurs but without deliberate intent. While injuries do occur with unintentional and intentional contact, body checking were found to be an independent risk factor of injury in hockey in multiple studies[15,16,38]. A meta-analysis of four studies investigated the effect of body checking as a risk factor for concussion reported an odds ratio of 1.71 (95% CI:

1.2 to 2.44)[35]. A systematic review of body checking policies came to the same conclusion that body checking were the main mechanism for injuries across divisions of play[37].

2.1.3.2.2 Divisions of Play.

Divisions of play was investigated as a risk factor for injury in four studies[14,35,39,40]. Emery *et al* found the upper three divisions of play to have a relative risk of 2.45 (95% CI: 1.15 to 5.81) compared to the lower three divisions of play in Pee Wee. Division of play was not a significant risk factor in Bantam (1.50; 95% CI: 0.82 to 2.9) nor in Midget (1.00; 95% CI: 0.59 to 1.63) in the same study[14]. However, the risk of injury was higher as division of play increased across all age groups (Atom, Pee Wee, Bantam, and Midget) in two other studies[39,40]. Wattie *et al* found that the odds of getting injured were 3.53 (95% CI: 1.90 to 656) times higher for Pee Wee and 3.21 (95% CI: 2.18 to 4.73) times higher in Bantam when comparing the upper quartile of division of play to the lower quartile of play[39]. Willer *et al* also found that the odds of getting injured are 6.1 times higher (95% CI: 3.8 to 10.0) for rep players than recreational league players for all age groups (Tyke, Atom, Pee Wee, bantam)[40]. Emery *et al* also looked at risk factors of injury and concussion in Pee Wee ice hockey between divisions of play in 2010[13]. The study found that division of play was a significant risk factor for all injuries, but not for severe injuries, concussions, and severe concussions between the upper 20% and the mid 40% divisions of play[13]. It is possible that the differences between studies were due to Wattie *et al* not accounting for exposure time between elite and non-elite players while the Emery study compared the divisions of play using incidence rate ratio which adjusted for exposure time. Overall, most of the studies identified divisions of play was a risk factor for hockey-related injuries.

2.1.3.2.3 Player Positions.

There are three general player positions in hockey: forward, defense, and goalie. In a systematic review, player position was identified as a risk factor where forwards had a higher risk of injuries than defensemen and goalies in two studies[35,41,42]. Using a 2x3 (position by age level) factorial ANOVA, forwards were found to have significantly higher injury rate than defensemen in a youth ice hockey tournament ($p<0.01$)[42]. The greatest difference was found between a centre and the left defence ($p<0.05$) using the Tukey's Honest Significant Difference post-hoc test[42]. In another study, Williamson *et al* found that among their injured players, 55% were forwards, 36% were defense, and 9% were goalies[43]. It was unknown if these proportions were significant since a descriptive analysis was only conducted. It was also possible that the results reflected the proportion of team players in each of these positions. Exposure time was also not considered in these analyses both by Williamson *et al* and Roberts may have overestimated the effect on the forward position[42,44]. One study found that the relative risk of injury went the other direction where forwards were 2.18 times less likely to be injured than defensemen[45]. While it appears that the literature is inconsistent on the direction of injury risk on player position, it is still possible that player position is an independent risk factor on injuries in youth ice hockey.

2.1.3.2.4 Sex as Risk Factor.

Sex may be a risk factor for injuries in youth ice hockey. Male players had an increased rate of injury (incident rate ratio (IRR)=2.31) compared to females but the sample size of girls was too small to conclude that the results were valid if the study was affected by selection bias among the girls sampled in the study[42].

No other study was found looking at sex as a risk factor due to limitations in sample size. As a result, it is unknown if sex is a risk factor in youth ice hockey and further research is needed to confirm if sex is a risk factor for injury in youth ice hockey.

2.1.3.2.5 Weight and height.

The effect of weight and height on injuries as a risk factor depends on the outcome[35]. Earlier studies found that differences in weight and height between players who are in the act of delivering a body check can increase the risk of injury to the recipient [41,46]. Wiggins *et al* using univariate analysis found that players who were injured had a significantly lower weight than players who were not injured[41]. Finke *et al* found that heavier players (160lbs or more) at the age of 16-18 years had a twofold increase risk of a shoulder injury than lighter players (less than 160lbs) at 14 or 15 years of age also using univariate analysis[46]. Rationale was not provided to identify the cut-off between lighter and heavier players in the article.

A more recent study conducted a multivariate analysis adjusting for confounding and clustering by team on weight (greater or less than or equal to 37 kg) in determining the risk of injury and concussion between Pee-Wee players in which body checking is permitted[13]. Weight was found to be a significant risk factor for all injuries (IRR= 1.40 95% CI (1.01-1.93) adjusting for clustering by team and covariates[13]. It was not found to be a risk factor for severe injuries after adjusting for clustering by team using univariate analysis[13]. Weight was also not found to be a risk factor for concussions when adjusting for teams using multivariate analysis, and severe concussions when adjusting for teams using univariate analysis[13].

Another study using a Poisson regression model controlling for year of play, weight, previous injury within the last year or any previous concussion, divisions of play or non-elite divisions of play, position and attitudes toward body checking, weight was explored as an independent risk factor in Pee Wee ice hockey in Alberta in 2011-2012 and 2013-2014 seasons[16]. Comparing Pee Wee players who were below or above 36.4 kg, weight was not a significant risk factor for all injuries (incidence rate ratio (IRR) =1.32, 95% CI: 0.92-1.90) nor for concussions (IRR=1.39, 95% CI: 0.89-2.15)[16]. Univariate Poisson regression models were used for severe injuries and severe concussions due to a small number of events observed in the study unable to power a fully adjusted analysis. Weight was not a risk factor for severe injuries (IRR=1.32, 95% CI: 0.81-2.13) nor for severe concussions (IRR=1.58, 95% CI: 0.69-2.01)[16].

2.1.3.2.6 Body Checking Experience.

Body checking experience was a potential confounder that was not commonly investigated and produced conflicting results[47]. One study observed the effects of changing body checking rules on injury rates five years before body checking was allowed years in Atom ice hockey and five years after body checking was allowed using retrospective data from Canadian Hospital Injury Reporting and Prevention Program (CHIRPP)[48]. The study stated that 59.9 (95% CI: 55.4 to 64.4) injuries per 1000 player-years occurred before body checking was allowed and 49.1 (95% CI: 44.8 to 53.3) injuries per 1000 player-years after body checking was allowed in Atom[48]. This showed that body checking experience may have significantly reduced the rate of injuries. The authors proposed this may be due to an additional year of adjusting to the game for skill development when body checking is allowed. This observation was also repeated in another study where severe injuries resulting in more than seven days of time loss from play was 33% lower (95% CI: 0.01 to 0.54) among players with two years of body checking experience in Pee Wee teams than players who played with body checking for the first time[47]. The results were not significant for concussions and game-related injuries[47]. A retrospective study evaluated data from 1994 to 2004 through the CHIRPP when body checking were introduced as young as 9 years in the 1998/1999 season[38]. It found that the odds of visiting an emergency department because of a body checking injury were 1.26 (95% CI: 1.16-1.38) times higher across age categories from 9 to 18 years[38]. The results of these studies conflict with another study that found the odds of receiving a checking injury were higher when body checking were introduced at a younger age compared to when body checking were introduced later[49]. This was due to the fact that CHIRPP is a hospital-based surveillance system that only used concussions admitted to the hospital and did not account for concussions that did not require hospitalization. Overall, body checking experience may or may not have an effect on decreasing the risk of injury.

2.1.3.2.7 Attitudes Towards Body Checking.

Body checking attitudes were identified as a possible risk factor for injuries in youth ice hockey. The theory was that more aggressive adolescents were less empathetic than their nonaggressive counterparts[50]. It was also suggested that children with less developed moral reasoning had higher levels of self-reported aggressive tendencies[51]. From this, it was possible that moral reasoning in sport settings can be used to value certain aggression in sport depending on how it was used.

Aggression in sport can either be hostile or instrumental[52]. Hostile aggression is behaviour that is intent on harming another[52]. Instrumental aggression is “an aggressive act that occurs in pursuit of a nonaggressive goal"[52]. Body checking can be method of either instrumental or hostile aggression in hockey depending on intent. It was hypothesized that body checking attitudes can be used to infer aggressive intent and independently affect injury rates in youth ice hockey.

A Body Checking Questionnaire was created to assess the attitudes toward body checking in youth ice hockey players using the mean scores to compare players who were allowed or disallowed from body checking[53]. The Body Checking Questionnaire has been tested for concurrent validity[51]. Players who were allowed to body check had a more favourable attitude (35.59 of 55, 95% CI: 34.52-36.65) towards body checking than players who were disallowed from body checking (22.43 of 55, 95% CI: 21.38-23.49)[53]. Injury rates were not influenced by attitudes towards body checking nor aggression. The incidence rate ratio was 2.87 (95% CI: 0.82-9.44) for players with a strong positive attitude towards body checking[53].

This result was consistent in recent literature investigating attitudes towards body checking as a confounder. Black *et al* (2016) also found there was no significant difference in positive and negative attitudes towards body checking on all injuries (IRR=0.72, 95% CI: 0.46 to 1.13), severe injuries (IRR=0.91, 95% CI: 0.47 to 1.77), concussions (IRR=0.76, 95% CI: 0.43 to 1.33), and severe concussions (IRR=0.84, 95% CI: 0.37 to 1.89) when comparing players who are allowed (Ontario) or disallowed body checking (Alberta)[16].

This was also investigated in a retrospective cohort when body checking policies were disallowed in the following year in Alberta in the lower 70% divisions of play[15]. Similar results were found in this study as well. In an adjusted Poisson regression model adjusting for clustering by team, year of play, weight, previous injury within the last year or any concussion, divisions of play, position, and attitudes toward body checking, attitudes toward body checking were not independently associated with an increased rate of injuries (IRR=1.02, 95% CI: 0.7 to 1.46) nor concussions (IRR=0.93, 95% CI: 0.62 to 1.40)[15]. In the same study, severe concussion and severe injuries outcomes were also explored where a univariate Poisson regression model was used due to small number of events. The results showed that players with a positive attitude towards body checking were not associated with an increased rate of severe injuries (IRR=1.19, 95% CI: 0.74 to 1.92) and severe concussions (IRR=1.07, 95% CI: 0.61 to 1.88)[15]. Overall, body checking experience was not found to be a risk factor for injury, severe injury, concussion, nor severe concussion in Pee Wee ice hockey.

2.1.3.2.8 Summary of Risk factors.

There are several risk factors for injuries in ice hockey. Body checking was found to be an independent risk factor for injury in youth ice hockey. Division of play was also found to be a risk factor for injury where players in higher levels of play had an increased rate of injury. Age was also found to be an independent risk factor where the risk of injury increased when players were older. Player position may be a risk factor but it is unknown if forwards or defensemen have a higher rate of injury. It is unknown if weight, height, body checking experience and sex are risk factors for injury and require more research. Attitude towards body checking were found not to be a risk factor for injury. Overall, information on these risk factors should be collected in studies observing injuries in youth ice hockey and controlled for in their analysis.

2.2 Background on Economic Evaluation

2.2.1 Economic Evaluation Definition.

In any healthcare system, there are limited resources within a budget to fund health care services. Under conditions of resource scarcity, there is an opportunity cost attached to each choice. If a new intervention is funded, some other intervention can not be funded and its associated benefits will be lost given a limited budget. These lost benefits are the opportunity costs. An economic evaluation is "a comparative analysis of alternative courses of action in terms of both their costs and consequences" which identifies the opportunity costs between alternative courses of action[54]. Economic evaluation provides results that can help inform decision makers about choices between interventions. The following section describes the elements of an economic evaluation based on the current guidelines to review new drugs submitted to the Canadian Agency for Drugs and Technologies in Health (CADTH)[55].

2.2.2 Target Population.

The target population is defined as the population intended for the intervention. It is recommended by CADTH to explicitly state the target population of the economic evaluation[55]. This will include relevant information such as age, disease state, and comorbidities. This is important because the effectiveness of the intervention may be dependent on these characteristics.

2.2.3 Perspective and Time Horizon.

To do an economic evaluation, a perspective must be adopted to identify the relevant costs and consequences[54]. In previous Canadian guidelines, it was recommended to use a societal perspective which encompasses all costs associated with the intervention which included public and private healthcare costs, transfer costs, productivity loss, transportation costs, and costs associated care givers. Currently, CADTH recommends using the public healthcare perspective because healthcare funding and decisions on healthcare funding are done by the government and require the relevant costs and effectiveness of interventions to make informed decisions[55]. Using perspectives outside of the societal and public healthcare perspective is not the norm, however, a disaggregated scenario (e.g. out-of-pocket cost only) can be used in additional to the main perspective to provide more information to the reader to allow them to take into account those costs relevant to their decision-making context.

A time horizon must be stated to identify the time frame over which costs and effects should be measured that is clinically relevant to the primary outcome measure of effectiveness[54]. CADTH recommends using a lifetime horizon to capture the full health benefits and costs associated with each alternative courses of action to provide the most complete information[55].

2.2.4 Discounting.

Discounting is a method to identify the current value of costs and effectiveness of an intervention that are spread across time beyond one year[54]. The current CADTH guidelines recommends using 1.5% as the reference case for both costs and outcomes[55].

2.2.5 Healthcare Resource Use and Unit Costs.

Resource use items relevant to the perspective and to the target population are then identified and measured (e.g. physician visits, medication, diagnostic imaging). Sources for unit costs are then determined and justified to value resource utilization relevant to the intervention (i.e.

administrative data on the costs of physician billing). CADTH recommends that all activities and resources that are likely to occur within the context of the target population, perspective, and time horizon should be included in an economic evaluation[55].

2.2.6 Effectiveness Measures.

Effectiveness measures used in an economic evaluation can be of any valid outcome relevant to the decision making context[55]. The term effectiveness in an economic evaluation is often used interchangeably with benefits or outcomes to refer to the results of the study. Effectiveness measures in economic evaluations depends on the type of analysis that is being conducted. There are four different types of economic evaluation that use different effectiveness measures: cost-utility analysis, cost-effectiveness analysis, cost-minimization analysis, and cost-benefit analysis[54]. A cost-utility analysis is a comparative analysis that looks at the cost per Quality of Adjusted Life Years (QALYs) between an intervention and standard care. CADTH recommends using Quality Adjusted Life Years (QALYs) as the primary outcome measure in a cost-utility analysis[55]. QALYs incorporate both life expectancy (mortality) and quality of life (morbidity) in measure. They can also be used to compare the outcomes of different interventions whereas effectiveness measures are limited to their clinical or health context[54]. QALYs can be a utility based measure that incorporate the formal consideration of preferences of health states under uncertainty if they used a utility based measure for quality of life[54]. In a cost-effectiveness analysis, clinical outcomes (e.g. injury rates) that are relevant to a clinical or health issue and to the decision are used[54]. One example in the context of injury prevention is injuries prevented. A cost-minimization analysis is where the consequences of two or more treatments are shown to be the same and the comparisons are made only in costs[54]. A cost-benefit analysis compares both the effect and costs of two or more intervention in monetary units. The effectiveness measure here requires the outcome to be valued in monetary terms.

2.2.7 Data Sources for Effectiveness.

There are various sources from which data for an effectiveness measure to inform an economic evaluation can be obtained: current literature (e.g., meta-analyses, systematic reviews), randomized clinical trials, and cohort studies[54]. Pooled estimates in meta-analyses and estimates in systematic reviews can be used to inform model based economic evaluations[54]. Economic evaluations are conducted alongside randomized clinical trials or prospective cohort studies to collect patient-specific data on costs and outcomes [54]. Conducting an economic evaluation alongside a prospective cohort study is open to selection/sampling bias unlike clinical trials which can be controlled using randomization. However, this can be accounted for in cohort studies by a robust sampling design, stratification, or adjusting for covariates in analyses.

2.2.8 Analysis and Type of Results from an Economic Evaluation.

There are three steps to the analysis. First, the mean difference in outcomes between interventions is calculated. Second, the mean cost difference between interventions is calculated separately. The third and last step divides the cost and effect difference to, if appropriate, calculate the incremental cost-effectiveness ratio (ICER) (Figure 1). Depending on the result, there are four types of results from this calculation as shown on the cost-effectiveness plane in Figure 2. The intervention can be (relative to the comparator):

1. More costly and less effective
2. Less costly and more effective

3. More costly and more effective
4. Less costly and less effective

In the first result, the intervention is dominated and can be recommended not to adopt the new intervention. In the second result, the intervention is dominant and it is recommended to use the intervention over the comparator. The third and fourth results are situations where the intervention is more effective and more costly, or less effective and less costly than the comparator. No clear recommendation can be made in this situation, but the analysis can reveal the trade-offs between effect and costs and quantify how much extra spending is needed to achieve a unit increase in effectiveness. For example in case 3, the improvements in effectiveness can only be achieved by spending additional resources. In order to increase the effectiveness, an increase in financial investment must be made. Under a limited budget, the financial investment would mean disinvesting in another intervention and incurring opportunity costs in forgone benefits. Judgement is required to make this decision about whether the value of increased benefits for one group, is worth the lost benefits to another. An ICER can be computed, in this scenario, which shows the incremental costs per unit of incremental effectiveness ($/QALYs or $/effect) of the intervention compare to the comparator. Below is the equation of an ICER

$$ICER = \frac{\bar{x}_{Cost\ A} - \bar{x}_{Cost\ B}}{\bar{x}_{Effect\ A} - \bar{x}_{Effect\ B}}$$

A=intervention

B=comparator

$\bar{x}$=sample mean

Figure 1. Incremental cost-effectiveness ratio Equation

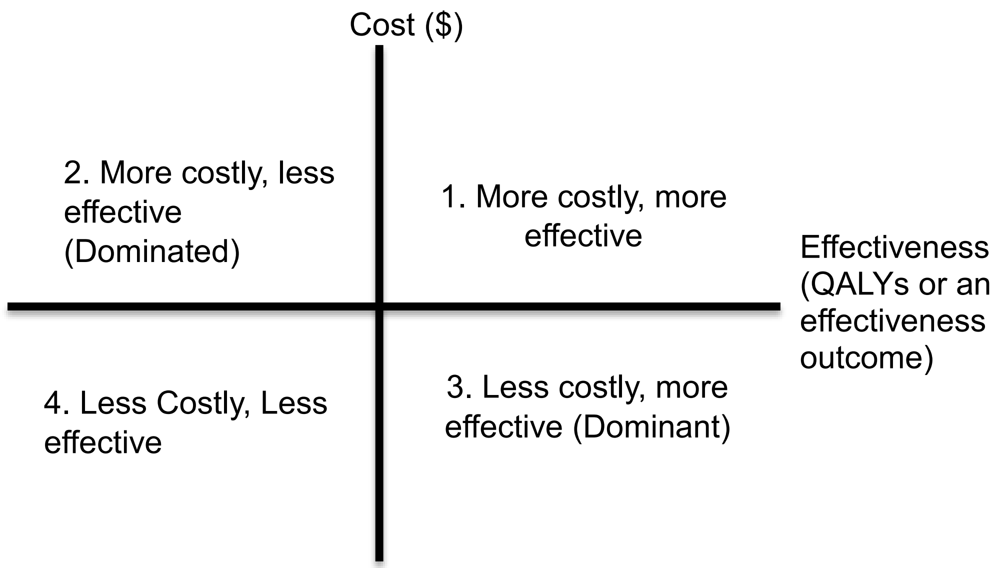

Figure 2. Cost-effectiveness plane.

In scenario 4 above, additional resources could be freed by choosing the less effective intervention and forego the more effective comparator. Under a limited budget, the freed resources could be used to invest in other interventions that may provide a higher health gain than the comparator making efficient use of available resources.

In cost-utility studies using the QALY as the outcome measure, cost-effectiveness thresholds are sometimes used in describing decision-making in scenario 3 above. If the decision-maker's willingness to pay for an additional QALY is known (as informed by opportunity costs), then one can compare the ICER to the threshold to determine a recommendation[54]. If the threshold is higher than the ICER, then one would recommend adoption[54]. However, if the adoption is not accompanied by a disenventment, this decision would require an increase to the overall budget. There is no similar threshold however in the case of cost-effectiveness studies using a clinically or context specific outcome measure (such as injury rates).

2.2.9 Sensitivity Analysis.

A sensitivity analysis characterizes how the uncertainty in key parameters from the costs and effectiveness data affects the results of the cost-effectiveness analysis. A parameter is a numerical characteristic of a population. Parameter uncertainty arises because there of differences between the expected and true parameter estimates used in an economic evaluation[54]. CADTH recommends using a probabilistic sensitivity analysis to characterize parameter uncertainty[55]. This method is preferred because it can show the parameter uncertainty in multiple parameters simultaneously.

Previously, deterministic sensitivity analysis was used to assess the uncertainty around parameters[54]. This is done by manually changing the inputs to varying values on one parameter and observe how it would affect the outputs. If outputs are highly sensitive to the changes in one input, it could move the cost-effective estimate and influence the decision on what alternative is cost-effective[54]. It is currently not recommended by CADTH because a deterministic sensitivity analysis is inherently linear and is misleading when it is applied to non-linear models or analyses[55].

2.3 Literature Review on Cost Burden and Economic Evaluation Studies in Injury Prevention on Youth

2.3.1 Cost Burden of Injury in Hockey.

In 2009, the Economic Burden of Injury in Canada reported that $97 million (CAD 2004) in healthcare costs and $91 million in productivity loss was due to being struck by/against sports equipment (as defined using ICD-10 Codes) for all ages in Canada[56]. In the same report, $12 million (CAD 2004) in healthcare costs and $13 million (CAD 2004) in productivity losses (lost income because of injury) occurred in Alberta in the same year[56]. The costs of being struck by/against sports equipment had not changed dramatically since 2004. In 2015, The Cost of Injury in Canada reported the same cost of being struck by/against sports equipment of $97 million (CAD 2010) in healthcare costs and a similar figure of $90 million (CAD 2010) in productivity loss due to injury for all ages in Canada over their lifetime[12]. The cost of injury report for Alberta in 2015 was unchanged from 2009 where $13 million (CAD 2010) in healthcare costs and $14 million (CAD 2010) in productivity was lost over their lifetime due to being struck by/against sports equipment[12]. It was not known what the costs were by age categories since literature on the cost burden of sport-related injuries in general was scarce. The definition of sport injuries using ICD-10 codes also used a subset of all sport injuries. Its definition did not include sport-related injuries that happen through falls or through physical contact with other players and underestimated the overall true cost of sport injuries. The cost of sport-specific injuries was not reported in the Cost of Injury in Canada and it was unknown in other known databases[12].

Based on current evidence on the economic burden of injury and that sport related injuries are the number one cause of injury in youth, there is a public health need for interventions to reduce the risk of injuries and public healthcare costs in this population. As such, economic evaluations on promising interventions are required to provide evidence to inform on policy decisions in this area.

2.3.2 Current Economic Evaluation Literature in Injury Prevention in Sport.

There are very few publications on the cost-effectiveness of injury prevention strategies in youth. There was only one economic evaluation in preventing injuries in ice hockey. That study compared leagues that allowed body checking in Alberta (n=1,108) and disallowed body checking in Quebec (n=1,046) from 2007-2008 in Pee Wee ice hockey. Players who were allowed to body check had a higher injury rate of 2.84 injuries (95% CI: 1.97 to 3.7) per 1000 player-hours and higher costs of $289 (95% CI: $153 to 432 CAD 2009) per 1000 player-hours in healthcare costs in one season compared to players who were not allowed to body check. This accounted for both game and practice time over one season. In other words, disallowing body checking in Pee Wee ice hockey was the recommended policy choice in that it both saved healthcare-related costs and prevented hockey-related injuries. The projected budget impact analysis showed that 1,273 injuries and $213,280 in public and private healthcare costs could have been prevented in one season in Alberta by removing body checking[20].

The most recent study was a cost-effectiveness analysis on a neuromuscular training program compared to a standard warm-up program in youth soccer using a randomized controlled trial. The study found a 38% reduction in injury rates (rate difference: -1.27/1000 player-hours; 95% CI: -2.2 to -0.33) and healthcare costs were reduced by 43% in the neuromuscular training group (rate difference:-$689/1000 player-hours; 95% CI: -$1,741 to $234) compared to standard warm-up. Projecting the results onto 58,100 youth soccer players, an estimated 4,965 injuries and over $2.7 million in healthcare costs would be avoided in one season if a neuromuscular training program were implemented for one season.

One other study investigated the cost reduction when using full cage helmets in adult men's ice hockey. Woods *et al* (2008) used data from a cross sectional study including 190 amateur male ice hockey players and asked if they used face protection on their helmets, if they had a previous injury, and what healthcare resources did they use for their injury. The authors concluded that there could be $6,000/5 years (2008 USD) in net savings from using face protection by reducing the odds of facial lacerations and facial fractures. Woods *et al* (2008) also reported the odds ratios of certain injuries if players did or did not wear a caged helmet[57]. The odds of players without face protection were 3.4 (95% CI: OR: 2.0 to 5.8) times higher to report facial lacerations and 10.1 (95% CI: OR: 1.23 to 83.4) times higher to report a facial bone fracture than players wearing face protection[57]. While odds ratios were reported for each type of injury between players who did and did not use full cage helmets, the mean risk difference between injury types were not reported and it is unknown how cost-effective the intervention was. The conclusions by the author are also problematic because players self-selected themselves into the comparison groups and costs and injuries were self-reported at one point in time.

Another related study in adult injury prevention, was a study by Verhagen *et al* (2005) which evaluated the cost-effectiveness of a proprioceptive balance board training program in men's and women's volleyball teams. The balance board reduced the rate of ankle sprains by 0.5 per 1000 player-hours (95% CI: 0.1 to 0.7) from 0.9 per 1000 player-hours (95% CI: 0.6 to 1.2) using standard training methods to 0.4 per 1000 player-hours (95% CI: 0.1 to 0.7) using balance board training on top of the usual routine. Using a societal perspective, the total cost per player was higher in the intervention group than the standard training routine by €18.05 (95% CI: €3.92 to €32.18) (Euro 2003). Based on their probabilistic sensitivity analysis, the cost difference between the two groups were due to the cost of the intervention material (€26.77/player, Euro 2003). It was also found the cost of preventing one ankle sprain was approximately €444.03 (Euro 2003). A summary of previous evidence is available in Table 1.

