The Epidemiology of Injuries in Ice Hockey Athletes

by

Deanna Nicole Pesun

Bachelor of Kinesiology – Athletic Therapy, University of Manitoba, 2020

Submitted to the Faculty of the

School of Health and Rehabilitation Sciences in partial fulfillment

of the requirements for the degree of

Master of Science

University of Pittsburgh

2023

UNIVERSITY OF PITTSBURGH

SCHOOL OF HEALTH AND REHABILITATION SCIENCES

This thesis was presented

by

Deanna Nicole Pesun

It was defended on

May 3, 2023

and approved by

Committee Member: Mary Murray, EdD, LAT, ATC, Associate Professor and Director for MS in Sports Medicine, Department of Sports Medicine and Nutrition, University of Pittsburgh

Committee Member: Katelyn Allison, PhD, Associate Professor and Interim Director for MS in Sports Science, Department of Sports Medicine and Nutrition, University of Pittsburgh

Thesis Advisor: Mita Lovalekar, MBBS, PhD, MPH, Associate Professor, Vice Chair for Academic Affairs, Department of Sports Medicine and Nutrition, University of Pittsburgh

The Epidemiology of Injuries in Ice Hockey Athletes

Deanna Nicole Pesun, MS, B. Kin, CAT(C)

University of Pittsburgh, 2023

Background: There is a lack of current research into the mechanism, incidence, and rate of all injuries within women's ice hockey, especially when trying to compare injuries with men's ice hockey. This narrative review explores the research pertaining to the incidence of ice hockey injuries, the anatomical location of injury, the mechanism of injury, and the diagnosis of injury.

Methods: Articles