Table 1. Summary of previous economic evaluation literature

Sport	Intervention	Results
Hockey[20]	Allowing vs disallowing body checking in Pee Wee Hockey	Players in leagues that allowed body checking had 2.84 injuries/1000 player-hours higher and $289/100 player-hours (2009 CAD) higher compared to players who were in leagues that disallowed body checking.
Hockey[57]	Using caged helmets	Caged helmet use had a net savings of $6000/5 years (2008 USD) with a decreased risk of facial injuries.
Soccer[58]	Neuromuscular Training Program	38% injury risk reduction (rate difference:-1.27/1000 player-hours; 95% CI: -2.2 to -0.33) 43% cost reduction (rate difference: -$689/1000 player-hours; 95% CI: -$1,741 to $234) with neuromuscular training compared to regular routine
Volleyball[59]	Balance Board Program	Reduced injury rate by 0.4/1000 player-hours (95% CI: 0.01 to 0.07) from 0.9 per 1000 player-hours (95% CI: 0.6 to 1.2) to 0.5 per 1000 player-hours (95% CI: 0.3 to 0.6) The total cost per player were significantly higher in the intervention group by €18.05 (95% CI: €3.92 to €32.18) (Euro 2003).

2.3.3 Gaps in literature and policy question.

Broadly speaking, the aim of body checking policy is to reduce the number of injuries in order to promote sport participation by reduce time lost from injury and, over time, time lost from disability as a result of severe injuries[60]. Currently, body checking can be introduced in Canada at the Bantam (age 13-14 years) age category at the discretion of municipal or provincial hockey organizations. There is conflicting evidence about when body checking should be introduced in youth ice hockey to provide a concrete recommendation. Age may play a role with older players having a higher risk of injuries when body checking is allowed[35], but a protective effect may occur when introducing body checking earlier for skill development[47,48]. There is evidence in the literature that disallowing body checking reduced all hockey-related injuries by 50% and concussions by 64%[15] and saved healthcare costs[20] in Pee Wee ice hockey, but it is unknown if the results would be the same for Bantam ice hockey. This study will estimate the effect on injuries and costs of different body checking policies at the Bantam age, and the results of the study will add to the policy discussion about if body checking should be allowed or disallowed in Bantam ice hockey at non-elite levels of play.

Chapter 3 Methods

This chapter describes the methods of the economic evaluation alongside a prospective cohort study and a budget impact analysis that compares non-elite Bantam ice hockey players who are allowed to body check in games to players who are disallowed from body checking to address the two research objectives: (1) To compare injury rates and healthcare costs between policy that allowing and disallowing body checking in non-elite Bantam ice hockey players (lower 70% by division of play); (2) To estimate the overall change in the frequency of injury and costs to the healthcare system in Alberta if body checking were disallowed for all non-elite Bantam ice hockey players over one season using a budget impact analysis. This includes the design of the prospective cohort study, the steps to a cost-effectiveness analysis and the budget impact analysis, and the steps to how the data were organized. Chapter three is organized as follows: Section 3.1 describes the prospective cohort design and how injury data were collected. Section 3.2 describes the methods of economic evaluation design. Section 3.3 discusses the data considerations for missing data, how it was cleaned, and security and ethical considerations. Section 3.4 describes the steps taken in the cost-effectiveness analysis, the probabilistic sensitivity analysis, and the budget impact analysis.

3.1 Prospective Cohort Design – Injury Data Collection

3.1.1 Recruitment.

The prospective cohort study was designed to compare players who were in a hockey league which disallowed body checking to players who were in a hockey league that disallowed body checking. A total of 1,004 Bantam ice hockey players in the lower 70% divisions of play were recruited from Hockey British Columbia and in Hockey Alberta. Bantam hockey teams in Calgary, Edmonton, Okanagan, and Vancouver were targeted for recruitment. Players were recruited from Calgary (n=153) and Edmonton (n=241) in 2014-2015 where body checking was allowed. Players were recruited from Okanagan (n=42) and from Vancouver (n=221) where body checking were disallowed in the same year. In 2015-2016, players in Calgary (n=133) were recruited where body checking were disallowed. Hockey Calgary, a municipal hockey organization, changed their policies to disallow body checking up to Midget ice hockey in the lower 70% divisions of play in between the 2014-2015 and 2015-2016 hockey season. Body checking were still allowed in Edmonton and 214 players were recruited in 2015-2016. Overall, 49 teams were recruited in a league that allowed body checking and 33 teams were recruited in a league that disallowed body checking from 2014-15, and 2015-2016 (Table 2). A total of 608 players in leagues that allowed body checking were recruited, and 396 players form leagues that disallowed body checking were recruited in the study. There were 60 players who participated in both 2014-2015 and 2015-2016 seasons in this study. Individual players were also encouraged to participate in the study through advertisements. Posters in arenas and community centers in each city, recruitment via social media, and on the Sport Injury Prevention Centre (SIPRC) webpage were used. Potential participants were encouraged to contact study coordinators via email or telephone to be recruited into the study. No individual players signed up into the study. All participants were part of teams that were recruited into the study.

Based on the sample size calculation from the original cohort study protocol on the concussion rate of body checking in Bantam ice hockey, assuming 33 teams were recruited in the policy that disallowed body checking, the injury rate among teams that play in a league that allowed body checking must be at least 1.9 injuries per 1000 player-hours (an effect size of 1.15 injury per

1000 player-hours)) to detect a difference between the leagues that allow body checking and leagues that disallow body checking. With an acceptable 0.05 type I error, this will provide a power of 0.9 in the study (β=0.1)[61]. A detailed calculation is available in Appendix A.

Table 2. Players and teams recruited in each city and year

League that allowed body checking			
Season years	**Locations**	**# of Players**	**# of Teams**
2014-2015	Calgary Edmonton	153 241	17 16
2015-2016	Edmonton	214	16
Total		**608**	**49**
League that disallowed body checking			
Season years	**Locations**	**# of players**	**# of Teams**
2014-2015	Okanagan Vancouver	42 221	4 19
2015-2016	Calgary	133	10
Total number of players		**396**	**33**
Grand total		1004	82

3.1.2 Data Collection.

A Pre-season Baseline Questionnaire, Weekly Exposure Sheets (WES) and an Injury Report Form (IRF), validated for youth hockey[14,62], were used to collect data. The pre-baseline questionnaire was completed by each player to identify baseline and demographic characteristics such as age, sex, and concussion history, player position, equipment, attitudes towards body checking, divisions of play, and medical history at the beginning of the study (Appendix B). During the cohort study, a coach or a team designated safety manager (a parent) on each team was asked to report, once a week, on the participation of each player using the WES for each practice and game. WES were used to record every game or practice participation for each week (Appendix C).

The IRF collected information on the context of the injury at the time of injury and on resources used towards their recovery. This included the injury type, whether it was a new injury or a recurring injury, and if the injury occurred in a game or practice. The full list of questions is available in Appendix D. Hockey-related injuries were identified during the season when an injury or a suspected concussion occurred in hockey and if the player: (1) received medical attention (2) could not complete the game in which the injury occurred (3) missed at least one day of sporting activity. The circumstance, mechanism of injury, healthcare resource use, and the presumed diagnosis were documented in the IRF by the team designate (the coach or the team designated safety manager). If there was an athletic therapist on the team, they were also asked to be the team designate for their team. If the player had a musculoskeletal injury, the IRF was submitted by the team designate when the player was cleared to return to play. If the player was diagnosed with a concussion, players were presented an opportunity to be treated by a sports medicine physician at sports medicine clinics specifically who helped fill out the IRF. If the player opted to be treated elsewhere, the IRF was completed using the same procedure as if the player had a musculoskeletal injury. The team designate was asked to fill the IRF and had it reported back to the research team when the player was cleared to return to sport or for hockey. All study forms were collected by the team designate on a weekly basis and checked for completeness by the study coordinator. If there was missing information, the study coordinator called players and their families to follow up to complete the IRF.

3.1.3 Exposure.

Players were observed over a season of play (eight months) in their respective leagues that allowed body checking (Hockey Alberta in 2014-2015 and in 2015-2016) or disallowed body checking

(Hockey British Columbia in 2014-2015 and Hockey Alberta in 2015-2016). Time at risk in practice and games were measured as individual participation hours in the WES. If players missed a game or practice, it was indicated as zero participation. Partial participation hours (<75%) were recorded as half of a full session. If a player was injured, the player was given an identification number (SSID) that linked their answers to the Pre-season baseline questionnaire, WES, and their IRF.

3.1.4 Measure of effectiveness (injuries)

The measure of effectiveness used in this analysis was the number of injuries. Injuries that occurred during games and practices were collected. Hockey-related injuries were identified during the season when the injured player: (1) received medical attention (2) was unable to complete the session in which the injury occurred (3) missed at least one day of sporting activity[61]. The main outcome variable used for the base case in this economic evaluation was injuries that occurred during hockey games. In scenario analyses, other outcome definitions were considered:

a) Game injuries (base case)

b) Practice Injuries (scenario)

c) All injuries: combined game and practice injuries

Outcomes were standardized to make comparisons between policies as rates using injuries per 1000 player-hours and injuries per 100 players. (See section 3.4.4 for further detail).

3.2 Economic Evaluation alongside a Prospective Cohort Study

3.2.1 Perspective.

The main perspective used for the base case analysis was the public healthcare system as recommended by CADTH. Costs were also presented in a disaggregated way to present other perspectives:

1. Public healthcare system perspective (base case)
2. Private healthcare cost perspective consisting of family borne out-of-pocket costs and productivity loss associated with injuries
3. Private healthcare costs without productivity loss
4. Total healthcare cost perspective was also used which summed the public healthcare cost perspective and the private healthcare cost perspective including productivity loss.

3.2.2 Target Population.

The target population was Bantam ice hockey players (age 13-14 years) in the lower 70% divisions of play in minor ice hockey. Players were recruited from leagues that included both girls and boys of the same age. Players in a girl's only league were not included in the study because body checking were not allowed in these leagues across Canada.

3.2.3 Comparator.

This study compared players who were in a league that allowed body checking to players who were in a league that disallowed body checking over the 2014-2015, and 2015-2016 seasons. Players from Alberta and British Columbia were recruited to directly compare the injuries and costs in leagues with different body checking policies. Body checking was allowed in Alberta for Bantam hockey players in Edmonton and Calgary at the time of recruitment and data collection in the prospective cohort study in 2014-2015. It was not allowed in British Columbia for players in Vancouver and Kelowna in 2014-2015. In the 2015-2016 season, body checking rules changed in Calgary and was disallowed in Bantam ice hockey. Players recruited during this season were in the cohort that were in leagues that disallowed body checking.

3.2.4 Time Horizon.

The time horizon used in this study to capture any health-related costs and hockey-related injuries was one hockey season (eight months). The time horizon captured both acute musculoskeletal injuries and concussions sustained over one season and the relevant costs of healthcare resource used towards their recovery[63]. For concussions, there is no defined, physiological time window for sport-related recovery[34]. Based on the most recent consensus statement on concussion in sport, most athletes recover from cognitive deficits, balance, and symptoms within the first month from a clinical perspective but for some symptoms persist months after[34]. It may be possible to use a modelling approach to capture the full possible cost and health gains when comparing body checking policies beyond the time horizon of a hockey season. This would require including cost and quality of life estimates from different data sources that identified the probability of hockey-related injuries to more chronic conditions that would affect both quality of life and life expectancy. This was beyond the scope of this study.

3.2.5 Cost.

3.2.5.1 Intervention Cost.

Intervention costs could include re-training referees to identify body checking as a penalty, and administrative costs to change the rule. However, these were likely to be minimal and, therefore, these costs attributed to changing the policy were not included.

3.2.5.2 Healthcare resource use.

As previously mentioned, healthcare resource use relevant to the health care system perspective as well as out of pocket family borne health costs and employment impact was collected via the IRF. Data on healthcare professional visits, diagnostic imaging, medical treatments, medication, and productivity loss from parents were collected. A full list is available in Appendix D.

3.2.5.3 Unit Cost Sources.

All unit cost sources used to value health resource use were taken from administrative health data in Alberta to standardize the costs in the economic evaluation. This ensured that any cost differences were based differences in injuries between body checking policies instead of inter-provincial unit cost differences. Any non-current costs were adjusted to CAD 2017 using the health care component of the annual consumer price index (CPI) from Statistics Canada[64]. All unit cost sources for items that were publicly funded were collected from administrative data provided by Alberta Health[65]. Unit cost sources for healthcare costs not covered by public health insurance were from financial data from the Foothills Hospital and a price list from a local physiotherapy clinic. The average income from Statistics Canada was used to value the hours lost from productivity loss[66]. Healthcare utilization and unit costs were reported separately and costs were computed in STATA v.14.2. A comprehensive list of unit cost sources is available in Appendix E for each item of healthcare resource use.

3.2.6 Discounting.

Discounting was not applied to the costs and consequences in this study because the time horizon of this study did not extend beyond one year.

3.3 Data Cleaning and Assumptions

3.3.1 Missing Data.

Data were cleaned and missing data for exposure and injuries were imputed as part of the primary cohort study analysis. Healthcare utilization data were cleaned and imputed as part of this economic evaluation.

3.3.1.1 Exposure.

The following describes the procedures for the exposure data. Missing data occurred with the WES and were imputed. If the date of the first game was similar to the start date for the team's league, based on division, age and city, the first game date was used. If these are missing, the PBQ start date was used. If this was missing, WES start date was used. If this was missing, the team's league start date was used.

If there was a situation where the player joined the study first and the rest of the team joined after, the player follows the rules for imputation and the rest of the team's start date follows. The player who joined first were then identified with the rest of the team in the data and removed their individual entries. If a participant joined the team after the team joined, then the participant's start date was the same as the team's start date. If a participant entered at injury, the player was not included in the study. If a participant entered the date when they were "ok" after a concussion, if entered same day as the team, then the participant was treated as the rest of the team. If they entered the study after the team, and since they were "cured", they were treated as a regular player with the same start date as the team.

To identify the date of the last game of the season, the date of the last playoff game was used. If the team did not have a playoff game or if the playoff game was not within a reasonable range, the last date of data collection (WES) was used. If the last date of data collection was not within range, the average end date of the teams in the same division was used.

For exposure imputation, the week range (determined by the end and start date), and the average weekly game and practice hours were calculated. Weekly exposure average was used if information was missing for some weeks at a participant level. If all exposure was missing for an individual, the average team exposure was used. If exposure data were missing at a team level, exposure would be imputed based on the average of the teams at the same division, age, city, and sex.

3.3.1.2 Healthcare Utilization.

Players who had missing data in healthcare utilization were followed up with a call to complete their answers. If this was not available, the number of sports medicine physician visits or physician visits provided by physicians were used if available. If this was not available, the mode of visits based on the similar time loss to injury, injury type and location was used to impute the number of imaging visits, medical devices used, and healthcare professional visits. Specifically for MRI visits, it was found that two players stated that they had an MRI done but did not state the number of imaging tests conducted. To be conservative, it was assumed that one MRI scan occurred for diagnostic purposes. For productivity loss, roughly 50% of entries were missing when asked for hours and days of productivity loss to care for their injured child. A conservative assumption was made where it was assumed that missing entries were replaced with 0 hours and days.

For medication, frequency and duration were missing which was required to value these resources. The mode for frequency and duration on each type of medication were imputed on missing entries. Refer to Appendix F for a more detailed description of the assumptions made on healthcare utilization.

3.3.3 Data security and ethics.

All participants had the option to opt out of the study and were not required to answer all questions. All participants were given a confidential unique study ID (SSID) upon study entry. Study data were entered and managed using REDCap (Research Electronic Data Capture) only accessible to authorized personnel. All identifiable information was removed from the REDCap database.

All hard copies of data are currently stored in locked cabinets in the research (KNB 3300) office at University of Calgary's Roger Jackson Centre for Health and Wellness Research, Sport Medicine Centre. Paper copies will be held for seven years before being destroyed. The Tri-Council Policy Statement 2 CORE (TCPS 2) Certification was obtained.

3.4 Data Analysis

3.4.1 Effectiveness.

The rate difference between policies was used to identify the association between policies and the outcome of all hockey-related injuries that occurred during games and in other injury scenarios after adjusting for clustering by team using a Poisson regression model. A Poisson regression model is a type of generalized linear model that is used to model count data and can also adjust for clustering. The mean injury rate in each policy group was multiplied by a 1000 to identify the mean number of injuries that would occur per 1000 player-hours and the difference between the two policy groups was calculated as shown in Figure 3. This was to adjust the varying exposure time between players and compare the rate of injury over the same time at risk. Injuries per 100 players were also used to compare the injury rate between the body checking policies. This was done by multiplying mean number of injuries per player that occur in each policy group by 100 to identify the mean number of injuries that occur per 100 players as shown in Figure 3. The rates were adjusted for clustering by team and for exposure. The incidence rate ratio was also used to identify the relative difference between body checking policies after adjusting for clustering by teams. Covariates such as previous injury, player size, body checking experience, sex, divisions of play, position, attitudes toward body checking, and year of play were not adjusted for in the model presented in this thesis. The injury analysis used in this study also assumed that the 60 players who played in both seasons were independent individuals and did not account for the fact that there are repeated observations for some players. Adjusting for other covariates, or for the clustering by player were both determined to be beyond the scope of this thesis.

In a Poisson regression model, the distribution of counts follow a Poisson distribution where the variance equals to the mean. The general linear model for the number of events C_{ij} is:

$$log\left(E[C_{ij}]\right) = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \ldots + \beta_{kij} x_{kij}$$

β_0= intercept

β=coefficients

x=risk factors or variables in the model

k=number of variables

i=individual

j=cluster

The model can include clustering by team to account for the possibility of the non-independence within teams.

In order to estimate rates, exposure can be added to the Poisson regression model mentioned above

$$\log(E[rate]) = \log\left(\frac{E[counts]}{exposure}\right) = \log(E[counts]) - \log(exposure)$$

If E_{ij} is the exposure, we have

$$log\left(E[rate_{ij}]\right) = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \ldots + \beta_{kij} x_{kij}$$

The expected number of events, C_{ij}, will be:

$$E[C_{ij}] = E_{ij} e^{\beta_0 + \beta_1 x_{1ij} + \cdots + \beta_k x_{kij}}$$

$$= e^{ln(E_{ij})+\beta_0+\beta_1 x_{1ij}+\cdots+\beta_k x_{kij}}$$

As such, the expected incidence rate per player-hour for the person i in jth group is assumed to be given by:

$$E(r_{ij}) = e^{\beta_0+\beta_1 x_{ij}\ldots+\beta_k x_{ij}}$$

The rate can be interpreted as per 1000 player-hours (by multiplying the above rate by 1,000). The Poisson incidence rate ratio uses the incidence rate as stated above to allow for individual comparisons (simplified):

$$Incidence\ rate\ ratio = \frac{incidence\ rate\ per\ 1{,}000\ player\ hours_A}{incident\ rate\ per\ 1{,}000\ player\ hours_B}$$

$$= \frac{\left(e^{ln(E_{ij})+\beta_0+\beta_1 x_{iij}+\cdots+\beta_k x_{ikj}}\right)_A * 1000 player\ hours}{\left(e^{ln(E_{ij})+\beta_0+\beta_1 x_{1ij}+\cdots+\beta_k x_{kij}}\right)_B * 1000 player\ hours}$$

$$=$$

$$Incidence\ rate\ ratio = \frac{incidence\ rate_A}{incident\ rate_B} = \frac{\frac{\left(e^{ln(E_{ij})+\beta_0+\beta_1 x_{1ij}+\cdots+\beta_k x_{kij}}\right)_A}{1000\ player\ hours}}{\frac{\left(e^{ln(E_{ij})+\beta_0+\beta_1 x_{1ij}+\cdots+\beta_k x_{kij}}\right)_B}{1000\ player\ hours}}$$

$$=$$

A=Disallowed body checking

B=Allowed body checking

Figure 3. Estimating the incidence rate ratio adjusted for clustering and exposure

3.4.2 Cost Analysis.

The costs associated with each policy were compared using rates. Table 3 shows the healthcare utilization that were valued in each perspective. For each policy, the total costs were divided by the total exposure hours giving the average cost per player-hour. This cost per player hour was converted into cost per 1000 player-hours by multiplying the rate by 1000. The difference in the cost per 1000 player-hours between policies was then calculated.

Table 3. Healthcare utilization that were valued in each perspective

Perspective	Healthcare utilization
Public healthcare system	General Practitioner visits, paediatrician visits, sports medicine visits, orthopaedic surgeon visits, emergency department visits (physician billing and technical fees), neurologist, MRI, CT Scan, Ultrasounds, X-rays
Private healthcare costs including productivity loss	Chiropractor visits, physiotherapist visits, sacrocranial therapist visits, massage therapist visits, athletic therapist visits, casts, braces, splints, crutches, over-the-counter and prescribed medication, productivity loss in days
Private healthcare costs without productivity loss	Chiropractor visits, physiotherapist visits, sacrocranial therapist visits, massage therapist visits, athletic therapist visits, casts, braces, splints, crutches, over-the-counter and prescribed medication
Total healthcare cost	public healthcare system + private healthcare costs including productivity loss

Costs were also compared between policies in costs per 100 players in each perspective. The mean cost per player first calculated, and then was multiplied by 100 to give the mean cost per 100 players. The difference in the cost per 100 players between policies was also calculated.

3.4.3 Cost-effectiveness analysis.

The cost-effectiveness analysis combined the components of the mean injury rate difference and the mean healthcare cost difference relevant to each perspective used. If appropriate, the ICER was calculated (Figure 4).

$$\frac{Cost\ per\ 1000\ player\ hours_{disallowed\ BC} - Cost\ per\ 1000\ player\ hours_{allowed\ BC}}{Injuries\ per\ 1000\ player\ hours_{disallowed\ BC} - Injuries\ per\ 1000\ player\ hours_{allowed\ BC}}$$

BC=Body checking

Figure 4. Equation to calculate the cost per 1000 player-hours.

If disallowing body checking caused more injuries and was costlier (dominated), then allowing body checking would be the recommended policy. If disallowing body checking cost less and prevented hockey injuries (dominant), then disallowing body checking would be the recommended policy. In scenarios where there were less injuries but higher costs (probably due to a higher number of severe injuries), judgement would be required to determine the optimal policy. Typically, if a new policy was more costly and effective, then the opportunity cost of providing more resources to prevent hockey-related injuries must be considered.

3.4.4 Base case Analysis.

The base case result is the main scenario and result of this study which considers game injuries and takes the public healthcare system perspective.

3.4.5 Scenario Analyses.

The analyses explored scenarios for other perspectives and injury contexts in addition to the base case. The scenario analyses were presented in the following order:

1. Base case (public healthcare system)
2. Private healthcare cost perspective including productivity loss
3. Private healthcare costs without productivity loss
4. Total healthcare cost perspective which included all costs used in this study (i.e. Base case plus scenario 1).

Within each scenario, costs were compared using the follow injury scenarios as shown in the table below:

Table 4. Organization of the scenario analyses

Injury Context	Public	Private including productivity	Private without productivity	Total
Game	Base case 1a	2a	3a	4a
Practice	Scenario 1b	2b	3b	4b
All	Scenario 1c	2c	3c	4c

3.4.6 Sensitivity Analysis.

A probabilistic sensitivity analysis was used to determine the impact of the overall parameter uncertainty around the result for each scenario. Patient-level sample data on cost and injury were available which made it possible to quantify the parameter uncertainty around the cost and injury estimates using nonparametric bootstrapping. Nonparametric bootstrapping is a method to randomly re-sample sample data with replacement to estimate the sampling distribution of mean cost and mean injury rate differences. Due to the cost data being highly skewed to the right, percentile based confidence intervals were used around the difference in injury rates and costs between policies for each analysis and perspective.

3.4.7 Budget Impact Analysis.

A budget impact analysis (BIA) was conducted to examine the projected changes in healthcare costs if body checking were disallowed for all Bantam hockey players in Alberta[20]. Based on the annual report from Hockey Canada, there were 8,231 Bantam hockey players registered in Alberta in the 2015-2016 season[1]. The budget impact analysis used the same data for the cost-effectiveness analysis. A simple cost calculator approach was used to calculate the budget impact. A cost calculator approach is a computing framework that is a costing tool used to estimate the potential cost of the intervention based on the population in which the budget impact is being applied[67,68]. The mean cost difference between body checking policies was multiplied by 8,231 players in Alberta. The same method was used to project the number of injuries that could have been prevented for all Bantam players if body checking were disallowed (Figure 5). The BIA was calculated for the base case and the other cost and injury scenarios. The calculation is as shown:

$$Total\ difference\ in\ costs\ in\ one\ season = \left(\frac{total\ costs_B}{total\ players_B} - \frac{total\ costs_A}{total\ players_A}\right) \times 8{,}231\ of\ players\ in\ Alberta$$

$$Total\ difference\ in\ injuries\ in\ one\ season = \left(\frac{total\ injuries_B}{total\ players_B} - \frac{total\ injuries_A}{total\ players_A}\right) \times 8{,}231\ of\ players\ in\ Alberta$$

Where:
A=Allowing body checking
B=Disallowing body checking

Figure 5. Budget Impact Analysis Equation.

There is parameter uncertainty around the projected cost and injury estimates from the BIA. A PSA was used to determine the extent of the parameter uncertainty of each result using the same methods for bootstrapping as stated in section 3.4.6. All data analyses were conducted in STATA v14.

3.5 Methods Summary

In summary, this study conducted an economic evaluation alongside a cohort study to estimate how body checking policy affects the base case (injuries that occur in games using the public healthcare perspective). Differences in injuries and costs were compared using 1000 player-hours and injuries and costs per 100 players. A probabilistic sensitivity analysis was conducted to characterize the parameter uncertainties around each estimate. A budget impact analysis was done to identify the overall changes in costs and injuries if body checking were disallowed in Alberta for 8,231 Bantam ice hockey players in the 2015-2016 season. The same analyses were conducted using different cost perspectives (private healthcare costs including productivity loss, private healthcare costs without productivity loss, total healthcare costs) and for different injury scenarios (practice injuries, all injuries). The results were used to make recommendation about policy adoption, if possible.

The next chapter will present the results of the base case scenario and the specific injury and perspective scenarios which will reveal the impact on the potential effectiveness of changing policies to reduce injuries as well as their associated impact on the healthcare system and on families.

Chapter 4. Results

This chapter describes the results of the cost-effectiveness analysis which address the first research question. It will also describe the results of the budget impact analysis which address the second research question. Section 4.1 begins a summary of the overall recruitment and data collection from the cohort study, the descriptive characteristics of players who were recruited into the study, and the healthcare utilization data collected by the cohort study. Section 4.2 reports the results of the cost effectiveness analysis, the probabilistic sensitivity analysis, and the budget impact analysis for the base case (healthcare perspective; game injuries). Section 4.3 reports the injury and cost results in other injury scenarios using the public healthcare perspective for all of the analyses. Section 4.4 to 4.6 reports the injury rate and cost difference in different injury and cost scenarios. The same organization is used in to report all of the analysis in other injury scenarios and in other cost perspectives in the following order:

1. Cost Perspective

    1a. Injury Scenario

    - The cost-effectiveness analysis results
    - The probabilistic sensitivity analysis results
    - The budget impact analysis results

4.1 Data Collected in Cohort Study

4.1.1 Recruitment & Exposure Summary.

A total of 82 teams comprising of 1,004 players were recruited in the study over two seasons (Table 5). There were 33 teams where 396 players who were disallowed from body checking and 49 teams where 608 players who were allowed body checking. Players who were disallowed from body checking had a total of 14,457 participation hours and 28,805 participation hours were observed in players who were allowed to body check. When body checking was allowed 146 injuries occurred, compared to 33 injuries when body checking was disallowed. Each player was followed for one season and there were 60 players who were part of the study for both seasons.

Table 5. Summary of recruitment.

Outcome		**Disallowing Body Checking**	**Allowing Body Checking**
Number of teams		33	49
Number of players		396	608
Player participation hours	Total	14,457	28,805
	Game	8,465	16,162
	Practice	5,992	12,643
Number of injuries	Total	33	146
	Game	31	129
	Practice	2	17

4.1.2 Baseline characteristics.

Table 6 shows the characteristics of players who were in leagues that allow or disallow body checking that were included in the study. There was a total of 987 males and 17 females. The mean height [165cm (SD=10cm) vs 167cm (SD=10cm)] and weight [54 kg (SD=12kg) to 56kg (SD=15kg)] was similar between the groups of players. A larger proportion of players were in their first year of play in Bantam ice hockey (ranged from 49% to 54%) where 524 players were in their first year of play compared to 423 players in their second year of play. A higher proportion of players were also forwards (range 49% to 53%) compared to defensive players.

The proportions of players who did not have a previous injury were similar when body checking was allowed and disallowed (71% vs. 70%). For previous concussion history over the course of their lifetime, the proportions were similar for players when body checking was disallowed compared to when body checking was allowed (64% v. 66%). Overall, the distribution of baseline characteristics within each policy were similar between the two policies. A more detailed table describing baseline characteristics by injury status is available in Appendix G.

Table 6. Player Characteristics

		Non-body checking	Body checking
		n=396	**n=608**
Sex n (%)	**Male**	390 (98)	597 (98)
	Female	6 (2)	11 (2)
	Missing data	0 (0)	0 (0)
Height, mean (SD) cm		165.7 (10)	164.90 (10)
Missing data, n (%)		86 (22)	109 (18)
Weight, mean (SD) kg		55.6 (14)	54.2 (12)
Missing data, n (%)		108 (27)	129 (21)
Year of play (%)	**First**	195 (49)	329 (54)
	Second	169 (43)	254 (43)
	Missing data	32 (8)	25 (3)
Position (%)	**Forward**	195 (49)	325 (54)
	Defence	103 (26)	176 (29)
	Goalie	28 (7)	50 (8)
	Missing data	70 (18)	57 (9)
Previous injury*	**No**	276 (70)	432 (71)
	Yes	72 (18)	139 (23)
	Missing data	48 (12)	37 (6)
Previous concussion°	**No**	252 (64)	403 (66)
	Yes	129 (33)	190 (31)
	Missing data	15 (3)	15 (3)

*Injury that occurred in the previous year
°Previous concussion over their lifetime

4.1.3 Healthcare resource use.

Public healthcare resource use and costs are presented separately by body checking policies for all injuries in Table 7. The most common types of public healthcare resource use were visits to general practitioners, sports medicine physicians, and x-ray visits for players within each policy. Private healthcare resource use and costs for type are presented separately by leagues that allow or disallow body checking for all injuries in Table 8. The most common types of private healthcare use were medications, visits to a physiotherapist, and to a chiropractor for players within each policy. Table 9 shows the estimated total costs and average cost per injury for each perspective and injury scenarios. Public healthcare costs associated with game injures were estimated at $33,495 (95% CI: $22,356, $44,172) when body checking was allowed and $5,483 (95% CI: $2,194, $9,294) when body checking was disallowed. For practice injuries, public healthcare cost was $2,679 (95% CI: $712, $5,167) when body checking was allowed and $834 (95% C: $0, $2,502) when body checking was disallowed. For all injuries, public healthcare resource use was estimated at $36,174 (95% CI: $24,407, $47,339) when body checking was allowed and $6,316 (95% CI: $2,251, $11,452) when body checking was disallowed.

The public healthcare cost per injury was estimated at $325.11 (95% CI: $219.73 to $434.37) when body checking were allowed and $323.75 (95%: CI $125.11 to $588.3) when body checking were disallowed. The other perspectives and injury scenarios are available in Table 9 for the total costs and for the cost per injury for each body checking policy.

Table 7. Public Healthcare Resource Use

	Non-body Checking		Body Checking	
Public Healthcare costs				
Healthcare professional visits	Units	Cost ($C)	Units	Cost ($C)
Emergency (visits)	7	$2,959	38	$14,811
General practitioner(visits)	8	$761	34	$3,120
Sports medicine physician (visits)	29	$1,457	99	$5,432
Pediatrician (visits)	0	0	6	$541
Orthopedic specialist (visits)	0	0	6	$574
Neurologist (visits)	0	0	1	$140
Eye specialist (visits)	0	0	1	$98
MRI	0	0	2	$1,720
X-ray	8	$570	42	$8,168
CT	1	$569	2	$1,138
Bone scan	0	0	0	0
Ultrasound	0	0	2	$866

Table 8. Private Healthcare Resource Use

	Non-body Checking		**Body Checking**	
Private Healthcare Costs	Units	Costs ($C)	Units	Costs ($C)
Craniosacral therapist (visits)	1	$105	0	0
Ambulance ride to hospital	1	$385	0	0
Physiotherapist (visits)	15	$1,335	26	$2,430
Athletic therapist (visits)	0	0	1	$77
Chiropractor (visits)	6	$360	15	$1,080
Massage therapist (visits)	0	0	0	0
Dentistry (visits)	0	0	0	0
Total		$8,501		$40,194
Casts	0	0	6	$655
Braces	1	$130	1	$53
Splints	0	0	5	$301
Surgery	0	0	0	0
Medication	8	$8	63	$56
Taping	2	$50	1	$25
Crutches	0	0	3	$195
Tensor	0	0	1	$6
Sling	2	$60	2	$60
Total treatments/devices	13	$248	82	$1,351
Medication				
OTC Medication	7	$8	62	$53
Prescribed Medication	0	$3	1	$3
Total Medication Cost	7	$8	63	$57
Productivity Loss				
Days	1.37	$679	15.71	$5,028
Total Costs		**$9,437**		**$45,836**

Table 9. Total and average healthcare costs for all injured players by Bantam ice hockey players in body checking policies by perspectives

		Estimated healthcare costs, $C (95% CI)	
Perspective		**Disallowing body checking**	**Allowing body checking**
Public	Game	$5,483 ($2,194, $9,294)	$33,495 ($22,356, $44,172)
	Practice injuries	$834 ($0, $2,502)	$2,679 ($712, $5,167)
	All injuries	$6,316 ($2,251, $11,452)	$36,174 ($24,407, $47,339)
Private	Game injuries	$2,289 ($1,100, $4,082)	$9,052 ($5,697, $15,034)
	Practice injuries	$823 ($0, $2,469)	$766 ($0, $2,127)
	All injuries	$3,112 ($1,033, $5,974)	$9,818 ($5,584, $14,601)
Total	Game injuries	$7,771 ($3,566, $12,666)	$42,547 ($28,125, $56,653)
	Practice injuries	$1,657 ($0, $4,970)	$3,445 ($788, $ 7,158)
	All injuries	$9,428 ($3628, $17,061)	$45,992 ($30,762, $60,812)
Average Cost Per Injury			
Number of injuries	Game injuries	33	146
	Practice injuries	31	129
	All injuries	2	17
Public	Game injuries	$177 ($81, $344)	$259 ($182, $359)
	Practice injuries	$417 ($0, $1,251)	$158 ($42, $304)
	All injuries	$191 ($78, $395)	$248 ($174, $338)
Private	Game injuries	$74 ($41, $151)	$70 ($46, $122)
	Practice injuries	$411 ($0, $1,234)	$45 ($0, $125)
	All injuries	$94 ($36, $206)	$67 ($40, $104)
Total	Game injuries	$250 ($132, $469)	$329 ($229, $461)
	Practice injuries	$828 ($0, $2,485)	$202 ($46, $421)
	All injuries	$286 ($220, $434)	$315 ($125, $588)

Primary Results

4.2 1a Base Case Results (Public healthcare system perspective & game injuries)

Due to the repetitive nature of the reporting on the results from the cost-effectiveness analysis and the budget impact analysis, a summary table is available in section 4.7 on page 93.

4.2.1 Per 1000 Player-hour Differences.

The base case considered game injuries only and took the public healthcare system perspective. Using a Poisson regression model which adjusted for clustering by team, the rate of games injuries when body checking was disallowed was 0.46 times the rate of game injuries when body checking was allowed and this was significant (95% CI: 0.26 to 0.81) (Table 10). Table 11 shows the injury rates after converting them from IRRs. Disallowing body checking significantly reduced the rate of injury in games by 4.32 injuries per 1000 player-hours (95% CI: 1.54 to 7.00) and saved $1,737 (95% CI: $662 to $2,751) per 1000 player-hours in public healthcare costs (Table 11). The injury rate difference was greater than the minimum estimate of 1.15 injuries/1000 player-hours to detect a difference. Since the alterative policy was dominant, an incremental cost effectiveness analysis (ICER) was not calculated.

4.2.2 Per 100 player Differences.

Game injuries were significantly less by 13.39 (95% CI: 7.03 to 19.69) injuries per 100 players when body checking was disallowed. The policy also saved $4,125 (2,103 to 6,232) per 100 players in public healthcare costs (Table 11). Overall, public healthcare costs and game injuries were significantly less when body checking was disallowed compared to the standard policy. Since the alterative policy was dominant, an incremental cost effectiveness analysis (ICER) was not calculated.

Table 10. Crude incidence rate ratios adjusting for clustering by team using the Poisson regression model

Comparators	Game Injuries IRR (95% CI)	Practice Injuries IRR (95% CI)	All Injuries IRR (95% CI)
Allowing Body Checking (reference)	1	1	1
Disallowing body checking	**0.46 (0.26 to 0.81)**	0.25 (0.06 to 1.01)	**0.45 (0.26 to 0.78)**

Table 11. Injury rates, absolute differences, and cost differences between body checking policies for the public healthcare system perspective for game injuries

Body checking Comparators	Crude Injury rates (95% CI)	Costs (95% CI)	Incremental Injury Rate (95% CI)	Incremental Costs (95% CI)
Per 1000 player-hours				
Allowing	7.98 (6.12, 10.07)	$2,589 ($1,437, $2,790)	**-4.32 (-7.00, -1.54)**	**-$1,737 (-$2,751, -$662)**
Disallowing	3.66 (2.00, 5.70)	$852 ($255, $1,158)		
Per 100 players				
Allowing	21.22 (16.12, 26.48)	$5,509 ($3,742, $7,436)	**-13.39 (-19.69, -7.03)**	**-$4,125 (-$6,232, -$2,103)**
Disallowing	7.83 (4.29, 11.87)	$1,384 ($543, $2,394)		

4.2.3 Base Case PSA Results.

Figure 6 shows the results of the PSA for public healthcare costs and game injures between body checking policies. In the base case, 99.80% of the 10,000 iterations found disallowing body checking reduced game injury rates and saved costs in the public healthcare system.

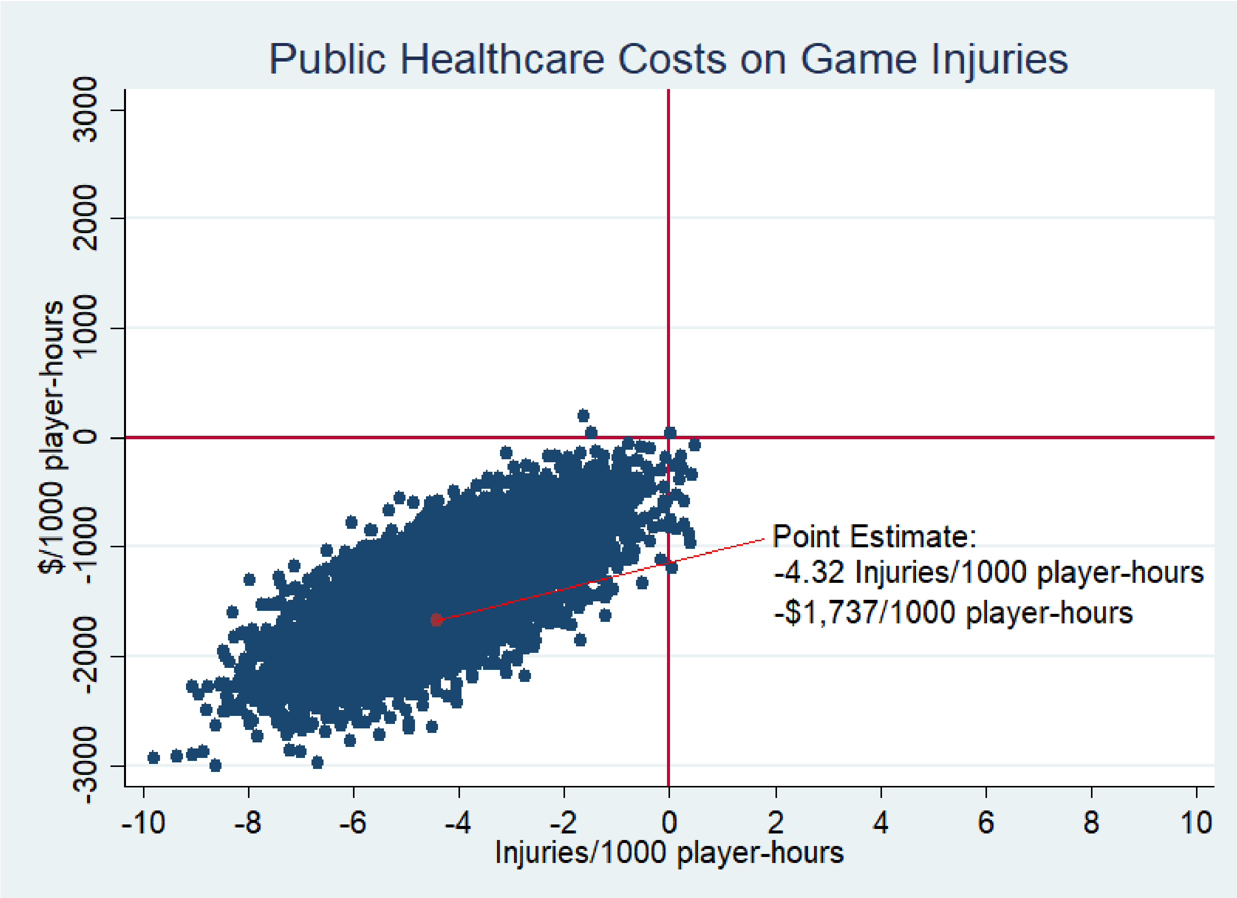

Figure 6. Probabilistic sensitivity analysis of mean game injury rates and mean cost differences by body checking policy.

4.2.4 Base Case Budget Impact Analysis Results.

Table 24 shows the potential change in game injuries if body checking were disallowed in all Bantam ice hockey leagues in 2015-2016 across Alberta. If body checking were allowed, the number of injuries that occur during games was estimated at 1,746 (95% CI: 1,327 to 2,180) game injuries would occur. This was much higher than the 644 (95% CI: 353 to 977) game injuries that could occur if body checking were disallowed. If body checking were disallowed across Alberta in the 2015-2016 season, it could have potentially prevented 1,102 (95% CI: 578 to 1,620) game injuries.

Table 24 shows the potential change in costs in the public healthcare system and injuries that occur in games if body checking were disallowed for 8,231 Bantam ice hockey players in 2015-2016 in Alberta. If body checking were allowed for all Bantam players in Alberta over one season, it was estimated at $445,479 (95% CI: 308,033 to $612,025) in public healthcare care was spent (. If body checking were not allowed for all Bantam players in Alberta over one season, it was estimated that $113,957 (95% CI: $44,698 to $197,054) in public healthcare was spent. As such, $331,522 (95% CI: $173,080 to $512,924) in incremental savings could have occurred in the public healthcare system.

4.3 Other injury Scenarios in Public Healthcare system perspective

The base-case looked at game injuries only, and the following scenarios consider other scenarios where practice and combined game and practice injuries were also included.

4.3.1 1b Practice Injuries in the Public Healthcare System Perspective.

4.3.1.1 Cost-effectiveness analysis results.

4.3.1.1.1 Per 1000 Player-hours Difference

Using a Poisson regression model which adjusted for clustering by team, disallowing body checking did not reduce the risk of practice injuries (IRR=0.25, 95% CI: 0.06 to 1.01) (Table 10). The IRR was converted into injury rates and the rate difference was taken. Disallowing body checking reduced practice injuries by 1.01 (95% CI: 0.20 to 1.79) practice injuries per 1000 player-hours (Table 12). Public healthcare costs associated with practice injuries was $349 (95% CI: -$356 to $285) per 1000 player-hours less when body checking was disallowed but it was not significant. As such, disallowing body checking does not reduce costs in the public healthcare system but may reduce the rate of injuries between policies.

4.3.1.1.2 Per 100 Players Difference.

Disallowing body checking significantly reduced practice injuries (2.29, 95% CI: 0.72, 3.95 per 100 players) (Table 12). The public healthcare cost associated with practice injuries between policies was less when body checking was disallowed by $230 per 100 players (95% CI: -$352 to $757) but the difference was not significant. As such, disallowing body checking reduce the rate of injuries but did not reduce costs in the public healthcare system. An ICER was not calculated because the results were not significant, and the cost and injury rate difference were in the dominant quadrant.

Table 12. Injury rates, absolute differences, and cost differences between body checking policies for the public healthcare system perspective for practice injuries

Type of Injury	Body checking Comparators	Crude Injury Rate(95% CI)	Costs (95% CI)	Incremental Injury Rate(95% CI)	Incremental Costs (95% CI)
Public Healthcare Cost Perspective					
Per 1000 player-hours					
Practice	Allowing	1.34 (0.74, 2.01)	$420 ($61, $407)	**-1.01 (-1.79, -0.20)**	-$349 (-$356, $285)
	Disallowing	0.33 (0, 0.84)	$71.64 ($0, $466)		
Per 100 players					
Practice	Allowing	2.80 (1.48, 4.28)	$441 ($120, $865)	**-2.29 (-3.95, -0.72)**	-$230 (-$757, $352)
	Disallowing	0.51	$211		

	(0, 1.26)	($0, $632)

4.3.1.2 Probabilistic Sensitivity Analysis Results.

The results showed that 69.43% of all bootstrap iterations found disallowing body checking to cost less and reduce injury rates (lower left quadrant) (Figure 7). The other 29.84% found disallowing body checking to reduce injury rates and cost more (upper left quadrant).

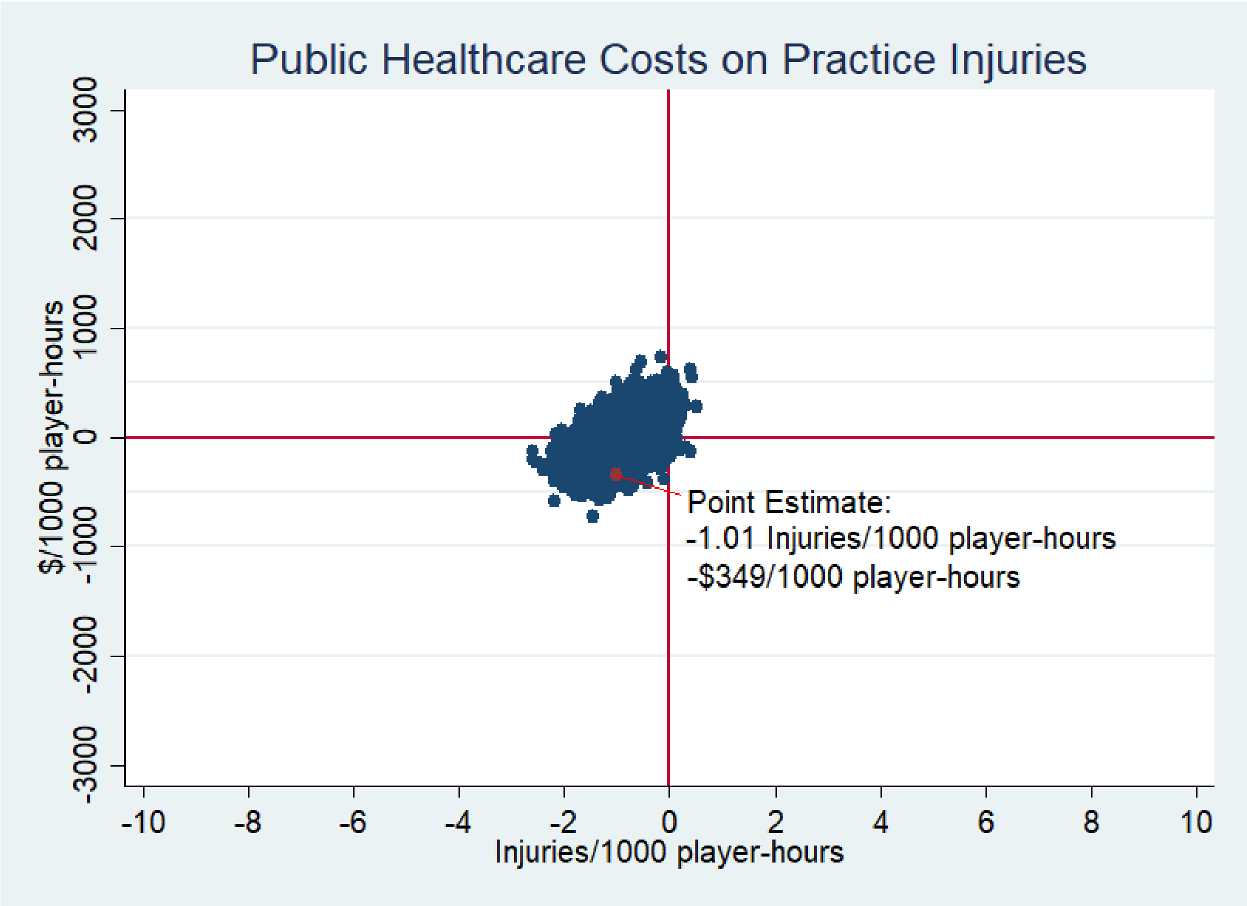

Figure 7. Probabilistic sensitivity analysis results on the mean practice injury rate and cost difference between policies that disallow and allow body checking.

4.3.1.3 Budget Impact Analysis.

Table 24 shows the potential change in practice injuries if body checking were disallowed for 8,231 Bantam ice hockey players registered for the 2015-2016 season in Alberta. It was estimated that 230 (95% CI: 122 to 352) practice injuries could have occurred if body checking were allowed and 42 (95% CI: 0 to 104) practice injuries could have occurred if body checking were disallowed for all Bantam players in Alberta over one season. If body checking were disallowed during the 2015-2016 season in Alberta, 189 practice injuries could have potentially been prevented (95% CI: 59-325).

Table 24 shows the potential change in public healthcare costs if 189 practice injuries were prevented and body checking was disallowed for all 8,231 Bantam players registered in the 2015-2016 season in Alberta. If body checking were allowed for all Bantam players in Alberta over one season, $36,266 (95% CI: $9,840 to $71,239) could have been spent on practice injuries. If body checking were not allowed, $17,332 (95% CI: $0 to $51,996) could have been spent on practice injuries. While $11,841 (95% CI: -$28,983 to $62,331) in savings could have occurred, the projected cost difference was not significant.

4.3.2 1c All (Game + Practice) Injuries Scenario Analysis in the Public Healthcare System Perspective.

4.3.2.1 Cost-effectiveness Analysis Results.

4.3.2.1.1 Per 1000 Player-hours.

Using a Poisson regression model to adjust for clustering by team, disallowing body checking significantly reduced the risk of all injuries by 55% (IRR=0.45, 95% CI: 0.26 to 0.78) (Table 10).

The IRR was converted into injury rates and the difference was taken. It was found that disallowing body checking reduced the injury rate by 2.79 (95% CI: 1.12 to 4.33) per 1000 player-hours than when body checking were allowed for all injuries (Table 12). The policy also saved costs to the public healthcare system by $980 (95% CI: $280 to $1,313) per 1000 player-hours (Table 13).

4.3.2.1.2 Per 100 Players.

Disallowing body checking significantly reduced the rate of all injuries by 15.71 injuries (95% CI: 8.57 to 22.82) per 100 players compared to when it was allowed (Table 13). It was also found that $4,355 (95% CI: $2,084 to $6,681) per 100 players in public healthcare costs were significantly saved when body checking was disallowed (Table 13).

Overall, disallowing body checking reduced both game and practice injuries and saved public healthcare costs. Since it was found that disallowing was the dominant policy, an ICER was not calculated.

Table 13. Injury and cost differences between body checking policies for the public healthcare system perspective for both game and practice injuries

Type of Injury	Body checking Comparators	Crude Injury Rate (95% CI)	Costs (95% CI)	Incremental Injury Rate (95% CI)	Incremental Costs (95% CI)
Public Healthcare Cost Perspective					
Per 1000 player-hours					
All	Allowing	5.07 (3.98, 6.19)	$1,490 ($892, $1,652)	**-2.79 (-4.33, -1.12)**	**-$980 (-$1,313, -$280)**
	Disallowing	2.28 (1.25, 3.54)	$511 ($157, $817)		
Per 100 players					
All	Allowing	24.01 (18.26, 30.10)	$5,950 ($4,056, $7,980)	**-15.68 (-22.82, -8.57)**	**-$4,355 (-$6,681, -$2,084)**

Disallowing	8.33 (4.54, 12.63)	$1,595 ($567, $2,904)

4.3.2.2 Probabilistic Sensitivity Analysis Results.

Figure 8 showed the results from the probabilistic sensitivity analysis on the differences between the combined game and practice injury rates and in public healthcare costs between body checking policies. Among the 10,000 iterations, 99.82% found that disallowing body checking reduced all injuries and saved costs to the healthcare system (lower left quadrant) (Figure 8).

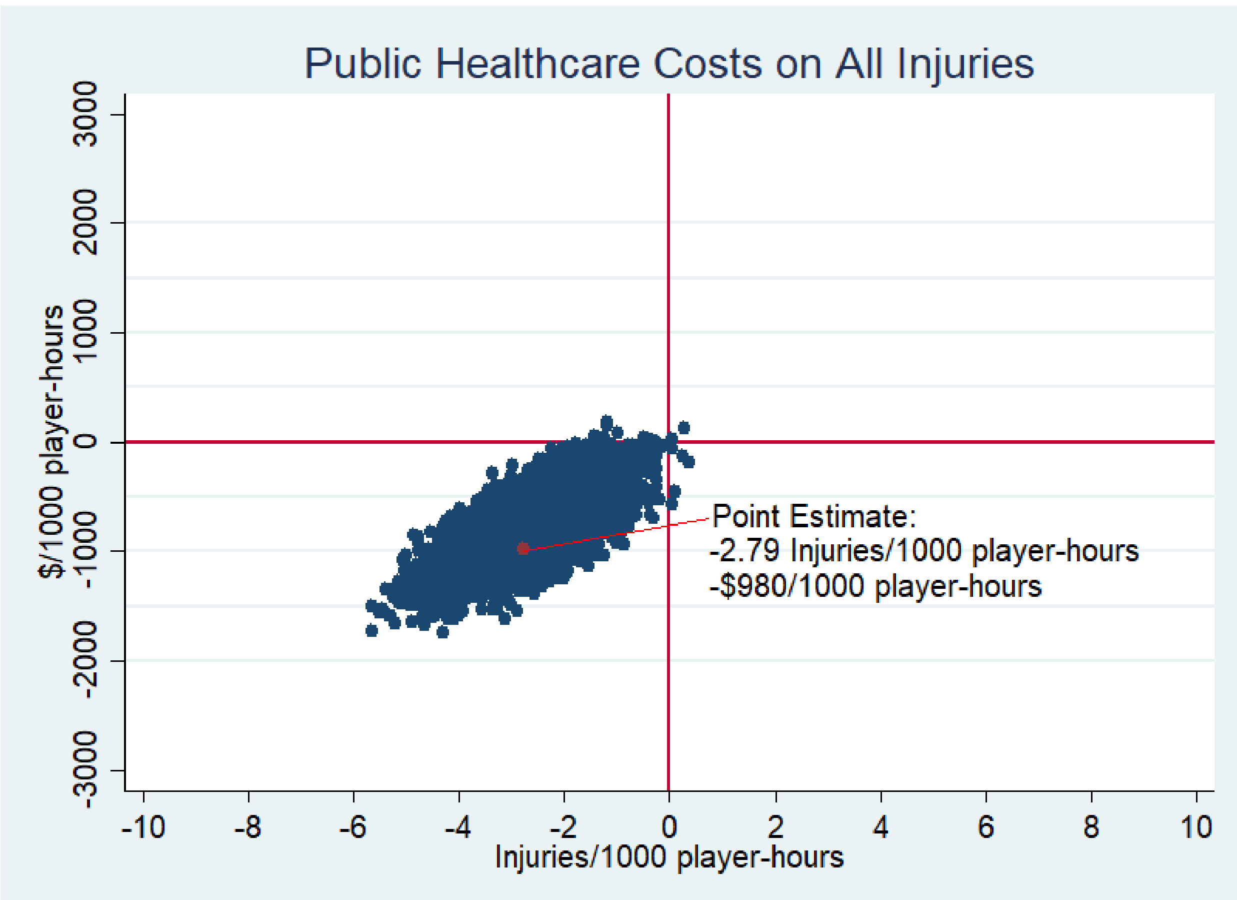

Figure 8. Probabilistic sensitivity analysis results on the difference in all injuries and in public healthcare costs between body checking policies.

4.3.2.3 Budget Impact Analysis Results.

Table 24 shows the potential number of game and practice injuries that could have been prevented if body checking were disallowed for 8,231 Bantam ice hockey players for the 2015-2016 season in Alberta. If body checking were allowed for all players in Alberta over one season, it was estimated that 1,915 (95% CI: 1,503 to 2,477) injuries could have occurred. If body checking were not allowed for all players in Alberta over one season, it was estimated that 603 (95% CI: -706 to -1,878) If that were the case, 1,292 (95% CI: 706 to 1878) game and practice injuries could have been prevented.

Table 24 shows the potential change in public healthcare costs if body checking were disallowed for 8,231 Bantam players in Alberta over the 2015-2016 season. If body checking were allowed for all Bantam players in the 2015-2016 season, public healthcare costs were estimated at $482,195 (95% CI: $333,819 to $656,824) for game and practice injuries. If body checking were not allowed for all Bantam players in the 2015-2016 season, public healthcare costs were estimated at $131,288 (95% CI: 46,707 to $239,034) for game and practice injuries. This showed the incremental savings of $350,906 (95% CI: $171,520 to $549,890) in the public healthcare system if body checking were disallowed.

4.4 Private Healthcare Costs (Including productivity Loss) Scenario Analysis

4.4.1 2a Game Injuries Scenario Analysis.

4.4.1.1 Cost-effectiveness Analysis Results

4.4.1.1.1 Per 1000 player-hours.

The cost difference between policies was not significant for game injuries in a private healthcare cost perspective including productivity. While costs were less when body checking was disallowed ($363, 95% CI: $117 to $465) compared to when it was allowed ($648, 95% CI: $333 to $820), the $285 (95% CI: -$7 to $597) per 1000 player-hours in savings was not significant (Table 14). In conclusion, disallowing body checking reduced the rate of game injuries but did not reduce private healthcare costs including productivity loss. An ICER was not calculated due to the cost and injury difference in the dominant quadrant and due to the non-significant cost result.

4.4.1.1.2 Per 100 players.

Players who were allowed to body check had $1,489 (95% CI: $841 to $2,273) per 100 players in private healthcare costs including productivity loss whereas it was estimated that $578 per 100 players (95% CI: $249 to $962) in private healthcare costs including productivity loss was observed when body checking were not allowed (Table 14). As such, disallowing body checking reduced private healthcare costs significantly by $911 (95% CI: $155 to $1,764) per 100 players. In conclusion, disallowing body checking reduced game injuries per 100 players and may reduce the private healthcare costs when it included productivity loss. An ICER was not calculated due to the cost and injury rate difference in the dominant quadrant.

Table 14. Private healthcare cost differences (including productivity loss) between body checking policies on game injuries

Type of Injury	Body checking Comparators	Crude Injury Rate(95% CI)	Costs (95% CI)	Incremental Injury Rate (95% CI)	Incremental Costs (95% CI)
Private Healthcare Cost Perspective (with Productivity Loss)					
Per 1000 player-hours					

Game	Allowing	7.98 (6.12, 10.07)	$651 ($333, $820)	**-4.32** **(-7.00, -1.54)**	-$287 (-$597, $7)
	Disallowing	3.66 (2.00, 5.70)	$364 ($117, $465)		
Per 100 players					
Game	Allowing	21.22 (16.12, 26.48)	$1,489 ($841, $2,273)	**-13.39** **(-19.69, -7.03)**	**-$911** **(-$1,764, -$155)**
	Disallowing	7.83 (4.29, 11.87)	$578 ($249, $962)		

4.4.1.2 Probabilistic Sensitivity Analysis Results.

The results from the probabilistic sensitivity analysis showed that private healthcare costs including productivity loss can be cost saving when body checking were disallowed. There were 97.13% of all iterations finding the alternative policy to reduce injury rates and save costs and 2.7% found disallowing body checking to reduce injuries and cost more (Figure 9).

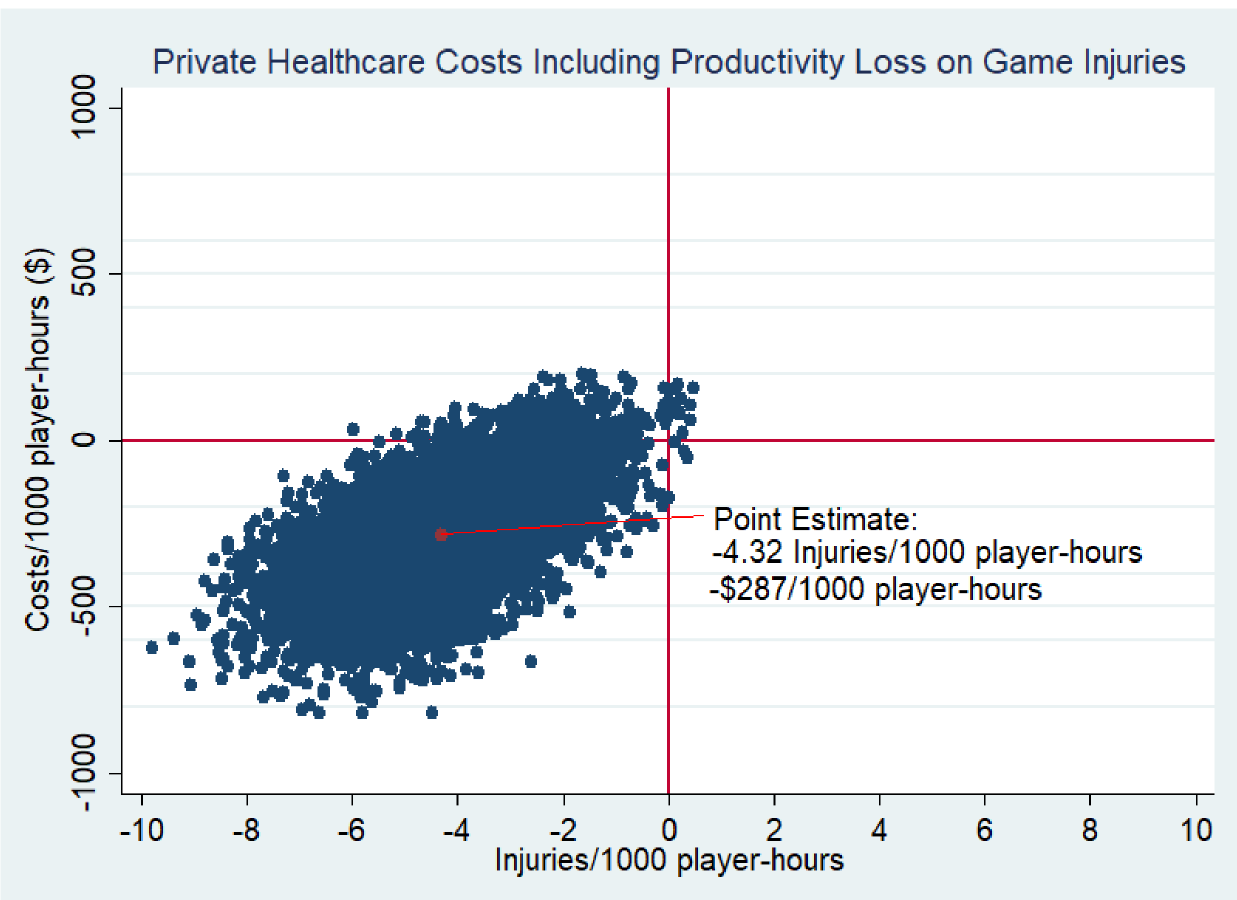

Figure 9. Probabilistic sensitivity analysis results for game injuries and private healthcare costs between body checking policies.

4.4.1.3 Budget Impact Analysis Results.

Table 24 shows the potential changes in private healthcare costs including productivity loss from preventing game injuries for 8,231 Bantam players registered in the 2015-2016 season in Alberta. It was estimated that $135,892 (95% CI: $69,191 to $187,051) in private healthcare costs including productivity loss was associated if body checking were allowed for all Bantam players in Alberta in the 2015-2016 season. If body checking were disallowed, that the private healthcare costs including productivity loss was estimated at $52,565 (95% CI: $20,470 to $79,162). As such $83,327 (95% CI: $12,729 to $145,163) could potentially be saved.

4.4.2 2b Practice Injuries Scenario Analysis.

4.4.2.1 Cost-effectiveness Analysis Results.

4.4.2.1.1 Per 1000 player-hours.

Private healthcare costs including productivity loss was reduced by $129 (95% CI: -$156 to $409 per 1000 player-hours) but the difference was not significant (Table 15). As a result, disallowing body checking reduced the rate of practice injuries but did not reduce the associated private healthcare costs when it included productivity loss. An ICER was not computed due to the cost and injury difference in the dominant quadrant and costs were not significant.

4.4.2.1.2 Per 100 players.

Private healthcare costs including productivity loss were higher but the difference was not significant between body checking policies ($82 per 100 players, 95% CI: -$325 to $608 per 100 players) (Table 15). As a result, disallowing body checking reduced practice injuries but did not reduce the associated private healthcare costs when it included productivity loss. An ICER was not computed due to the cost and injury differences lying in the dominant quadrant.

Table 15. Injury and cost differences between body checking policies for the private healthcare cost perspective on practice injuries

Type of Injury	Body checking Comparators	Crude Injury Rate (95% CI)	Costs (95% CI)	Incremental Injury Rate(95% CI)	Incremental Costs (95% CI)
Private Healthcare Cost Perspective (with Productivity Loss)					
Per 1000 player-hours					
Practice	Allowing	1.34 (0.74, 2.01)	$200 ($0, $185)	**-1.01 (-1.79, -0.20)**	-$129 (-$156, $409)
	Disallowing	0.33 (0, 0.84)	$71 ($0 to $460)		
Per 100 Players					
Practice	Allowing	2.80 (1.48, 4.28)	$126 ($0, $359)	**-2.29 (-3.95, -0.72)**	$82 (-$325, $608)
	Disallowing	0.51 (0, 1.26)	$208 ($0 to $623)		

4.4.2.2 Probabilistic Sensitivity Analysis Results.

The results from the probabilistic sensitivity analysis confirms the non-significant result in this scenario. For practice injuries, 59.74% found disallowing body checking to reduce injury rates and cost more. The 39% found the same policy to reduce injury rates and save costs (Figure 10).

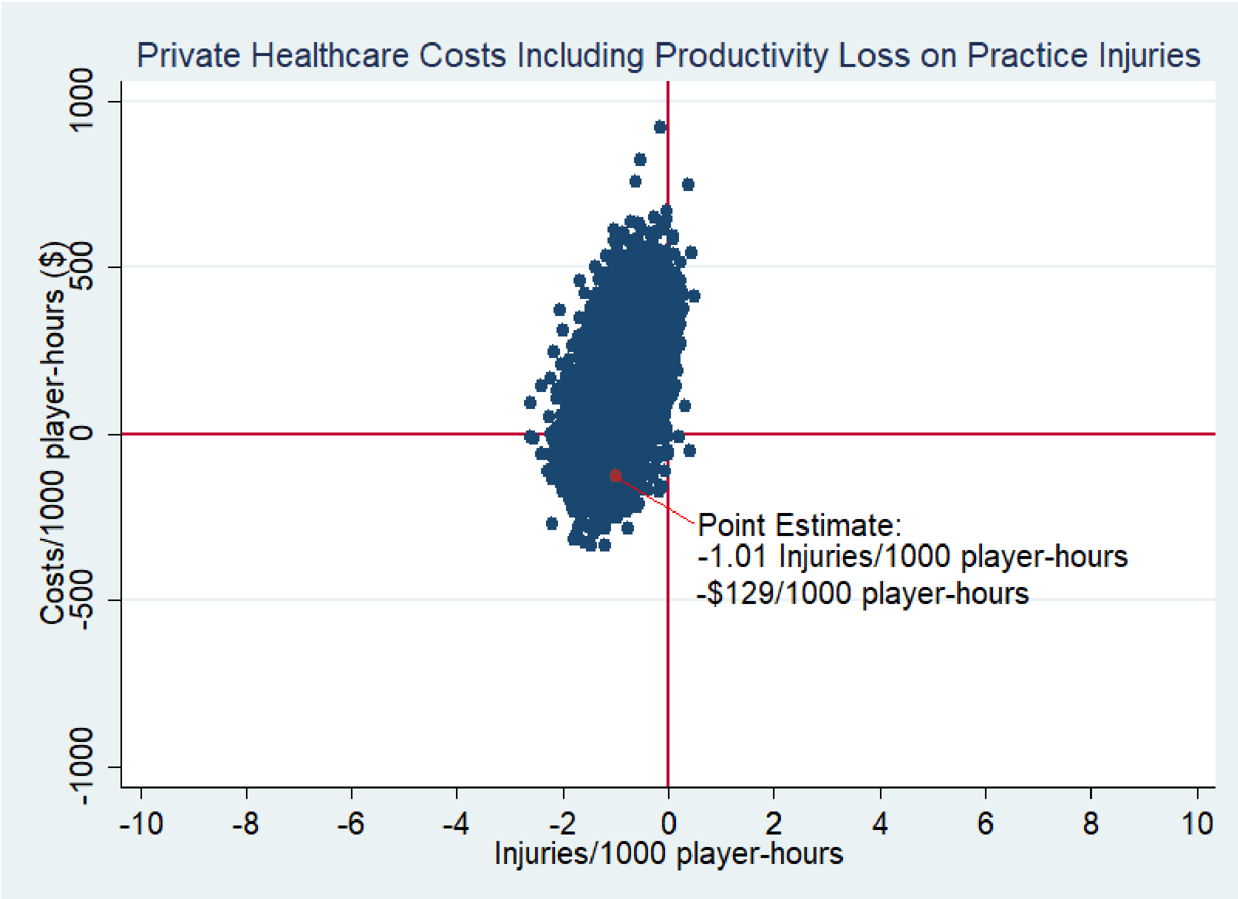

Figure 10. Probabilistic sensitivity analysis results for private healthcare costs including productivity loss in practice injuries only.

4.4.2.3 Budget Impact Analysis Results.

Table 24 shows the potential changes in private healthcare costs including productivity loss in Alberta if 189 practice injuries could be prevented for 8,231 Bantam players registered in the 2015-2016 season. If body checking were allowed for all Bantam players, the private healthcare costs including productivity loss were estimated at $10,011 (95% CI: $10 to $29,509) on practice injuries. If body checking were not allowed for all Bantam players, the private healthcare costs including productivity loss were estimated at $17,104 (95% CI: $0 to $51,313). If body checking were disallowed for 8,231 Bantam players were registered in Alberta for the 2015-2016 season, it could have cost more by $7093 (95% CI: -$26,369 to $50,084) but the difference was not significant.

4.4.3 2c All Injuries Scenario Analysis.

4.4.3.1 Cost-effectiveness Analysis Results.

4.4.3.1.1 Per 1000 player-hours.

While the cost rate was lower when body checking was disallowed ($246, 95% CI: $74 to $425) compared to the standard policy ($397, 95% CI: $208 to $492) for all injuries, the mean difference was not significant (-$151, 95% CI: -$339 to $124) (Table 16). As such, disallowing body checking reduced the rate of all injuries but did not reduce private healthcare costs when it included productivity loss. Since the cost and injury difference were in the dominant quadrant, an ICER was not calculated.

4.4.3.1.2 Per 100 Players.

The $/100 players for all injuries had the same results where disallowing body checking reduced costs by -$829 (95% CI: -$1,810 to $167) but was not significant (Table 16). Since the cost and injury difference were in the dominant quadrant, an ICER was not calculated.

Table 16. Injury and cost differences between body checking policies for private healthcare costs including productivity loss on all injuries

Type of Injury	Body checking Comparators	Crude Injury Rate(95% CI)	Costs (95% CI)	Incremental Injury Rate(95% CI)	Incremental Costs (95% CI)
Private Healthcare Cost Perspective (with Productivity Loss)					
Per 1000 player-hours					
All	Allowing	5.07 (3.98, 6.19)	$397 ($208, $492)	**-2.79 (-4.33, -1.12)**	-$151 (-$339, $124)
	Disallowing	2.28 (1.25, 3.54)	$246 ($74, $425)		
Per 100 Players					
All	Allowing	24.01 (18.26, 30.10)	$1,615 ($937, $2,422)	**-15.68 (-22.82, -8.57)**	-$829 (-$1,810, $167)
	Disallowing	8.33 (4.54, 12.63)	$786 ($261, $1,531)		

4.4.3.2 Probabilistic Sensitivity Analysis Results.

When looking at combined game and practice injuries, 85.39% of the bootstrapped iterations found disallowing body checking to reduce injury rates and cost saving. Additionally, 14.53% of the bootstrapped iterations found disallowing body checking to reduce injury rates and cost more when observing all injuries (Figure 11).

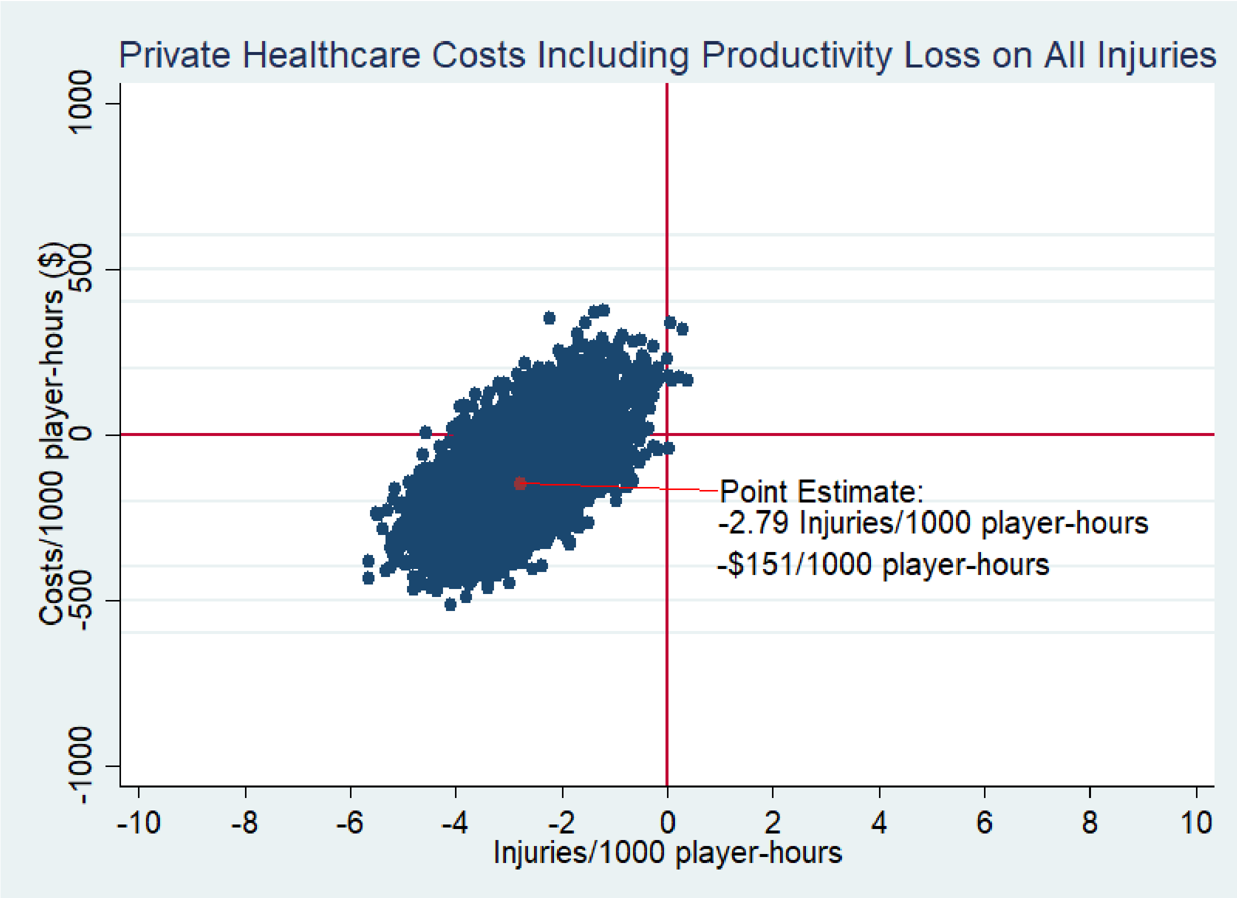

Figure 11. Probabilistic sensitivity analysis results for the injury rate and cost difference on game injuries in the private healthcare cost (including productivity loss) perspective.

4.4.3.4 Budget Impact Analysis Results.

Table 24 shows the potential change in private healthcare costs including productivity loss if body checking were disallowed for all 8,231 Bantam players registered in the 2015-2016 season. If body checking were allowed for all Bantam players in Alberta, the private healthcare costs including productivity loss were estimated at $131,931 (95% CI: $77,098 to $199,363). If body checking were disallowed for all Bantam players in Alberta, the private healthcare costs including productivity loss were estimated at $64,681 (95% CI: $2,153 to $125,996) on all injuries. If body checking were disallowed for 8,231 Bantam players in Alberta, $67,250 in private healthcare cost savings including productivity loss could have occurred but the savings were not significant (95% CI: -$13,751 to $148,986) .

4.5 Private Healthcare Cost Perspective without Productivity Loss

4.5.1 3a Game Injuries (CEA Analysis).

4.5.1.1 Cost-effectiveness Analysis Results

4.5.1.1.1 Per 1000 player-hours.

Table 17 shows the costs associated with each body checking policy and the difference between the policies. Cost savings of -$81/1000 player-hours (95% CI: -$265 to $70 per 1000 player-hours) was observed if body checking were disallowed but the savings were not significant. As such, disallowing body checking reduced the rate of game injuries but did not reduce the private healthcare cost without productivity loss. An ICER was not calculated due to the cost and injury differences lying on the dominant quadrant.

4.5.1.1.2 Per 100 Players.

The costs associated with game injuries were not significant between the body checking policies (-$358 per 100 players, 95% CI: -$781 to $71) (Table 17). As such, disallowing body checking reduced game injuries but did not reduce the private healthcare cost without productivity loss. An ICER was not calculated due to the cost and injury rate differences lying on the dominant quadrant.

Table 17. Injury and cost differences between body checking policies for private healthcare costs without productivity loss on game injuries

Type of Injury	Body checking Comparators	Crude Injury Rate(95% CI)	Costs (95% CI)	Incremental Injury Rate(95% CI)	Incremental Costs (95% CI)
Private Healthcare Cost Perspective without Productivity Loss					
Per 1000 player-hours					
Game	Allowing	7.98 (6.12, 10.07)	$288 ($148, $367)	**-4.32 (-7.00 to -1.54)**	-$81 (-$265, $70)
	Disallowing	3.66 (2.00, 5.70)	$207 ($43, $287)		
Per 100 Players					
Game	Allowing	21.22 (16.12, 26.48)	$676 ($379, $1,016)	**-13.39 (-19.69, -7.03)**	-$358 (-$781, $71)
	Disallowing	7.83 (4.29, 11.87)	$318 ($89, $617)		

4.5.1.2 Probabilistic Sensitivity Analysis Results.

The cost estimate for game injuries was less uncertain where 88.49% of all iterations found disallowing body checking to save costs and reduce injuries (Figure 12). The remaining 11.33% found disallowing body checking to increase costs and reduce injuries.

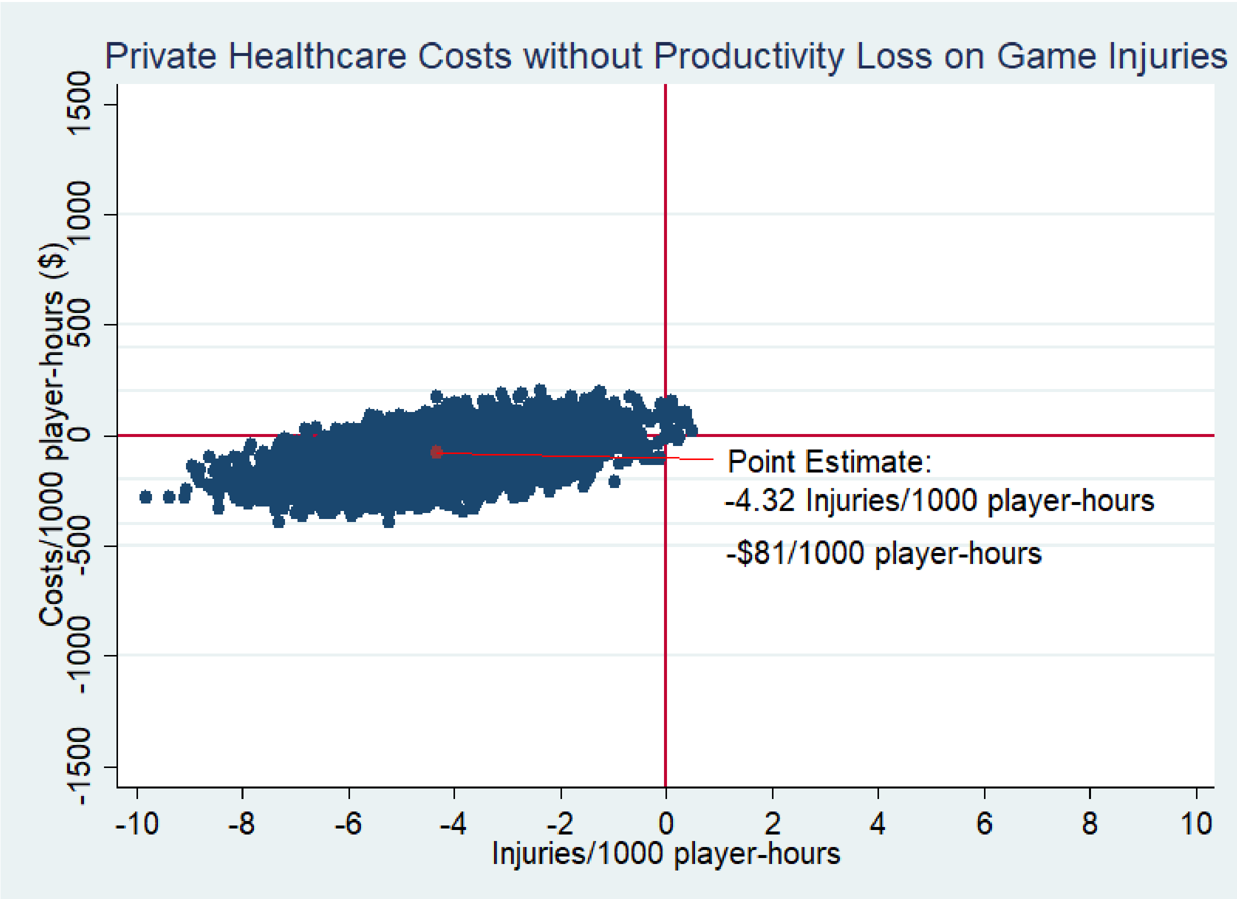

Figure 12. Probabilistic sensitivity analysis results for the injury rate and cost difference on game injuries in the private healthcare cost (without productivity loss) perspective.

4.5.1.3 Budget Impact Analysis Results.

Table 24 shows the potential changes in private healthcare costs without productivity loss if body checking were disallowed for all 8,231 Bantam players registered in the 2015-2016 season in Alberta. If body checking were allowed for all Bantam players in Alberta, private healthcare costs without productivity was estimated at $54,901 (95% CI: $31,221 to $83,620). If body checking were disallowed for all Bantam players in Alberta, private healthcare costs without productivity loss was estimated at $26,175 (95% CI: $4,792 to $44,068). If body checking were disallowed for 8,231 Bantam players registered in Alberta for the 2015-2016 season, a significant savings of

$28,726 (95% CI: 8,863 to $69,868) could occur when 1,102 game injuries could have been prevented in the 2015-2016 season.

4.5.2 3b Practice Injuries.

4.5.2.1 Cost-effectiveness Analysis Results.

4.5.2.1.1 Per 1000 player-hours.

For practice injuries, private healthcare costs without productivity loss were lower when body checking was disallowed (-$75 per 1000 player-hours, 95% CI: -$135 to $609) on practice injuries but it was not significant (Table 18). As such, disallowing body checking reduced the rate of practice injuries but did not reduce the private healthcare costs when productivity loss was not included. An ICER was not calculated because the cost and injury rate differences were in the dominant quadrant.

4.5.2.1.2 Per 100 players.

Cost was not significant ($184 per 100 players, 95% CI: -282 to 874) in practice injuries using private healthcare costs without productivity loss (Table 18). As such, disallowing body checking reduced practice injuries but did not reduce the private healthcare costs when productivity loss was not included. An ICER was not calculated because the injury and cost differences were in the dominant quadrant.

Table 18. Injury and cost differences between body checking policies for private healthcare costs without productivity loss on practice injuries

Type of Injury	Body checking Comparators	Crude Injury Rate(95% CI)	Costs (95% CI)	Incremental Injury Rate (95% CI)	Incremental Costs (95% CI)
Private Healthcare Cost Perspective without Productivity Loss					
Per 1000 player-hours					
Practice	Allowing	1.34 (0.74 to 2.01)	$175 ($0 to $162)	**-1.01 (-1.79 to -0.20)**	-$75 (-$135 to $609)
	Disallowing	0.33 (0 to 0.84)	$100 ($0 to $655)		
Per 100 Players					
Practice	Allowing	2.80 (1.48 to 4.28)	$112 ($0 to $316)	**-2.29 (-3.95 to -0.72)**	$184 (-$282 to $874)
	Disallowing	0.51 (0 to 1.26)	$296 ($0 to $889)		

4.5.2.2 Probabilistic Sensitivity Analysis Result.

The cost estimate for practice injuries was highly uncertain where 35.85% of all iterations found disallowing body checking to save costs and reduce the rate of injuries (Figure 13) and 62.88% found disallowing body checking to increase costs and reduce the rate of injuries.

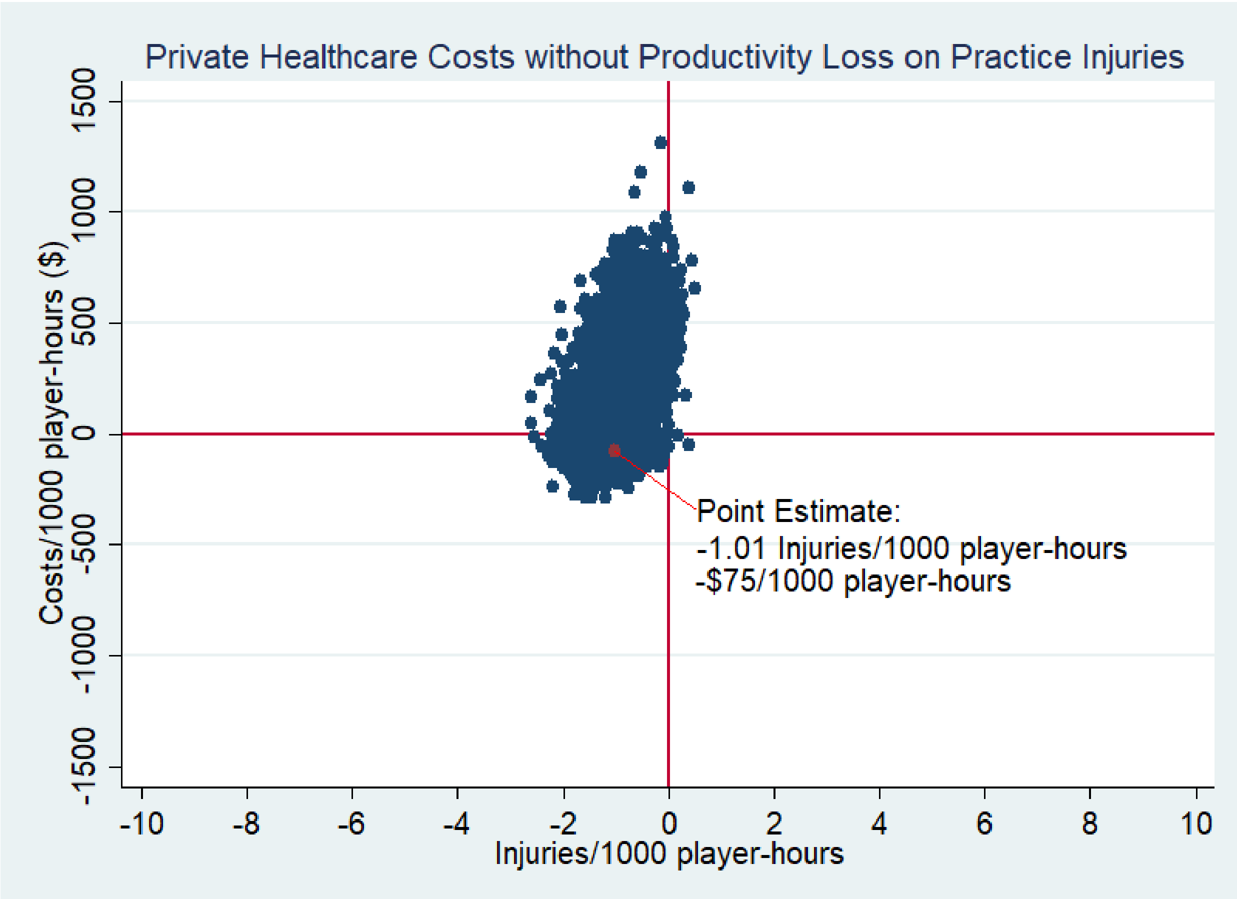

Figure 13. Probabilistic sensitivity analysis results for the injury rate and cost difference on practice injuries in the private healthcare cost (without productivity loss) perspective.

4.5.2.3 Budget Impact Analysis Results.

Table 24 shows the potential changes in private healthcare costs if body checking were disallowed for 8,231 Bantam players registered in the 2015-2016 season in Alberta. If body checking were allowed, private healthcare costs including productivity loss were estimated at $8,834 (95% CI: $10 to $25,976) on practice injuries. If body checking were disallowed, it was estimated that $16,381 (95% CI: $0 to $46,644) was spent. The cost difference of $7,547 (95% CI: -$23,183 to $46,406) when body checking was disallowed was not significant.

4.5.3 3c All Injuries.

4.5.3.1 Cost-effectiveness Analysis Results.

4.5.3.1.1 Per 1000 player-hours.

When body checking was disallowed, private healthcare costs without productivity loss were estimated at $168.51 (95% CI: $38.50 to $371.77) per 1000 player-hours (Table 19). When body checking was allowed, costs were estimated at $193.65 (95% CI: $95.57 to $234.94) per 1000 player-hours on all injuries. While the private healthcare costs without productivity loss were less when body checking was disallowed, the cost difference was not significant (-$25.13, 95% CI: -$147.76 to $215.30 per 1000 player-hours) (Table 19). Since the cost and injury difference were in the dominant quadrant, an ICER was not calculated.

4.5.3.1.2 Per 100 players.

Costs were lower when body checking was disallowed but the difference was not significant (-$161.67/100 players, 95% CI: -$813.49 to $621.54/100 players) in private healthcare costs without productivity loss for all injuries (Table 19). Since the cost and injury difference were in the dominant quadrant, an ICER was not calculated.

Table 19. Injury and cost differences between body checking policies for private healthcare costs without productivity loss on all injuries

Type of Injury	Body checking Comparators	Crude Injury Rate(95% CI)	Costs (95% CI)	Incremental Injury Rate(95% CI)	Incremental Costs (95% CI)
Private Healthcare Cost Perspective without Productivity Loss					
Per 1000 player-hours					
All	Allowing	5.07 (3.98, 6.19)	$196 ($101, $237)	**-2.79 (-4.33, -1.12)**	-$27 (-$149, $214)
	Disallowing	2.28 (1.25, 3.54)	$169 ($39, $368)		
Per 100 Players					
All	Allowing	24.01 (18.26, 30.10)	$788 ($456, $1,164)	**-15.68 (-22.82, -8.57)**	-$174 (-$813, $622)
	Disallowing	8.33 (4.54, 12.63)	$614 ($132, $1,346)		

4.5.3.2 Probabilistic Sensitivity Analysis Results.

For all injuries, 52.4% of all 10,000 iterations found disallowing body checking to save costs and reduce injuries (Figure 14) and 47.52% of the total iterations found disallowing body checking to reduce injuries at a higher cost.

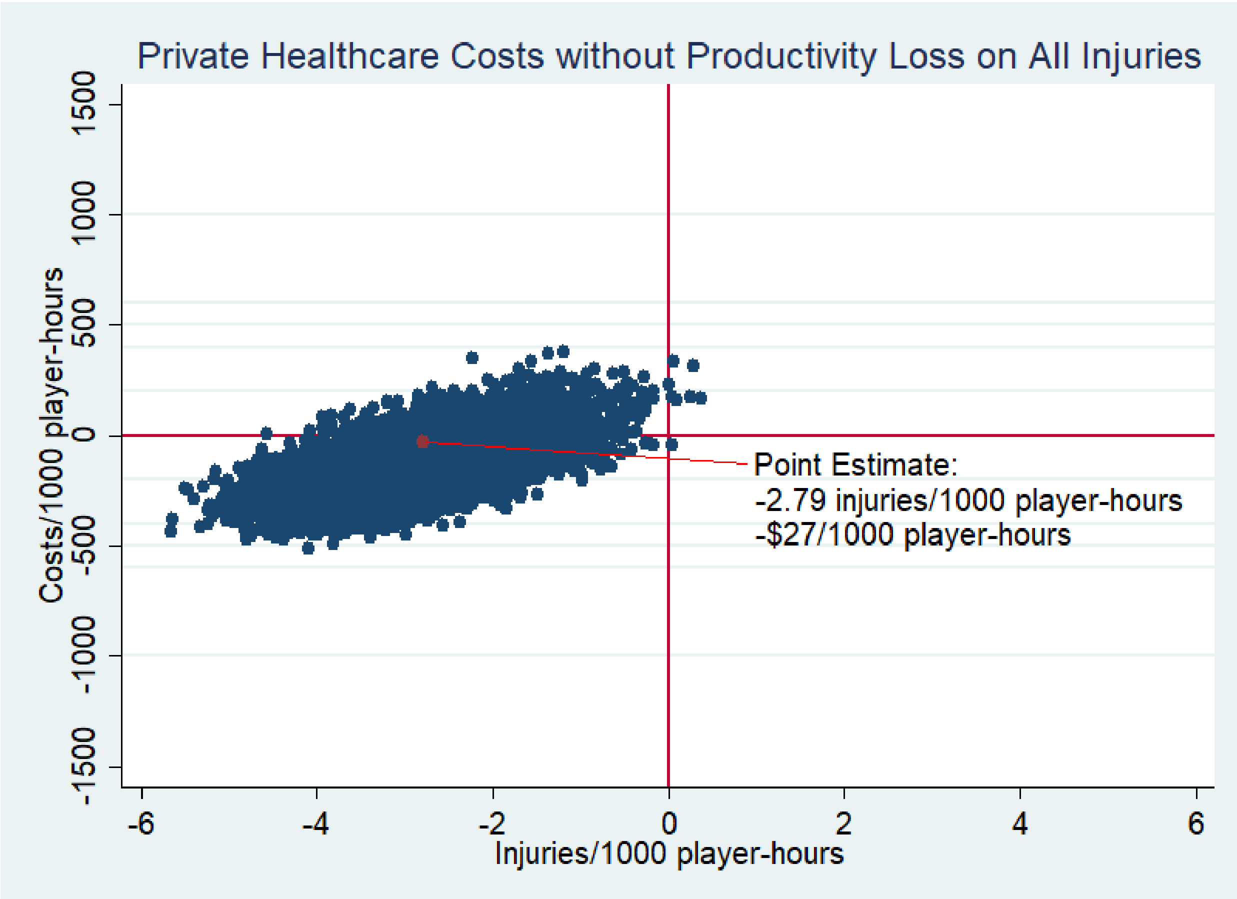

Figure 14. Probabilistic sensitivity analysis results for the injury rate and cost difference on all injuries in the private healthcare cost (without productivity loss) perspective.

4.5.3.3 Budget Impact Analysis Results.

Table 24 shows the potential changes in private healthcare costs without productivity loss if body checking were disallowed and prevented 1,292 game and practice injuries for 8,231 Bantam players registered in the 2015-2016 season in Alberta. If body checking were allowed, private healthcare costs without productivity loss were estimated at $63,873 (95% CI: $37,557 to $95,812) for game and practice injuries. If body checking were disallowed for all Bantam players in Alberta, the private healthcare costs without productivity loss were estimated at $50,538 (95% CI: $7,064 to $72,132) for game and practice injuries. If body checking were disallowed for 8,231 Bantam players in the 2015-2016 season, $13,334 (95% CI: -$74,668 to $15,563) was saved but the savings were not significant.

4.6 4a Total Healthcare Cost Perspective Scenario Analyses.

4.6.1 Game Injuries Scenario Analysis.

4.6.1.1 Cost-effectiveness Analysis Results

4.6.1.1.1 Per 1000 player-hours.

When body checking was disallowed, it had a lower estimated total healthcare costs by $2,024 (95% CI: $662 to $2,751) per 1000 player-hours compared to when body checking was allowed (Table 20). Since the difference in total healthcare costs and game injuries were in the dominant quadrant, an ICER was not calculated.

4.6.1.1.2 per 100 players.

When body checking was disallowed, total healthcare costs were estimated at $1,962 (95% CI: $873 to $3,240). This was higher than $6,998 (95% CI: $4,712 to $9,525) when body checking was allowed (Table 20). This showed significant savings on total healthcare costs on game injures (-$5,036 per 100 players, 95% CI: -$7,795 to -$2,413) (Table 19). As such, disallowing body checking is the dominant policy to reduce the rate of game injuries and total healthcare costs. An ICER was not calculated.

Table 20. Injury and cost differences between body checking policies for total healthcare costs on game injuries

Type of Injury	Body checking Comparators	Crude Injury Rate(95% CI)	Costs (95% CI)	Incremental Injury Rate (95% CI)	Incremental Costs (95% CI)
Total Healthcare Cost Perspective					
Per 1000 player-hours					
Game	Allowing	7.98 (6.12, 10.07)	$3,240 ($1,818, $3,530)	**-4.32 (-2.61, -6.22)**	**-$2,024 (-$2,751, -$662)**
	Disallowing	3.66 (2.00, 5.70)	$1,216 ($411, $1,567)		
Per 100 players					
Game	Allowing	21.22 (16.12 to 26.48)	$6,998 ($4,712, $9,525)	**-13.39 (-19.69, -7.03)**	**-$5,036 (-$7,795, -$2,413)**
	Disallowing	7.83 (4.29 to 11.87)	$1,962 ($873 to $3,240)		

4.6.1.2 Probabilistic Sensitivity Analysis Results.

The probabilistic sensitivity analysis results found that 99.79% of all bootstrap iterations were in the bottom left quadrant (Figure 15).

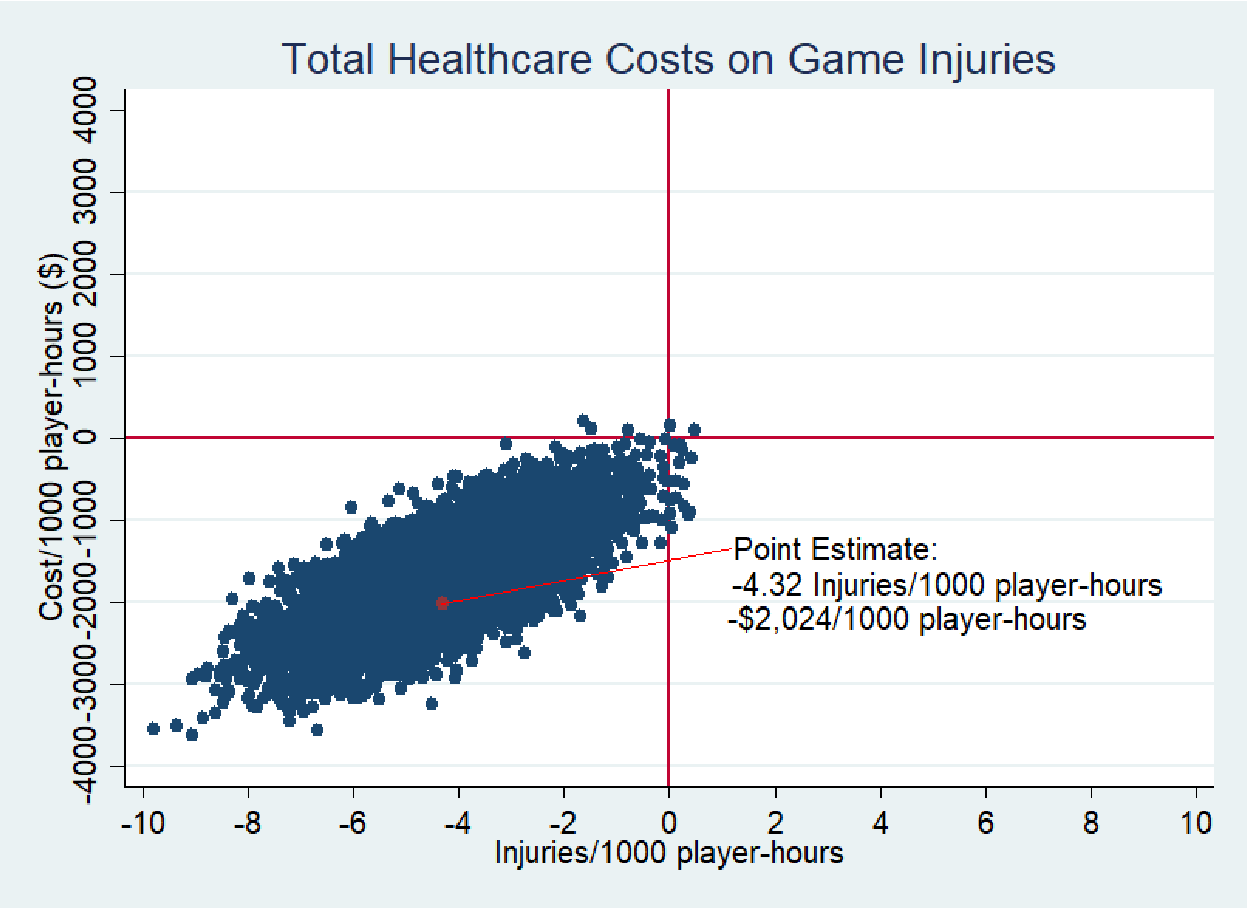

Figure 15. Probabilistic sensitivity analysis results for the injury rate and cost difference on game injuries in total healthcare costs.

4.6.1.3 Budget Impact Analysis Results.

Table 24 shows the potential total cost savings for game injuries if body checking were disallowed for 8,231 Bantam players registered for the 2015-2016 season in Alberta. If body checking were allowed for all Bantam players in Alberta, total healthcare costs were estimated at $567,320 (95% CI: $387,854 to $783,994). If body checking were allowed for all Bantam players in Alberta, total healthcare costs were estimated at $161,533 (95% CI: $71,818 to $266,644) for all injuries. If body checking were disallowed for all Bantam hockey players in Alberta for the 2015-2016 season,

$405,787 (95% CI: $193,210 to $626,127) could have been saved in total healthcare costs for game injuries to prevent 1,102 game injuries.

4.6.2 4b Practice Injuries Scenario Analysis.

4.6.2.1 Cost-effectiveness Analysis Results

4.6.2.1.1. Per 1000 player-hours.

Total healthcare costs were estimated at $578 (95% CI: $57 to $549) on practice injuries when body checking was allowed (Table 21). Total healthcare costs were estimated at $133 (95% CI: $0 to $868) on practice injuries when body checking was disallowed. There was a cost difference of -$445 (95% CI: -$465 to $643) per 1000 player-hours but the cost savings were not significant. Since the cost and injury differences were in the dominant quadrant, an ICER was not calculated.

4.6.2.1.2 Per 100 players.

Total healthcare costs were estimated at $533 (95% CI: $115 to $1,130) per 100 players when body checking was allowed (Table 21). Total healthcare costs were estimated at $392 (95% CI: $0, $1,177) when body checking was disallowed. Costs were lower by $141/100 players (95% CI: -$870 to $967) when body checking was disallowed compared to when it was allowed on practice injuries but the cost difference was not significant. Since the cost and injury differences were in the dominant quadrant, an ICER was not calculated.

Table 21. Injury and cost differences between body checking policies for total healthcare costs and practice injuries only

Type of Injury	Body checking Comparators	Crude Injury Rate (95% CI)	Costs (95% CI)	Incremental Injury Rate (95% CI)	Incremental Costs (95% CI)
Total Healthcare Cost Perspective					
Per 1000 player-hours					
Practice	Allowing	1.34 (1.28, 2.18)	$578 ($57, $549)	**-1.01** **(-2.22, -1.80)**	-$445 (-$465, $643)
	Disallowing	0.33 (0.09, 1.27)	$133 ($0, $868)		
Per 100 players					
Practice	Allowing	2.80 (1.48, 4.28)	$533 ($115, $1,130)	**-2.30** **(-3.94, -0.72)**	-$141 (-$967, $870)
	Disallowing	0.50 (0, 1.26)	$392 ($0, $1,177)		

4.6.2.2 Probabilistic Sensitivity Analysis Results.

The probabilistic sensitivity analysis found that 53.65% of all bootstrap iterations fell in the bottom left quadrant. It also found that 45.62% of all the iterations were in the top left quadrant (Figure 16).

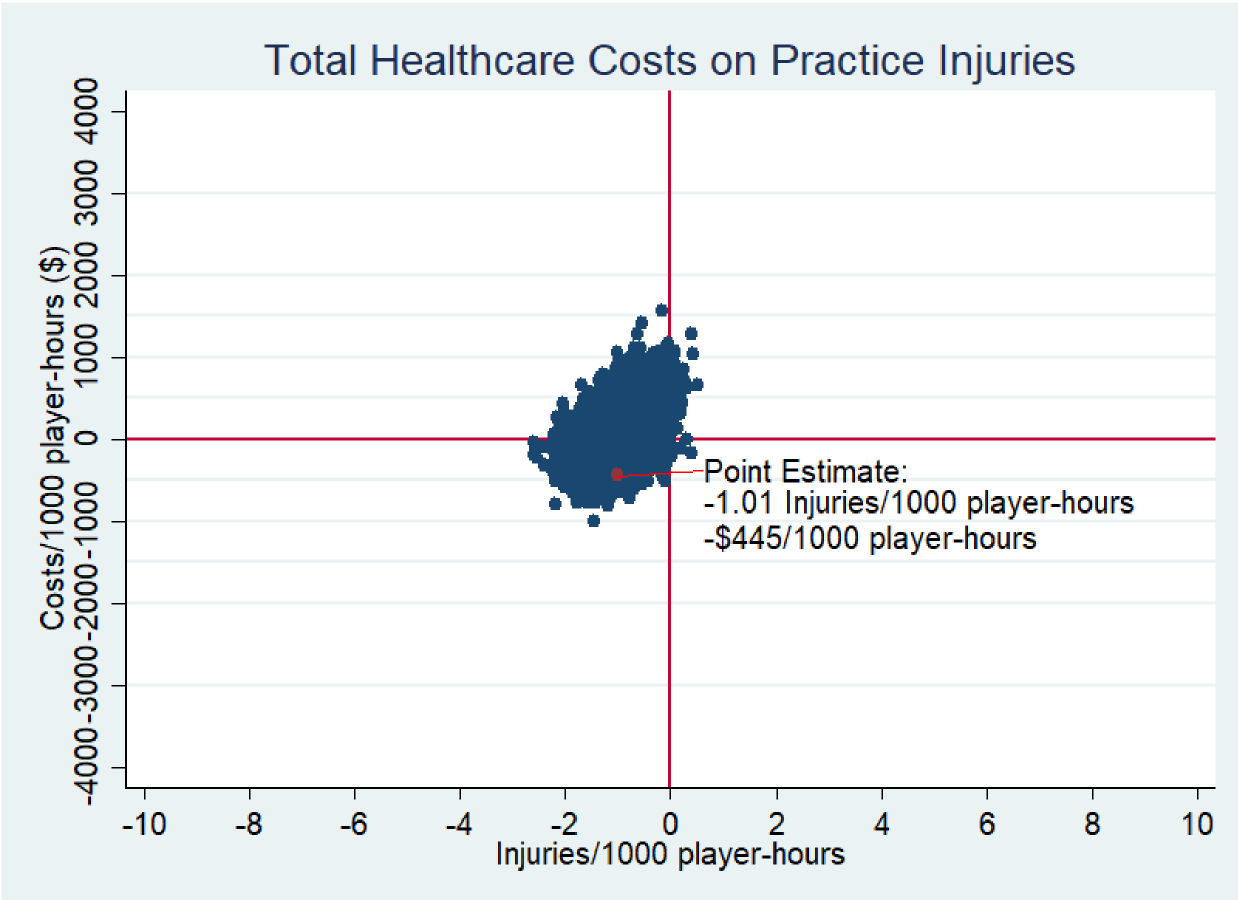

Figure 16. Probabilistic sensitivity analysis results for the injury rate and cost difference on practice injuries in total healthcare costs.

4.6.2.3 Budget Impact Analysis Results.

Table 24 shows the potential change in total healthcare costs if body checking were disallowed for 8,231 Bantam players registered in the 2015-2016 season in Alberta. If body checking were allowed for all Bantam players in Alberta, total healthcare costs were estimated at $46,277 (95% CI: $9,475 to $93,035) on practice injuries. If body checking were not allowed for all Bantam players in Alberta, total healthcare costs were estimated at $34,436 (95% CI: $0 to $96,860) on practice injuries. Between the policies, $11,841 in potential savings could have occurred (95% CI:

-$79,585 to $71,577) if 189 practice injuries could have been prevented over the same season but the difference was not significant.

4.6.3 4c All Injuries Scenario Analysis.

4.6.3.1 Cost-effectiveness Analysis Results

4.6.3.1.1 Per 1000 player-hours.

Total healthcare costs were estimated at $1,888 (95% CI: $1,129 to $2,091) per 1000 player-hours for all injuries when body checking was allowed (Table 22). Total healthcare costs were estimated at $757 (95% CI: $252 to $1,218) when body checking was disallowed. Total healthcare costs were significantly lower by $1,131 (95% CI: $214 to $1,596) when body checking was disallowed compared to when it was allowed. Since the cost and injury differences were in the dominant quadrant, an ICER was not calculated.

4.6.3.1.2 Per 100 players.

Total healthcare costs were estimated at $7,564 (95% CI: $5,149 to $10,204) when body checking was allowed on all injuries (Table 22). Total healthcare costs were estimated at $2,381 (95% CI: $903 to $4,389) when body checking was disallowed. There were significant cost savings of $5,183 (95% CI: $2,087 to $8,286) when body checking was disallowed compared to when it was allowed. Since the cost and injury differences were in the dominant quadrant, an ICER was not calculated.

Table 22. Injury and cost differences between body checking policies for total healthcare costs on all injuries

Type of Injury	Body checking Comparators	Crude Injury Rate (95% CI)	Costs (95% CI)	Incremental Injury Rate(95% CI)	Incremental Costs (95% CI)
Total Healthcare Cost Perspective					
Per 1000 player-hours					
All	Allowing	5.07 (3.98, 6.19)	$1,888 ($1,129, $2,091)	**-2.79 (-4.33, -1.12)**	**-$1,131 (-$1,596, -$214)**
	Disallowing	2.28 (1.25, 3.54)	$757 ($252, $1,218)		
Per 100 players					
All	Allowing	24.01 (18.26, 30.10)	$7,564 ($5,149, $10,204)	**-15.68 (-22.82, -8.57)**	**-$5,183 (-$8,286, -$2, 087)**
	Disallowing	8.33 (4.54, 12.63)	$2,381 ($903, $4,389)		

4.6.3.2 Probabilistic Sensitivity Analysis Results.

The probabilistic sensitivity analysis had 99.25% of all 10,000 bootstrap iterations in the bottom left quadrant showing that the point estimate for the mean cost and injury rate differences were less when body checking were disallowed (Figure 17).

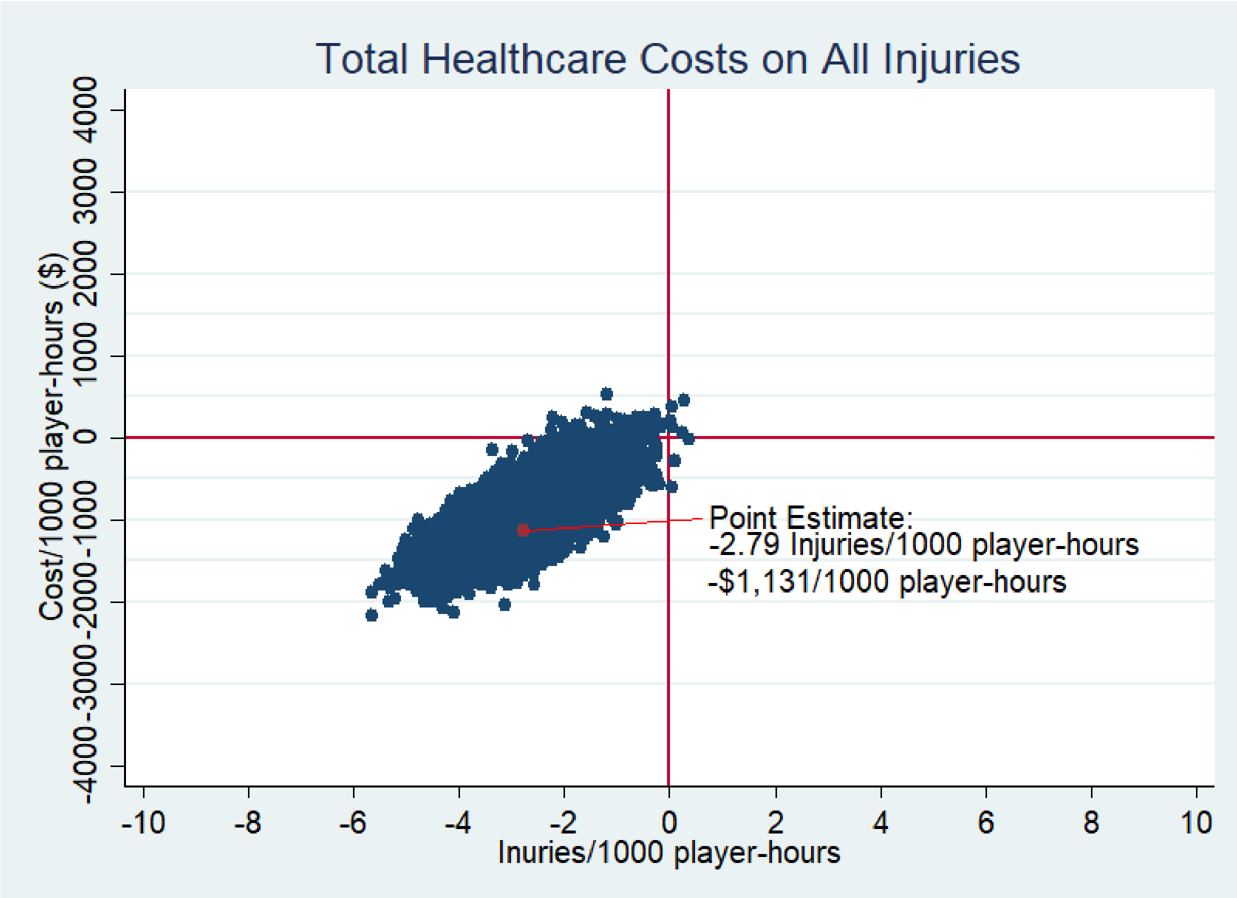

Figure 17. Probabilistic sensitivity analysis results for the injury rate and cost difference on all injuries in total healthcare costs.

4.6.3.3. Budget Impact Analysis Results.

Table 24 shows the potential change in total healthcare costs if body checking were disallowed for 8,231 players in Alberta for the 2015-2016 season. If body checking were allowed, total healthcare costs were estimated at $613,597 (95% CI: $423,790 to $389,869) on all injuries. If body checking were disallowed, total healthcare costs were estimated at $195,969 (95% CI: $75,334 to $361,251) on all injuries. As such, the incremental savings that could occur was $417,628 (95% CI: $171,784 to $682,014) between the two policies and the difference was significant.

4.7 Summary of results

Disallowing body checking reduce the rate of all the injury scenarios. Costs were also reduced in public healthcare costs, private healthcare costs including and without productivity loss, and total healthcare costs on game injuries and all injuries. While public, and total healthcare costs were lower when body checking was disallowed on practice injuries, the differences were not significant. Private healthcare costs with or without productivity loss were higher when body checking was disallowed on practice injury scenarios, but the differences were not significant. The direction of the cost-effectiveness analysis was the same for the budget impact analysis. Differences in costs and injuries were significant in the same scenarios as observed in the cost-effectiveness analysis. Table 23 and 24 show a summary of the results for the cost-effectiveness analysis and the budget impact analysis respectively.

Table 23. Summary of cost-effectiveness analyses

Injuries	Body checking Comparators	Crude injury rate (95% CI)	Costs (95% CI)	Incremental injury rate (95% CI)	Incremental Costs (95% CI)
Base case (public healthcare system perspective)					
Game	Allowing	7.98 (6.12, 10.07)	$2,589 ($1,437, $2,790)	**-4.32(-7.00, -1.54)**	**-$1,737 (-$2,751, -$662)**
	Disallowing	3.66 (2.00, 5.70)	$852 ($255, $1,158)		
Practice	Allowing	1.34 (0.74, 2.01)	$420 ($61, $407)	**-1.01 (-1.79, -0.20)**	-$348.77 (-$356, $285)
	Disallowing	0.33 (0, 0.84)	$71.64 ($0, $466)		
All	Allowing	5.07 (3.98, 6.19)	$1,490($892, $1,652)	**-2.79 (-4.33, -1.12)**	**-$980 (-$1,313, -$280)**
	Disallowing	2.28 (1.25, 3.54)	$511 ($157, $817)		
Private healthcare costs including productivity loss perspective					
Game	Allowing	7.98 (6.12, 10.07)	$651($333, $820)	**-4.32 (-7.00, -1.54)**	-$287 (-$597, $7)
	Disallowing	3.66 (2.00, 5.70)	$364 ($117, $465)		
Practice	Allowing	1.34 (0.74, 2.01)	$200 ($0, $185)	**-1.01 (-1.79, -0.20)**	-$129 (-$156, $409)
	Disallowing	0.33 (0, 0.84)	$71 ($0 to $460)		
All	Allowing	5.07 (3.98, 6.19)	$397 ($208, $492)	**-2.79 (-4.33, -1.12)**	-$151 (-$339, $124)
	Disallowing	2.28 (1.25, 3.54)	$246 ($74, $425)		
Private healthcare costs without productivity loss perspective					
Game	Allowing	7.98 (6.12, 10.07)	$288 ($148, $367)	**-4.32 (-7.00, -1.54)**	-$81 (-$265, $70)
	Disallowing	3.66 (2.00, 5.70)	$207 ($43, $287)		
Practice	Allowing	1.34 (0.74, 2.01)	$175 ($0, $162)	**-1.01 (-1.79, -0.20)**	-$75 (-$135, $609)
	Disallowing	0.33 (0, 0.84)	$100 ($0, $655)		
All	Allowing	5.07 (3.98, 6.19)	$196 ($101, $237)	**-2.79 (-4.33, -1.12)**	-$27 (-$149, $214)
	Disallowing	2.28 (1.25, 3.54)	$169 ($39, $368)		
Total healthcare cost perspective					
Game	Allowing	7.98 (6.12, 10.07)	$3,240 ($1,818, $3,530)	**-4.32 (-2.61, -6.22)**	**-$2,024 (-$2,751, -$662)**
	Disallowing	3.66 (2.00, 5.70)	$1,216 ($411, $1,567)		
Practice	Allowing	1.34 (1.28, 2.18)	$578 ($59, $549)	**-1.01 (-2.22, -1.80)**	-$445 (-$465, $643)
	Disallowing	0.33 (0.09, 1.27)	$133 ($0, $868)		
All	Allowing	5.07 (3.98, 6.19)	$1,888 ($1,129, $2,091)	**-2.79 (-4.33, -1.12)**	**-$1,131 (-$1,596, -$214)**
	Disallowing	2.28 (1.25, 3.54)	$757 ($252, $1,218)		

Table 24. Potential number of injuries and costs that could have been avoided if body checking was disallowed for all Bantam players in Alberta over the 2015-2016 season

Injuries	Body Checking (95% CI)	Disallowed Body Checking (95% CI)	Total Differences 95% CI)
Potential number of injuries prevented			
All	1,914 (1,435, 2,396)	603 (333, 915)	**-1,293 (-1,861, -737)**
Game	1,665 (1,273, 2,085)	561.21 (312, 852)	**-1,102 (-1,603, -619)**
Practice	230 (122, 366)	42 (0, 104)	**-189 (-311, -59)**
Base case (public healthcare system perspective)			
All	$482,195 ($333,819, $656,824)	$131,288 ($46,707, $239,034)	**-$350,906 (-$549,890, -$171,520)**
Game	$445,479 ($308,033, $612,025)	$113,957 ($44,698, $197,054)	**-$331,522 (-$512,924, -$173,080)**
Practice	$36,266 ($9,840, $71,239)	$17,332 ($0, $51,996)	-$11,841.30 (-$62,331, $28,983)
Private healthcare costs including productivity loss perspective			
All	$131,931 ($77,098, $199,363)	$64,681 ($2,153, $125,996)	**-$67,250 (-$148,986, $13,751)**
Game	$135,892 ($69,191, $187,051)	$52,565 ($20,470, $79,162)	**-$83,327 (-$145,163, -$12,729)**
Practice	$19,011 ($10, $29,509	$17,104 ($0, $51,313)	-$67,250 (-$7,093, $50,065)
Private healthcare costs without productivity loss perspective			
All	$63,873 ($37,557, $95,812)	$50,538 ($7,064, $72,132)	-$13,334 (-$74,668, $15,563)
Game	$54,901 ($31,221, $83,620)	$26,175 ($4,792, $33,068)	**-$28,726 (-$69,868, -$8,863)**
Practice	$8,834 ($10, $25,976)	$16,381 ($0, $47,644)	$7,547 (-$23,183, $46,406)
Total healthcare costs perspective			
All	$613,597 ($423,790, $839,869)	$195,969 ($75,334, $361,251)	**-$417,628 (-$682,014, -$171,784)**
Game	$567,320 ($387,854, $783,994)	$161,533 ($71,818, $266,644)	**-$405,787 (-$641,571, -$198,641)**
Practice	$46,277 ($9,475, $93,035)	$34,436 ($0, $96,860)	-$11,841 (-$79,585, $71,577)

Chapter 5. Discussion

This chapter provides the overview of the findings, the implications of the results, and the strengths and limitations of the study. Section 5.1 of the discussion summarizes the results of this study. Section 5.2 discusses the implications of the results and go into detail in the interpretations. Section 5.3 compares the results to previous literature. Section 5.4 and 5.5 describe the strengths and limitations of this study respectively. Finally, section 5.6 concludes the discussion.

5.1 Overview of Study Findings

Disallowing body checking was associated with reduced costs and injuries in Bantam ice hockey. The rate of injury in games were reduced by 4.32 (95% CI: 1.54 to 7.00) injuries per 1000 player-hours and reduced costs to the public healthcare system by $1,737 (95% CI: $662 to $2,751) per 1000 player-hours. The probability that disallowing body checking would reduce the rate of injuries in games and save costs in the public healthcare system was 99.80%. If body checking were disallowed for all Bantam players in Alberta for the 2015-2016 season, it could have prevented 1,102 injuries that occur during games and saved $331,522 in the public healthcare system. Costs and the rate of all injuries were reduced when body checking was disallowed compared to when it was allowed. The probability of body checking to reduce the rate of all injuries and public healthcare costs was 99.82%. If body checking were disallowed for all Bantam players in Alberta for the 2015-2016 season, 1,292 game and practice injuries could have been prevented, $417,628 in public and private healthcare costs including productivity loss could have been saved, and $350,906 in public healthcare costs only could have been saved.

5. 2 Policy Implication of Study Findings

This study can provide some information on body checking policies on Bantam ice hockey. Although further analysis of injury rates is required (see below under limitations) before moving to policy recommendations, broadly speaking this type of analysis can provide evidence to inform policy in the following ways. The first objective provides information for families who are stakeholders that can influence the decision on allowing or disallowing body checking in Bantam hockey. The results were presented by different injury scenarios to provide information on the risk of injury each time they are on the ice for practice, games, and overall for individual players. The body checking policy directly affects game injuries since the policy is enforced during games. It appears there is a spillover effect on practice injuries since it was found that the rate of practice injuries was lower for players in a league that disallowed body checking. However, this may also indicate that there was a lower risk of injury in the league that disallowed body checking in games that was not related to the policy. Costs were shown in a disaggregated way to show the average cost that could be saved in public health and private health spending and productivity losses by reducing the rate of injuries on their children when body checking was disallowed. The results from the second objective provided the overall impact on total costs and of total injuries of the decision to allow or disallow body checking on all players and their families which can help to inform decision makers within Hockey Canada about policy recommendations. By being informed on the estimated impact on their members, decision makers within Hockey Canada can make informed decision that will benefit the health of Bantam players to play in a safe manner and alleviate concerned parents.

5.3 Comparing with Previous Literature

An economic evaluation was conducted in Pee Wee hockey in 2009[20]. The reduction in public healthcare costs were 3.8 times higher and in the rate of game injuries were 1.5 higher in Bantam than in Pee Wee players. The projected cost savings on total healthcare costs are 2 times higher and the number of game and practice injuries that could be prevented was 19 higher than in Pee Wee. The projected cost savings on public healthcare costs are 2.4 times higher in Bantam than in Pee Wee.

Not all healthcare utilization was similar between the studies. The number of sports medicine visits were higher in Bantam when body checking was not allowed compared to the number of visits observed in Pee Wee in the same policy. There were 18 visits when body checking was disallowed and 57 visits when body checking was allowed in Pee Wee compared to 29 sports medicine visits when body checking was disallowed and 99 visits when body checking was allowed in Bantam[20]. The differences in emergency department visits were also higher in Bantam where 31 more visits were made when body checking was allowed compared to 25 additional visits when body checking was allowed in Pee Wee. The differences in visits to sports medicine and emergency visits between the two studies may be due to updated management protocols for concussions and injuries in hockey since the Pee Wee study that was conducted in 2009.

In 2012, the recent consensus statement on sport-related concussions outlined the Concussion in Sport Group (CISG) management recommendations[69]. The recent recommendations require the use of the Standardized Concussion Assessment Test (SCAT3) which is effective in identifying a suspected concussion[69]. The recommendations also require players to be removed from play and be evaluated by a medical professional to assess their cognitive functioning and concussion symptoms[69]. There were 59 concussions when body checking was disallowed and 19 concussions when body checking was disallowed in Bantam. This is less than what was reported the Pee Wee study where 73 concussions occurred when body checking was allowed and 20 concussions when it was disallowed. At the same time, 30 severe concussions occurred in Bantam when body checking was allowed and eight severe concussions when it as disallowed compared to 14 severe concussions when body checking was allowed and four severe concussions when it was disallowed in Pee Wee. As a result, there were more sports medicine physician visits in this study to adhere to the recent concussion consensus in re-evaluating suspected concussions and identifying and allocating the necessary resources in managing a severe concussion.

While the number of injuries that could have been prevented in this Bantam study were comparable compared to what was found in Pee Wee, the rate at which game and practice injuries occurred were higher in Bantam hockey.

5.4 Strengths

This study has a number of strengths. The Poisson regression model controlled for clustering by team. This ensures that the comparisons are between individuals and not by teams.

An economic evaluation alongside a comparative prospective cohort study is a unique opportunity to link the healthcare utilization directly from players as a result of their injuries. While the strongest design for internal validity would be a double blinded randomized controlled trial, the prospective cohort design used in this study capitalized on the variation in body checking policies across Canada to provide an environment for a natural experiment to compare body checking policies and its effect on the rate of injuries. A prospective observational study is internally valid when conducted well and provides a temporal relationship between the exposure and outcome. As such, the results of this study can provide the probability of an injury expected to occur after a certain amount of time exposed to the risk of injury. Also, it is not feasible to allocate adolescent hockey players on different hockey leagues under the assumption that one policy is hypothesized to increase the risk of injury. It would be unethical.

The results of this type of analysis may be generalizable to other provinces in Canada since the hockey leagues are similar to the leagues used in this study. This accounts for rules, age categories, and the number of games and practices players are exposed to in a season. Since the 'AA' league structure model is adopted in all provinces while varying to some degree, it is likely that the results will be similar in other parts of Canada[22].

5.5 Limitations

There are some limitations in this study. Only player position (for goalies compared to forwards), previous injury history, and previous concussion history were found to be associated with an increased injury risk. These covariates were not adjusted for and the current results may overestimate the effect of body checking policies on injury risk. Since previous injury and concussion history were identified as risk factors for sport-related injury in youth ice hockey, their effect was mixed with the association between body checking policies and hockey-related injuries without adjusted for them. As such the model would overestimate the effect of body checking policies on injuries. There were missing exposure data in both policies that were addressed through imputation and do not suggest any selection bias.

Certain out-of-pocket costs that are related to treatment such as travel costs were not collected and may underestimate the true out of pocket costs from this study. If this were included, it may increase the overall savings between policies. Missing data occurred for productivity and medications where roughly 50% of responses for productivity and medication were missing. Since a conservative imputation method was used, it underestimated the costs difference since 51 and 58 responses were missing for productivity and medication when body checking was allowed respectively, and 15 and 11 responses were missing for productivity and medication when body checking was disallowed.

Also, due to the time horizon of the study (one season of play), the long terms consequences of injuries and concussions were not captured in this study. All costs were collected from injuries that were observed in the study, but the time horizon cannot capture the costs for chronic conditions that can arise from these injuries such as post-traumatic osteoarthritis that can arise 3-10 years after an anterior cruciate tear[28]. As a result, the implications of their long-term consequences and their healthcare utilization were not captured and the current results underestimate the overall healthcare costs associated with hockey-related injuries and on final outcomes that impact quality of life.

This study used injury rates as an intermediate outcome, thus, it does not show evidence on the overall consequence on mortality and quality of life between policies. Injury rates were used because quality of life measures that can be incorporated into utilities were not collected in the study.

Lastly, there were 60 players who participated in both 2014-2015 and 2015-2016 seasons for this study and thus had repeated observations in the data but were assumed to be independent individuals. This means that the confidence intervals for injury rates that were reported in the study were more precise than the true confidence interval. Cost differences between policies were not affected by this assumption.

5.6 Future Directions

The next step in this research is to incorporate more advanced injury analysis into the cost-effectiveness analysis. This study used injury rates that accounted for exposure and for team clustering but did not adjusting for any other covariates. However, the other issue of repeated observations for some players would require a different modelling approach to account for the fact that some players were recruited for both years of the cohort study. For example, a multilevel Poisson regression with 2 random effects: one at a team level and one at a player level. This would account for the fact that these players should not be treated as independent observations in the study.

This cost-effectiveness study used injury as the outcome, and injury is an intermediate outcome. Ultimately of interest is the longer terms impacts of injuries on quality of life or life expectancy. A decision-modelling approach could be used to extrapolate over an appropriate time horizon and link intermediate (in this case, injuries) to final outcomes (ex. death, QALYs, life expectancy) to identify the effect of body checking policies on the long-term consequences from injuries using longitudinal data linking injury risks to long-term consequences. Using a lifetime horizon will capture the relevant costs and quality of life changes from hockey-related injuries that could lead to ongoing disability in life. Using QALYs as an outcome captures health gain as a result of reduced morbidity and mortality as a downstream benefit when body checking is disallowed. It can also be used to inform on the overall health gain when comparing other interventions that are looking at other clinical outcomes.

5.6 Conclusion

Disallowing body checking was associated with a lower injury rate by 4.32 injuries/ 1000 player-hours and $1,737/1000 player-hours in one season. A probabilistic sensitivity analysis on the joint uncertainty between private healthcare costs including productivity loss and the rate of game injuries showed that 97.13% of all iterations found disallowing body checking to be dominant.

If body checking had been disallowed in the 2015-2016 season, it could potentially have prevented 1,292 game and practice injuries and $350,906 on the public healthcare system in Alberta. It can also potentially save $67,250 in private healthcare cost spending in the same season on injuries that occurred during games. While the results show promise, the next step is to conduct analysis of injury rates to adjust for confounding factors and control for players who participated in both policies in the study and update the cost-effectiveness analysis and budget impact accordingly. The findings of the next phase of this work can inform policy decisions whether body checking should be introduced in Bantam ice hockey in Canada and in international hockey communities.

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APPENDIX A: SAMPLE SIZE CALCULATION – LOWER 70% DIVISIONS OF PLAY

Sample size calculations were taken from the prospective cohort study protocol[61]

Assumptions made in the following:

$\alpha = 0.05$, acceptable type I error (using 2-tailed test)

$\beta = 0.1$, acceptable type II error

$\lambda_c = 0.0015$ injury per player-hour, anticipated rate of concussion in the body checking leagues

$\lambda_i = 0.00075$ injury per player-hour, anticipated rate of concussion in the non-body checking leagues

A total player-hours required for the total non-clustered design sample size is 42,029.69.

From previous work, the average exposure time in 75.53/person-hours for the duration of the study, and the cluster size (team size), on average, is 13. Then the exposure per cluster is 75.53*13=981.89/person-hours (y*).

Also based on previous work, the coefficient of variations across teams is k=0.575.

Sample size formula:

$$c = 1 + \frac{\left({}^{z_\alpha}/_2 + z_\beta\right)^2 \left[\frac{\lambda_c + \lambda_i}{y^*} + k^2(\lambda_c^2 + \lambda_i^2)\right]}{(\lambda_c - \lambda_i)^2}$$

The formula yields 61.16 clusters per arm and rounded up to 62 teams per arm totaling to 806 (from 62 teams *13 players) players.

When considering a potential dropout rate of 0.05, the sample size will be 806/0.95= 849 players. When we divide this number by the average 13 players, we would need 66 teams per arm.

Effect Size Calculation

Using the same values from the initial sample size calculation done in the protocol and with the number of teams recruited, the effect size required to detect a difference in this study will be calculated. Since the rate of injury is the primary outcome, it will be assumed that the rate of concussion is the same as the rate of injury.

λ_c=?

λ_i=0.00075 injury per player-hour (rate of injury in non-body checking arm)[16]

c=33 (the number of teams recruited in the arm that disallowed body checking. This is the least number of teams recruited for one of two policies in this study.

k=0.575 coefficient for variation across teams (standard deviation/ mean)

y*=981.89 exposure hours per team

$z_{\alpha/2}$=1.96

z_β=1.28

$$c = 1 + \frac{({}^{z_\alpha}/_2 + z_\beta)^2[\frac{\lambda_c + \lambda_i}{y^*} + k^2(\lambda_c^2 + \lambda_i^2)]}{(\lambda_c - \lambda_i)^2}$$

$$33 = 1 + \frac{(1.96 + 1.28)^2[\frac{\lambda_c + 0.00075}{981.89} + 0.575^2\left({\lambda_c}^2 + 0.00075^2\right)]}{(\lambda_c - 0.00075)^2}$$

$$32 = \frac{(3.24)^2[\frac{\lambda_c + 0.00075}{981.89} + 0.33\left({\lambda_c}^2 + 0.00000056\right)]}{(\lambda_c - 0.00075)^2}$$

$$32(\lambda_c - 0.00075)^2 = 10.5[\frac{\lambda_c + 0.00075}{981.89} + 0.33\left({\lambda_c}^2 + 0.00000056\right)]$$

$$3.05(\lambda_c - 0.00075)^2 = \frac{\lambda_c}{981.89} + 0.00000076 + 0.33{\lambda_c}^2 + 0.00000018]$$

$$3.05\lambda_c^2 - 0.0046\lambda_c + 0.0000017 = \frac{\lambda_c}{981.89} + 0.00000094 + 0.33{\lambda_c}^2$$

$$2.72\lambda_c^2 - 0.0056\lambda_c + 0.00000076 = 0$$

$\lambda_c = 0.0019$

With at 33 teams recruited in the policy that disallowed body checking, the injury rate among teams that play in a league that allowed body checking must be at least 0.0019 injuries per player-hour (an effect size of 0.00115 injury per player-hour) in order to detect a difference. With an acceptable 0.05 type I error, this will provide a power of 0.9 in the study (β=0.1).

APPENDIX B: PRE-SEASON BASELINE QUESTIONNAIRE

UNIVERSITY OF CALGARY | Sport Injury Prevention Research Centre

Pre-season Baseline Questionnaire

OFFICE USE ONLY:
SSID:____________
Team number:________

Player name:______________________|________________

Date (MM/DD/YY): ______/______/______

Person completing form:
❑Mother ❑Father ❑Player ❑Other:______________
Parent phone#:______________________________
Parent email:______________________________

Birth date (MM/DD/YY): _____/_____/_____

Dominant hand (writing): ☐Right ☐Left

Sex: ☐Male ☐Female

Height:_______ft/inches OR _______cm

Weight:__________lbs OR _______kg

City:____________________________

Association:______________________

Level of Play: ☐Pee Wee ☐Bantam ☐Midget

Team name:______________________

Division: ☐AAA ☐AA ☐A ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐11 ☐12 ☐Rec.

Position: ☐Forward ☐Defense ☐Goalie

Have you ever participated in a University of Calgary Hockey Study?
☐No ☐Yes - If yes, what year?________________

Years of organized hockey you have played prior to this season:
☐0 yrs ☐1 yr ☐2 yrs ☐3 yrs ☐4 yrs ☐5 yrs ☐6 yrs ☐7 yrs
☐8 yrs ☐9 yrs ☐10 yrs ☐11 yrs ☐12 yrs ☐12 yrs ☐Other:____________

EQUIPMENT (check all that apply):

Mouthguard:
worn at GAMES: ☐Always ☐Less than 75% ☐Never

worn at PRACTICE: ☐Always ☐Less than 75% ☐Never

type: ☐Dentist custom-fit ☐Off the shelf (incl. boil and bite)

Helmet:
make: ☐Bauer ☐CCM ☐Itech ☐Jofa ☐Mission ☐Nike ☐RBK ☐Other:______________

model:______________________________

type: ☐Full clear visor ☐Full wire cage ☐Combination visor/cage

age: ☐New this season ☐New last season ☐2-3 yrs old ☐>3 yrs old

MEDICAL HISTORY:

Have you ever been diagnosed by a physician with a:
☐Bone fracture, arthritis, or other muscle or bone condition?
Year:__________ Describe:______________________
☐Systemic disease (eg, cancer, thyroid disease, heart disease)?
Year:__________ Describe:______________________
☐Circulation or heart problem (eg, murmur, congenital deformity, irregular beat)?
Year:__________ Describe:______________________
☐Neurological disorder (eg, cerebral palsy, pinched nerve, "stinger", MS)?
Year:__________ Describe:______________________

Have you ever experienced headaches? ☐No ☐Yes
If **yes**, are they associated with:
☐Nausea ☐Vomiting ☐Light sensitivity ☐Noise sensitivity

Have you been diagnosed with migraines? ☐No ☐Yes
If **yes**, year of diagnosis:______________

Do any family members experience headaches? ☐No ☐Yes
If **yes**, which member?______________________________

Have you ever been concerned that you have an attention or learning issue? ❑No ❑Yes
If yes, describe:______________________________
____

Have you ever been diagnosed by a health care professional with any of the following (check all that apply):
☐Cognitive delay ☐Learning disability
☐ADHD ☐Persuasive developmental disorder
☐Mood disorder ☐Communication disorder
☐Anxiety disorder ☐Disruptive behaviour disorder
☐Depression ☐Oppositional defiant disorder
☐Conduct disorder ☐Bi-polar disorder
☐Other:______________________________

Are you currently taking:
Medications (eg, inhaler, Tylenol, antidepressants, birth control)?
☐No ☐Yes:______________________
Supplements (eg, vitamins, minerals, protein powder)?
☐No ☐Yes:______________________

V.2

INJURY HISTORY:

Have you ever had a concussion (either diagnosed or not) or been "knocked out" or had your "bell rung"? ☐No ☐Yes

If **yes**, please list below:

Date (MM/DD/YY)	**Sport/activity at the time**	**Time unconscious** (minutes or seconds)	**Memory loss?**	**Time loss before FULL return to sport** (days)
			☐No ☐Yes	
			☐No ☐Yes	
			☐No ☐Yes	
			☐No ☐Yes	

If **yes**, do you have persistent problems with:

Memory? ☐No ☐Yes
Dizziness? ☐No ☐Yes
Headaches? ☐No ☐Yes

In addition to injuries listed above, have you had any injury requiring medical attention OR at least 1 day of missed participation from sport or physical activity in the past 12 months? ☐No ☐Yes

If **yes**, please list below:

Date (MM/DD/YY)	**Sport/activity at the time**	**Injury type**	**Body part**	**Treatment?** (eg, first aid, physio, etc.)	**Time loss before FULL return to sport** (days)

Do you have any incompletely healed injuries? ☐No ☐Yes - describe:________________________________

If **yes**, are you currently receiving treatment for this injury/these injuries? ☐No ☐Yes - describe:____________________

The following questions ask about body checking in hockey. We ask that you answer as honestly as possible, without any influence from other people. Please circle the number that best matches your answer:

	Strongly disagree 1	Disagree a little 2	Neither 3	Agree a little 4	Strongly agree 5
1) I like body checking.	1	2	3	4	5
2) I like to be body checked.	1	2	3	4	5
3) My coach encourages me to body check.	1	2	3	4	5
4) My parents encourage me to body check.	1	2	3	4	5
5) My teammates encourage me to body check.	1	2	3	4	5
6) I could be seriously injured by a body check.	1	2	3	4	5
7) I could seriously injure someone else with a body check.	1	2	3	4	5
8) I think body checking increases my teams' chances of winning.	1	2	3	4	5
9) I would try to harm an opponent with a body check if it would increase my team's chance of winning.	1	2	3	4	5
10) I think body checking should be allowed in Pee Wee hockey.	1	2	3	4	5
11) I would body check another player even if I know it would injure them.	1	2	3	4	5

APPENDIX C: WEEKLY EXPOSURE SHEETS

UNIVERSITY OF CALGARY

YOUTH HOCKEY STUDY

Weekly Exposure Sheet

Sport Injury Prevention Research Centre
UNIVERSITY OF CALGARY

Age Group: ☐ Pee Wee
☐ Bantam
☐ Midget

Division:
Team:
Team ID:

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Date (Month/Day)	/	/	/	/	/	/	/
Session (Game=G, Practice= P, Dryland=D)							
Score & Game Outcome (Win=W, Tie=T, Loss=L)							
Game Penalty Minutes by team (your team / opponent)	/	/	/	/	/	/	/
Duration of game or practice (minutes)							
Session Description (ie. regular season game, playoff game, (tournament game, skill training, conditioning, scrimmage, etc.)							

Player name	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID	PC	R	IID

PC (Participation Code)

Please enter a participation code (**PC**) for each player indicating:

F *Full* (75%)

P *Partial* (<75%)

0 *None* (0)

R (Reason)

If athlete is NOT fully participating (i.e. coded "P" or "0") please indicate if they are:

I Injured in hockey
(Note MUST complete Injury Report Form)

N Non-hockey related injury
(Note do not need to complete Injury Report Form)

S Sick

O Other

IID (Injury ID #) *specifies injury report form ID # to attribute time loss*

APPENDIX D: INJURY REPORT FORM

UNIVERSITY OF CALGARY Sport Injury Prevention Research Centre UNIVERSITY OF CALGARY

Hockey Study Injury Report Form

OFFICE USE ONLY:
Injury ID#: ________

Please complete this form for **any injury** including suspected concussion **occurring in hockey (game/practice/dryland, etc.)** which receives:
1) medical attention **OR**
2) results in the inability to complete the session in which the injury occurred **OR**
3) results in the player missing at least one day of sporting activity

Person completing form: ❑Mother ❑Father ❑Player ❑Team designate ❑Other:________________
Parent phone#:________________
Parent email:________________

1. Player name:________________________________

2. Player SSID#:______________ **3. Team #:** __________

4. Today's date (MM/DD/YY): ________/______/______

5. Injury date (MM/DD/YY): ________/______/________

6. Injury status:
☐ New injury
☐ Recurrence of injury from this hockey season
☐ Recurrence of injury from previous hockey season

7. Did the player return to play the same game/practice?
☐No ☐Yes ☐Non-hockey injury (Go to 16)

8. At the time of injury, were any of the following worn?
Mouthguard: ☐Unknown ☐No ☐Yes
Brace: ☐Unknown ☐No ☐Yes: ☐Left side ☐Right side
if yes, worn on: ☐Knee ☐Ankle ☐Wrist ☐Other:________
Tape: ☐Unknown ☐No ☐Yes: ☐Left side ☐Right side
if yes, worn on: ☐Knee ☐Ankle ☐Wrist ☐Other:________

9. Have you changed any equipment (since baseline?)
☐No ☐Yes ☐No baseline - entering study at injury
If yes, which? ☐Mouthguard ☐Helmet ☐Other:__________

10. Position playing at time of injury:
☐Forward (Centre) ☐Forward (Wing) ☐Defense
☐Goalie ☐Other:______________________

11. Injury occurred during:
☐ Game
a) ☐Regular season ☐Tournament ☐Playoff ☐Exhibition
b) ☐Warm-up ☐1st period ☐2nd period ☐3rd period
☐ Practice on ice
☐ Other (eg, dryland) Please specify:____________________

12. This injury involved:
☐ Sudden onset & contact with another player
☐ Sudden onset & NO contact with another player
☐ Gradual Onset/Overuse (Go to 15) ☐ Unknown (Go to 13)

13. Cause of injury (check all that apply):
☐ Body check: ☐Delivered ☐Received
☐ Other intentional player contact:
☐Elbowing ☐Roughing ☐Head contact ☐Cross-checking
☐Tripping ☐Slashing ☐High Sticking
☐ Unintentional contact with player or equipment
☐ Contact with the environment, NOT another player
☐Puck ☐Boards ☐Net ☐Ice ☐Other:__________

14. Mechanism of injury (check all that apply):
☐Direct blow to head: ☐Right ☐Left ☐Front ☐Back
☐Fell & hit head: ☐Back ☐Forward ☐Side
☐Hit head: ☐On boards ☐On ice ☐On net ☐Other:________
☐Non-head injury

15. Was a penalty called directly related to the injury event?
☐No ☐Yes
If yes, ☐Body checking related ☐Stick-related ☐Head-contact
☐Fighting ☐Other:____________________
If yes, ☐2 min minor ☐Double minor ☐5 min major
☐Penalty shot ☐10 min misconduct ☐Match penalty
☐Game misconduct ☐Suspension: length______________
If yes, who received the penalty ? (check all that apply)
☐Injured player ☐Injured player's teammate ☐Other team

16. Describe events surrounding injury:
____
____
____

17. Injury location for each type of injury (check all boxes that apply AND circle which side the injury occurred on):

Type of Injury	Head	Face	Ears (L/R)	Eye (L/R)	Nose	Teeth	Neck	Throat	Shoulder (L/R)	Collarbone (L/R)	Upper arm (L/R)	Elbow (L/R)	Forearm (L/R)	Wrist (L/R)	Hand (L/R)	Finger (L/R)	Back	Side (L/R)	Ribs (L/R)	Chest	Abdomen	Pelvis	Hip (L/R)	Groin (L/R)	Genitals	Upper Leg (L/R)	Knee (L/R)	Lower leg (L/R)	Ankle (L/R)	Foot (L/R)	Toes (L/R)	Other:
Knocked out																																
Concussion																																
Bruise																																
Burn																																
Bleeding																																
Abrasion/scrape																																
Cut																																
Blister																																
Joint swelling																																
Joint/ligament sprain																																
Dislocation																																
Broken bone																																
Muscle Strain																																
Tendonitis																																
Other:______																																

V.2

ONLY complete this section once the athlete has fully returned to play AND has completed all injury related care

18. Date of full medical clearance for return to: Normal daily activities (MM/DD/YY): ______/_____/______

Non-contact sports (full participation) (MM/DD/YY): ________/_____/______

Collision/contact sports (full participation) (MM/DD/YY): ________/_____/______

19. Who provided clearance to return to play? ☐Physician ☐Therapist ☐Coach ☐Parent ☐Self ☐Other: ________________

20. Total time parent/guardian missed work as a direct result of the player's injury: _____days + _____hours ☐Not working

21. Parent/guardian's occupation:_________________________ ☐Not working

22. Was an ambulance called? ☐No ☐Yes - If yes, did the player ride to the hospital in the ambulance? ☐No ☐Yes

23. Was the player admitted to the hospital (other than an emergency department visit)? ☐No ☐Yes

If yes, primary reason for hospitalization:____________________ # nights in the hospital:____________

If yes, did the player have surgery in the hospital? ☐No ☐Yes - Name or describe the surgery:____________________

24. Did the player see any health care professional(s) for assessment/treatment of this injury? ☐No ☐Yes (check all that apply):

☐On-site first aid	Total # visits:____	☐Paediatrician	Total # visits:____	☐Athletic Therapist	Total # visits:____
☐EMT/Paramedic	Total # visits:____	☐Surgeon	Total # visits:____	☐Massage Therapist	Total # visits:____
☐Family Physician/GP	Total # visits:____	☐Radiologist	Total # visits:____	☐Dentist	Total # visits:____
☐ER Physician	Total # visits:____	☐Chiropractor	Total # visits:____	☐Other:__________	Total # visits:____
☐Sport Med. Physician	Total # visits:____	☐Physiotherapist	Total # visits:____	__________	

25. Did the player have any tests or receive any other treatment for this injury? ☐No ☐Yes

If yes, check all that apply:

☐MRI	# of times:____ Body part:__________	☐Cast	# of casts:_____ Body part:__________ Type:__________
☐X-ray	# of times:____ Body part:__________	☐Brace	# of braces:_____ Body part:__________ Type:__________
☐CT scan	# of times:____ Body part:__________	☐Splint	# of splints:_____ Body part:__________ Type:__________
☐Bone scan	# of times:____ Body part:__________	☐Taping	# of tape rolls:___ Body part:__________ Type:__________
		☐Crutches	
		☐Other:__	____________________

26. Did the player take any medications for this injury? ☐No ☐Yes

If yes, name:________________________ type (eg, oral, injected):____________________

duration (days):____________ frequency (eg, # doses/day):______________ dosage (eg, 200mg):______________

If the player sees a physician, therapist, or other practitioner, have this healthcare provider complete the following section (unless a fee is involved). Upon completion, return to your Team Designate or study personnel.

HOCKEY STUDY 2013-2018	**Player's Name:**
Medical practitioner's name:____________________ Occupation: ☐Sport Med. Physician ☐Family Physician/GP ☐ER Physician ☐Athletic Therapist ☐Physiotherapist ☐Other:______________________________	**Date** (MM/DD/YY): ______/______/______ Diagnosis/clinical impression (check both if needed): ☐Concussion ☐Other:________________
Treatment plan: ☐Rest until asymptomatic ☐Begin RTP steps ☐Return to full participation ☐Other:	
Conditions of clearance: ☐Asymptomatic ☐Complete RTP steps ☐Other:	
ONCE PLAYER IS CLEARED TO RETURN TO UNRESTRICTED COMPETITION: Date of clearance (MM/DD/YY): ______/______/______	*Office use only* IID:__________ UCDC:__________

APPENDIX E: COST ITEMS WITH UNIT COST SOURCE

Table 25. Unit cost data applied to healthcare utilization data in this study

Items	Unit Cost source(s)	Year	Amount ($)		CPI	Amount with CPI adjustment ($)
Parent productivity loss (days + hours)	Statistics Canada[66]	2010-2011	$139,700		1.0876	$151,938
Ambulance service – treatment on-site	Alberta Health[70]	2017	$250.00		n/a	$250.00
Ambulance service – transport to hospital	Alberta Health[70]	2017	$385.00		n/a	$385.00
Emergency Room visits	Schedule of Medical Benefits Price List[71]	April 1 2017	HSC: 305 DR + TEV	$51.52	n/a	$51.52
			HSC 03.04G	$119.26	n/a	$119.52
	Ambulatory Care Classification System[72]	2009-2010	Spinal (E.D visit)	$757.98	1.07	$811.04
			Closed Fracture & dislocations Other (Code: 1005)	$245.55	1.07	$262.74
Emergency Room visits	Ambulatory Care Classification System[72]	2009 -2010	Sprains (E.D visit) Code 1009	$203.32	1.07	$217.55
			Managemen t head injury	$97.45	1.07	$104.27
			Diag inv head injury (1028)	$382.81	1.07	$409.61
Family Physician/GP	Schedule of Medical Benefits Price List[71]	2017	Health Service Code (HSC): 03.04A GP Comprehens ive visit	$40.14	n/a	$40.14
			HSC 03.03A GP	$37.35	n/a	37.35
		2017	CMXC30	$71.41	n/a	71.41

Sport Med. Physician	Schedule of Medical Benefits Price List[71]		CMXV15	$40.71	n/a	40.71
Paediatrician	Schedule of Medical Benefits Price List[71]	2017	HSC 03.04A PED using a pediatrics (PED) modifier comprehensive visit for a Pediatrician HSC 03.03A PED	$120.18 $60.09	n/a n/a	$120.18 $60.09
Orthopaedic Surgeon	Schedule of Medical Benefits Price List[71]	2017	HSC 03.08A ORTH comprehensive consultation HSC 03.03A ORTH	$108.92 $29.17	n/a n/a	$108.92 $29.17
Radiologist	Schedule of Medical Benefits Price List[71]	April 1 2017	X-rays – radiologist fee for imaging services			
		April 1 2017	HSC 03.04A DIRD	$65.79	n/a	$65.79
			HSC X22 Ribs	$47.81	n/a	$47.81
			HSC X2 - Skull	$68.47	n/a	$68.47
			HSC X4 - Facial bones	$54.31	n/a	$54.31
			HSC X31 - Wrist or carpal bone	$36.72	n/a	$36.72
			HSC X32 - Radius and ulna	$36.34	n/a	$36.34
			HSC X33 - Elbow	$32.89	n/a	$32.89

Radiologist	Schedule of Medical Benefits Price List[71]		HSC X34 - Humerus	$36.34	n/a	$36.34
			HSC X35- Clavicle	$36.34	n/a	$36.34
			HSC X36- Shoulder Girdle	$54.31	n/a	54.31
			HSC X36A - Scapula	$46	n/a	$46.00
			HSC X38 - Toe	$20.65	n/a	$20.65
			HSC X39 - Foot	$32.13	n/a	$32.13
			HSC X40 - Ankle	$36.72	n/a	$36.72
			HSC X42 - Tibia and Fibula	$36.34	n/a	$36.34
			HSC X43 - Knee	$41.69	n/a	$41.69
			HSC X46 - Femur, including hip and knee	$91.42	n/a	$91.42
			Ultrasounds – radiologist fee for ultrasound assessment services			
		April 1 2017	HSC X303 - head and/or neck, soft tissue	$102.51	n/a	$102.51

Radiologist			HSC X325 - Pediatric ultrasound head through open fontanel	$162.66	n/a	$162.66
Chiropractor	Fee provided from a clinic in Calgary	2017	Assessment - child	$90.00	n/a	$90.00
			Treatment	$45.00		Treatment range $45- $59.00
Chiropractor		2017	Treatment - two areas	$59.00		
Physiotherapist	Fee provided from a clinic in Calgary	2017	Assessment Treatment Treatment - Complex Treatment with dry needling treatment - 2 areas	$105.00 $70.00 $85.00 $85.00 $105.00	n/a	$105.00 (assessment) $86.25 (mean) Range $70 - $105.00 (treatment)
Athletic Therapist	Fee provided from a clinic in Calgary	2017	Athletic Therapy visit	$77.50	n/a	$77.50
Massage Therapist	Fee provided from a clinic in Calgary	2017	Massage treatment - 30 min Massage treatment 45 min Massage treatment 60 min Massage treatment 75 min	$60.00 $70.00 $85.00 $95.00	n/a	$85.00 (mean) Treatment range $60- 115

			Massage treatment 90 mins	$115.00		
MRI	Ambulatory Care Classification System[72]	2009-2010	Discrete MRI	$556.59	1.07	$595.55
CT Scan	Ambulatory Care Classification System[72]		Discrete CAT scan	$333.35	1.07	$356.68
X-Ra			Discrete chest X-ray	$83.28	1.07	$89.11
	Ambulatory Care Classification System[72]	2009-2010	Discrete Other X-ray	$183.77	1.07	$196.63
Ultrasound	Ambulatory Care Classification System[72]		Discrete Ultrasound	$302.81	1.07	$324.01
Brace Splint Cast	Cost of all devices provided from a private clinic in Calgary	2017	Ankle brace (mean) Knee Brace (mean) wrist/thumb brace (mean) tensor bandage Taping	$111.20 $224.71 $53.94 $5.75 $5.31	n/a	$111.20 $51 to $172.44 $224.71 $93 to $400 $53.94 $19.5 to $150 $5.75 Range n/a $5.31 $2.89 to $8.49
Crutches Other:	Cost of all devices provided from a private clinic in Calgary	2017	Donjoy Procare Crutches (medium) Donjoy Procare Crutches (large)	$65.00 $65.00	n/a	$65.00 $65.00

Table 26. Medication Cost

Medication	Unit Cost Source(s)	Year	Assumptions	Amount ($)	Range
Advil regular strength	Cost recorded from retail stores in Calgary*	2017	Assumed the costs apply across Alberta	$0.18/pill	$0.1 to $0.35/pill
Advil liquid gels regular strength				$0.3/pill	$0.17 to $0.69/pill
Advil extra strength				$0.36/pill	$0.21 to $0.56/pill
Ibuprofen				$0.13/pill	$0.07 to $0.29/pill
Pediatric Ibuprofen				$0.08/pill	$0.08 to $0.09/mL
Tylenol regular strength				$0.13/pill	$0.07 to $0.28/pill
Voltaren				$16.2/100g	$9.52 to $28.98/100g
Naproxen				$0.16/pill	$0.11 to $0.19
Robaxacet Platinum Caplets				$0.67/pill	$0.45 to $1.00/pill
Tempra				$0.46/pill	n/a
Arnica				$0.18/pill	n/a
Tylenol No. 3	Alberta Drug Benefit List[73]	April 1 2017	Assumed the costs apply across Alberta	$0.10/pill	n/a

*: The cost of out of pocket medications were recorded from seven major retail stores in Calgary. The cost was recorded for all available container sizes for each dose. The residing pharmacist was asked to confirm if the cost of these medications vary from store to store. Costs were recorded in an additional store in a different geographical area within Calgary for each retail chain to confirm that the cost is the same. It is safe to assume that the cost of medication is the same across Calgary and very similar across Alberta.

2: The cost per pill derives from the sum of all cost samples of varying container sizes from all stores over the total sample size.

APPENDIX F: DATA CLEANING ASSUMPTIONS

This document explains the steps taken to clean costing variables with information collected using the IRF. This also includes the type and location of the injury which was not cleaned at the time the data were received. For this economic evaluation, healthcare utilization data were taken from a prospective cohort study and it was cleaned as part of this study. This includes healthcare professional visits, diagnostic imaging, medical devices used, medication, and productivity loss. As such, only the cost data were required to be cleaned and described in this section. It also explains the assumptions that were made for missing data.

Injury Location and Injury Type

Injury type and location were available in the data. Injury was defined as causing the player to miss time from hockey. Both injury and type were numerical variables that contained information on the type and location of injury represented by a number (Figure 18). To visually represent how this was done, below is the section of the IRF where the location and type of injury was asked of the player:

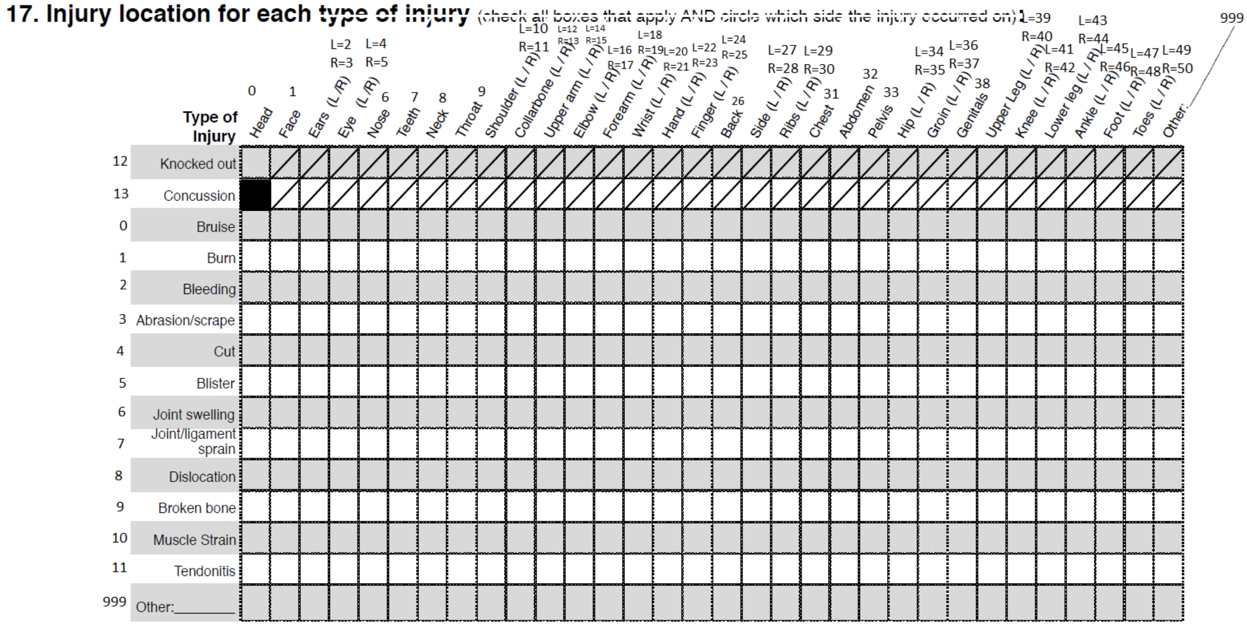

Figure 18. Question on the Injury Report Form asking for the injury type and location caused in hockey.

The number beside each type and location of injury indicates the numerical value that was entered in the dataset. For example, if a player had a concussion and it was their only injury, the box above will be filled in. When the form is coded into the dataset, the numerical value corresponding to the location and time of injury will be entered such that il1=0 for head and it1=13 for concussion. Within the dataset, up to 8 injury type and location variables were created (e.g. it1, it2, it3…it8) in case players had more than one injury at the time when they were injured. Costs associated with the first injury were valued only because they were the primary injury causing time loss from hockey.

There were instances where injury location and type were not available. This was the case if the IRF was incomplete. In these cases, the injury location and type were coded as missing and labelled as 888 during data cleaning. The same thing applied if more than one injury occurred at the time of injury and a type or a location was not provided. This could happen if parents filling in the IRF form circled the injury location and did not use the rubric as intended, or when a medical interview with a research coordinator occurred and the parent did not remember the other types of injury or where the other injuries were located. Ex. il2 (second injury location at the time of injury) stated that the injury occurred at the wrist but did not provide a type of injury (sprain, broken, etc.) in it2 (second injury type at the time of injury) and was left blank. In this case, 888 was coded in it2. There were 27 unknown injury location and two missing injury location entries which was 16% of all entries. There were also 29 unknown injury types and three missing injury types which were 18% of all entries. If injury type and location was not available, costing could not be done. For all of the unknown and missing injury type and location data, no cost data were entered and did not require assumptions around missing data.

Parent Productivity (Days and hours)

Parents were asked if they took time away from work to care for their children. If they did, they were asked for the number of days and the number of hours. A variable was created to combine days and hours together using hours as the unit of measure. The days were converted into hours assuming that one day equals to an 8-hour working day (Table 27).

Table 27. Example of the type of answers in days or hours lost from work			
Player injury id	Days lost	Hours lost	Total productivity
1	1	2	(1x8)+2=10 hours
2	0	5	(0x8)+5=5 hours

If data in either hours or days had no responses or were stated as missing, it was coded as missing. Days and hours were cross referenced with the variables containing data on lost to follow-up, if the form was complete, and if the player returned to play to find the reason behind the missing entries (Table 28). It was also to confirm that the reason why the responses were missing were due to non-responses and not due to entry error.

Table 28. Variables used to cross-reference the reason behind missing entries in days or hours lost from work

Variable	Type	Description
irf_lost_followup	Categorical and Numerical	Identifies if players lost to follow up
irf_lastcontact_explained	Open text and string	Describes the context of the last contact made with the players and parents
irf_personformcomplete	Categorical and numerical	Identifies if the form was complete and who completed it
irf_otherformcomplete	Open text and string	If irf_personformcomplete stated that a person outside of the categories completed the form, then irf_otherformcomplete states who the person is
notes_for_rtp_date	Open text and string	Provides notes on when players return from injury. This variable can also identify if players were lost to follow up
irf_parent_nw	categorical and numerical	The Parent states if they are not working. If it is checked (checkbox), then days and hours are entered as 0.

Using these variables, it confirmed that "missing" strings mean that participants did not respond to the question because players were lost to follow up or did not answer the question at the time of follow-up. There were 58 missing productivity hour entries (50% missing) and 101 missing productivity days (57% missing) entries in the data.

It was difficult to make assumptions around missing productivity such as using a mode for similar injury types. Players may require bed rest at home which required parent supervision depending on the nature of their injury. At the same time, it is possible that players went to school when they were injured and did not require time away from work from their parents. As such a conservative assumption was used where missing entries in either days or hours meant that parents did not take time away from work (Table 29).

Table 29. Example of assumptions made in productivity

irf_parent_days	irf_parent_hours	total_productivity
1	2	(1x8)+2=10 hours
888	5	(0x8)+5=5 hours
888	888	0

Healthcare professional visits and for imaging and devices (MRI, brace, splint, bone scan, tape)

Players were asked if they saw any healthcare professional for an assessment or treatment for their injury (Figure 19). The first set of variables consisted of yes/no responses from players who stated whether they visited certain types of healthcare professionals. The second set of variables identified the number of visits made for each professional.

24. Did the player see any health care professional(s) for assessment/treatment of this injury? ❑No ❑Yes (check all that apply):

☐On-site first aid	Total # visits:_____	☐Paediatrician	Total # visits:_____	☐Athletic Therapist	Total # visits:_____
☐EMT/Paramedic	Total # visits:_____	☐Surgeon	Total # visits:_____	☐Massage Therapist	Total # visits:_____
☐Family Physician/GP	Total # visits:_____	☐Radiologist	Total # visits:_____	☐Dentist	Total # visits:_____
☐ER Physician	Total # visits:_____	☐Chiropractor	Total # visits:_____	☐Other:___________	Total # visits:_____
☐Sport Med. Physician	Total # visits:_____	☐Physiotherapist	Total # visits:_____	___________	

Figure 19. Question from the Injury Report Form asking for healthcare professional visits.

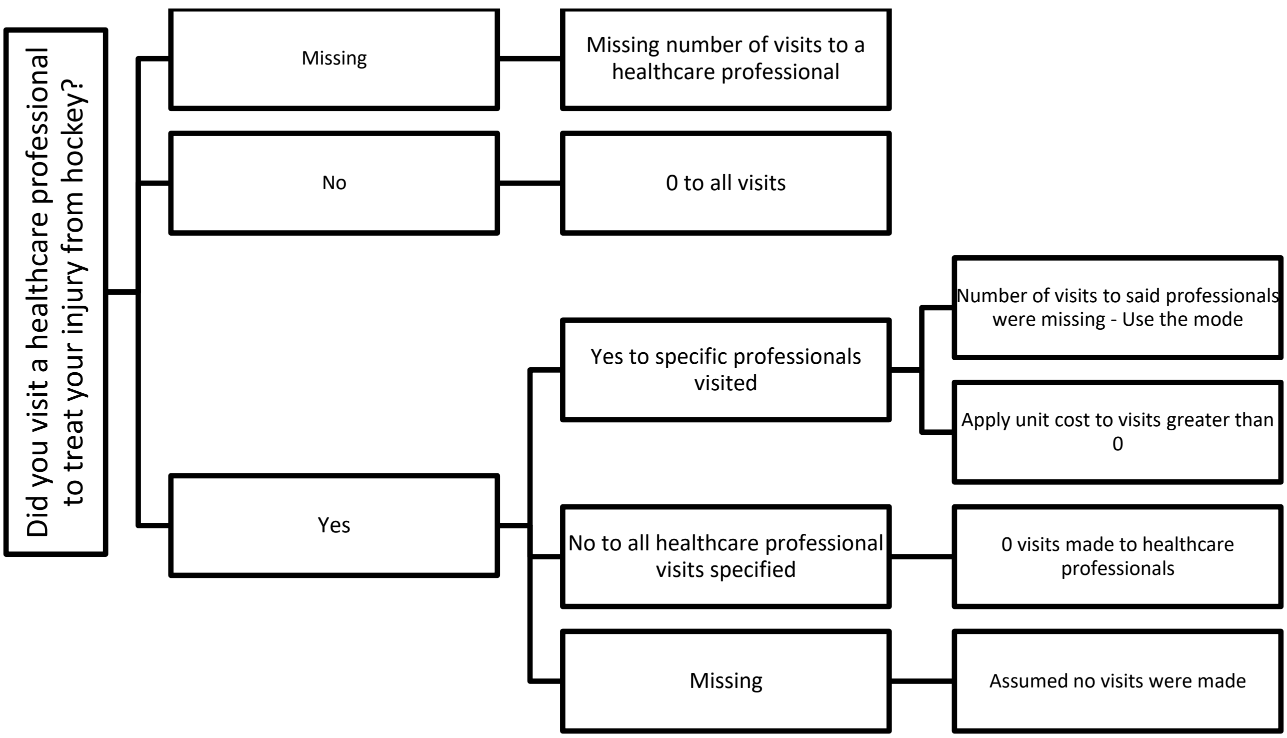

Figure 20. Data cleaning decisions made in healthcare professional visits

Figure 20 explains the decision and assumptions made based on how the question was asked on the Injury Report Form.

Figure 20 shows the data cleaning decisions made in healthcare professional visits. Players were asked to check if they saw a health care professional, and then check all that apply. They were also asked to provide the total number of visits.

If the player checked “no” in the initial check box, then no visits were made.

If a player checked “yes” but did not check off specific healthcare professionals, this information was missing.

If the player said they saw a healthcare professional and specified the type of healthcare professional, the number of visits is needed to cost all treatments and tests for their injury. If players checked “No”, then the frequency of visits were coded as 0.

If healthcare professionals were specified, but the number of visits were not provided, the number of visits were missing. It was assumed that the player visited the specified healthcare professional once which was the mode of observations within each specific healthcare professional visit variables. The mode was one for all the healthcare professionals listed in the IRF except Dentists and massage therapists who did not have any visits.

If a player did not specify a healthcare professional but stated that they saw a professional (whether IRF forms were lost or players were lost to follow-up) then variables reflecting the frequency of visits were coded as 0 because not enough information was available to identify the specific healthcare professional that was visited to make an assumption on the number of visits.

The number of missing entries for each type of healthcare professional visit is shown in Table 30. The proportion of missing entries ranged from 7% to 45%.

Table 30. Number of missing entries in healthcare professional visits

Healthcare professional	Total number of entries (including missing)	Number of missing visits
General Practitioner	35	5 (14%)
Emergency Department	41	6 (15%)
Sports Medicine Visits	56	4 (7%)
Paediatrician	3	1 (33%)
Orthopaedic specialist	5	1 (20%)
Physiotherapist	13	2
Athletic Therapist	1	0
Dentist	0	0
Chiropractor	11	5 (45%)

Imaging and medical devices/other treatments

Extra tests or treatments were asked in a similar way as the healthcare professional visits (Figure 21). Players were first asked if they had any tests or received any other treatment for the injury (Figure 21). They were then asked to specify the type of tests or treatments, and then the number of tests or treatments received unique to the treatment/device variables, a third set of variables were also applied. These variables ask players the type of device and the body part it applied to.

25. Did the player have any tests or receive any other treatment for this injury? ☐No ☐Yes
If yes, check all that apply:

☐MRI	# of times:_____ Body part:_____________	☐Cast	# of casts:______ Body part:_____________ Type:_____________
☐X-ray	# of times:_____ Body part:_____________	☐Brace	# of braces:_____ Body part:_____________ Type:_____________
☐CT scan	# of times:_____ Body part:_____________	☐Splint	# of splints:_____ Body part:_____________ Type:_____________
☐Bone scan	# of times:_____ Body part:_____________	☐Taping	# of tape rolls:___ Body part:_____________ Type:_____________
		☐Crutches	
		☐Other:__	

Figure 21. Question on the Injury Report Form asking if players had tests done or received other treatments.

Figure 22 shows the decisions on data cleaning and assumptions for tests and extra treatments used. If players said yes to receiving tests or receiving other treatment for the injury, and imaging or medical device were specified along with the number of treatments, costs were applied.

If treatments were not specified, it meant that tests or treatments were not used. If these responses were missing (whether it was from a missing form or page), it was assumed that players did not have treatments or tests done. This is because there is not enough information to identify the specific treatment or imaging to make assumption on the number of imaging or treatments done. If players stated that they did not have any tests or receive any other treatment, then they did not receive other treatments.

There were situations where players stated they were using specific medical devices or imaging services but did not provide the number of visits. The mode of the observed number of visits within each specific tests or treatments were used to replace these missing entries. The mode for most of the types of imaging and treatments was one. All entries for MRI were missing. It was assumed that at least one visit was made. As a result, it was assumed that players had at least one treatment or test done if they stated that these services were used if they did not provide the number of times these services were used. Table 31 shows the number and proportions of missing entries for each type of imaging and treatments used in this study.

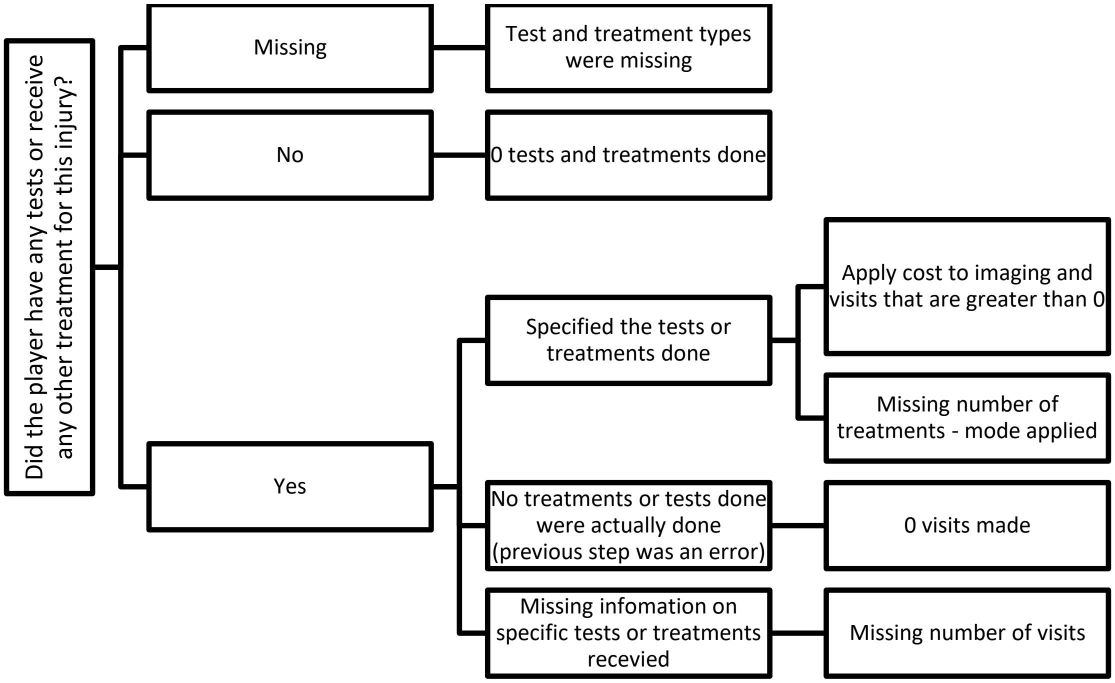

Figure 22. Data cleaning decisions on extra tests done or treatments received

Table 31. Number of missing visits for imaging and treatments used		
Imaging and Treatments used	Number of entries	Number of missing values
MRI	2	2 (100%)
CT Scans	3	2 (66%)
Casts	6	3 (50%)
Braces	2	1 (50%)
Splints	3	6 (50%)
Surgery	0	0
X-rays	33	7 (21%)
Bone Scans	0	0
Tape	3	0
Crutches	3	0

Ambulance services

Players were asked if they had an ambulance called and if they took a ride to the hospital in the ambulance (Figure 23).

22. Was an ambulance called? ☐No ☐Yes - If yes, did the player ride to the hospital in the ambulance? ☐No ☐Yes

Figure 23. Question that asked players if an ambulance was called and if they were given a ride to the hospital in an ambulance.

Figure 24 shows the data cleaning decisions for ambulance services. If a player stated that an ambulance was called, and the player took the ambulance to the hospital, the full cost of the ambulance ride was applied. This also meant that the player required more than usual treatment on-site from an EMT. Since the player was given a ride to the hospital, any entries stating that they were also treated onsite were set to “No”. This was to remove double counting and only the cost of the ride to the hospital was applied.

If the player stated that an ambulance was called and the player did not take a ride to the hospital, then it was assumed that the player was treated at the rink and costed appropriately.

There were 57 missing entries out of 173 responses when asked if an ambulance was called at the time of the injury which consisted of 32% of the answers in the study. Only one player answered that an ambulance was called at the time of the injury. Due to the disparity between the number of ambulances that were called at the time of injury and the number of missing responses, it was assumed that no ambulance was called if there were missing responses.

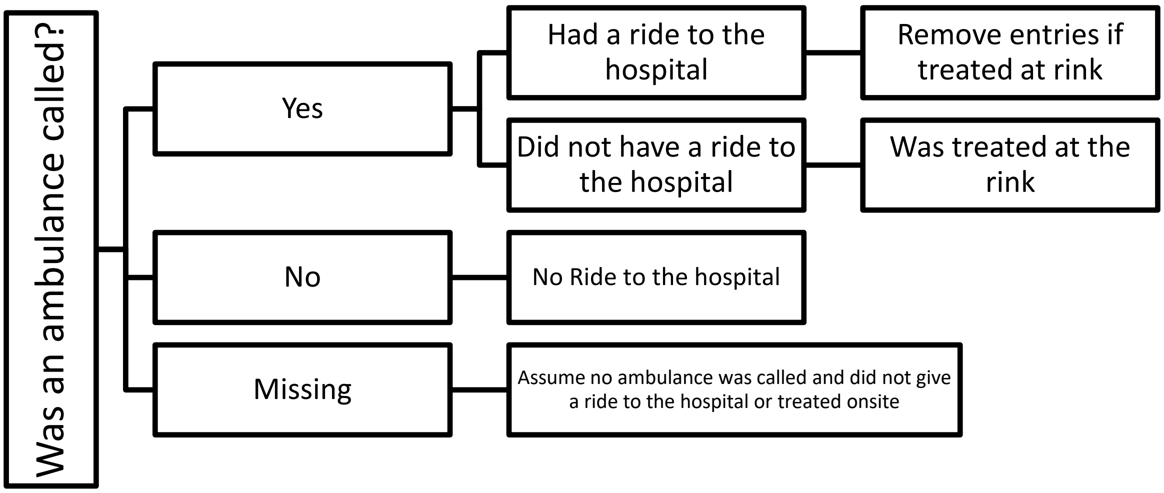

Figure 24. Data cleaning decisions for ambulance services.

Medication

Players were asked if they took any medications for their injury (Figure 25). If they did, the name, type, duration, frequency, and dosage was asked for in open text responses. Costing in medication was in cost per pill or cost per 100mL of cream. This meant the duration and frequency of use were required to cost medication.

There were cases where multiple medications were used by one player. To account for this, multiple variables were duplicated for name, type, duration, frequency, and dose. Up to three variable duplicates were made as three was the maximum number of medications stated from a player within this study.

26. Did the player take any medications for this injury? ☐No ☐Yes
If yes, name:__________ type (eg, oral, injected):__________
duration (days):__________ frequency (eg, # doses/day):__________ dosage (eg, 200mg):__________

Figure 25. Question from the Injury Report Form asking for medication taken for their injury.

Figure 26 shows the data cleaning decisions made on medication. If there were no information on if players took medication towards their injury whether if there were no answers or was stated missing, it was assumed that no medications were taken. If players did take medication, the medication names were asked. If they did not provide a name, there was no way to cost their medications. As a result, a conservative assumption was made and assumed that no medication was taken. If a name was provided, dose, duration, and frequency were asked for.

While most respondents provided numbers, some answers were ambiguous and did not provide sufficient information to identify how long and frequently medication was used. Some assumptions were made in the answered that were provided by players:

- when needed
- as required,
- on and off 2 weeks
- not long
- as needed
- as needed for headache every 4 hours

Not only there were ambiguous string entries, there were missing data on duration and frequency which made it difficult to make assumptions on how long and frequently they took medication. There were 76 responses missing out of 171 when asked if medication was used. From the responses that did state that medication was taken, 14 out of 54 responses did not state the duration of use. The raw data did not provide a variable for dose and a variable for frequency and needed to be generated. There were 26 entries out of 54 that responded that did not provide frequency data. Overall, there was 84% incomplete answers in medication. Table 26 summarizes the number of missing entries.

Table 32 shows the number of missing entries for each medication question that was asked for in the IRF. The mode was used to impute the missing entries for duration and frequency. Dose was assumed based on the name of the medication. The mode for duration and frequency was also applied to ambiguous string entries that did not provide the necessary information to make assumptions on their medication behaviour.

Using STATA, the mode was calculated for both frequency and duration which was 2 instances of medication use for frequency and 2 days respectively.

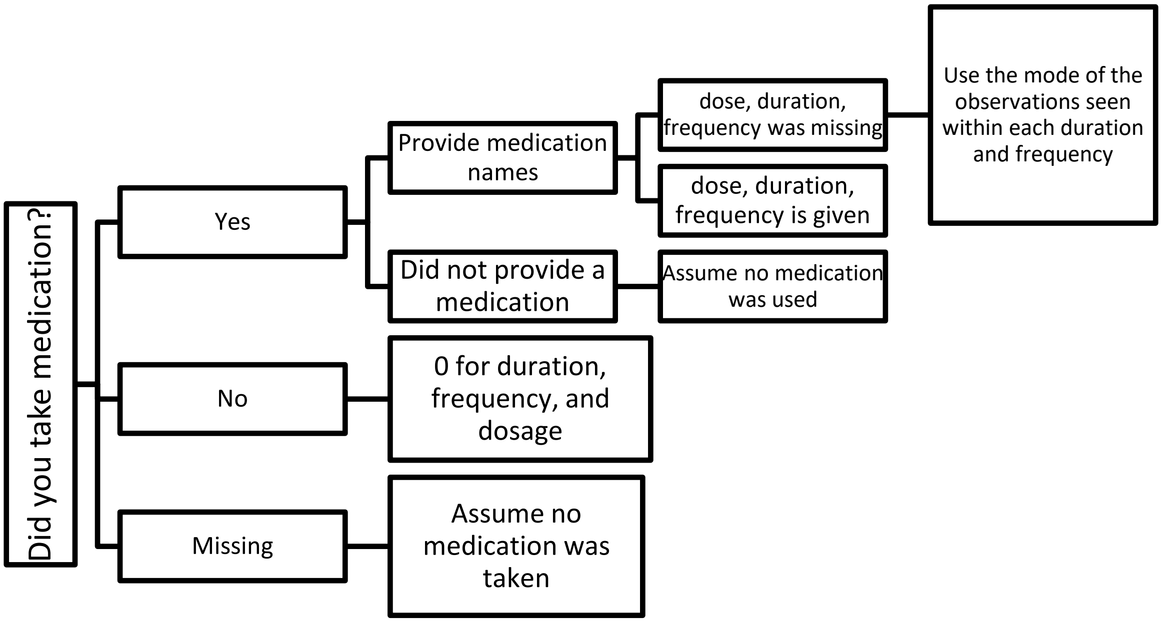

Figure 26. Data cleaning decisions for medication.

Table 32. Number of missing entries in medication		
Medication question	Total responses	Number of missing entries
Did you use medication?	171	76 (44%)
Duration	54	14 (26%)
Frequency	26	54 (48%)
Total completed questions	171	144 (84%)

Specifically, for Traumeel, this is a homeopathic cream and does not provide a medical recommendation on the amount of cream that should be used in one sitting. As a result, it was assumed that the same amount was used as Voltaren which as a medical recommendation of using 1 gram for each use.

Hospitalization (irf_hosp)

This variable identifies if players stayed overnight at a hospital. This variable was coded as 999 if there were blank cells.

To note, no entries stated yes in this variable. As such, this was not used in the analysis.

APPENDIX G: BASELINE CHARACTERISTICS BY INJURY STATUS

Table 33. Baseline characteristics by injury status and body checking policies

		Injured		Not Injured	
		Non - body checking	**Body checking**	**Non - body checking**	**Body checking**
		2014-2015	**2015 - 2016**	**2014 - 2015**	**2015 - 2016**
		N=25 (%)	**N=126 (%)**	**N=371 (%)**	**N=482 (%)**
Sex n (%)	**Male**	25 (100)	122 (96.46)	365 (98.39)	475 (98.59)
	Female	0	4 (3.54)	6 (1.61)	7 (1.41)
	Missing data	0	0	0	0
Height, mean (SD) cm		167.21 (9.50)	163.79 (10.37)	165.58 (10.36)	165.21 (9.71)
Missing data, n (%)		5 (20.00)	18 (14.29)	81 (21.83)	91 (18.88)
Weight, mean (SD) kg		59.23 (17.26)	54.95 (13.16)	55.34 (13.45)	53.95 (11.02)
Missing data, n (%)		7 (28)	25 (19.84)	101 (27.22)	104 (21.58)
Year of play	**First**	14 (56)	69 (54.76)	181 (48.79)	260 (53.94)
	Second	8 (32)	50 (39.68)	161 (43.40)	204 (42.32)
	Missing data	3 (12)	7 (5.56)	29 (7.82)	18 (3.73)
Position	**Forward**	16 (64)	73 (57.94)	179 (48.25)	252 (52.28)
	Defence	3 (12)	46 (36.51)	100 (26.95)	130 (26.97)
	Goalie	2 (8)	1 (0.79)	26 (7.01)	49 (10.17)
	Missing data	4 (16)	6 (4.76)	66 (17.79)	51 (10.58)
Previous injury	**No**	15 (60)	88 (69.84)	261 (70.35)	344 (71.37)
	Yes	9 (36)	32 (25.40)	63 (16.98)	107 (22.20)
	Missing data	1 (4)	6 (4.76)	47 (12.67)	31 (6.43)
Previous concussion	**No**	12 (48)	78 (61.90)	240 (64.69)	325 (67.43)
	Yes	13 (52)	46 (36.51)	116 (31.27)	144 (29.88)
	Missing data	0	2 (1.59)	15 (4.04)	13 (2.70)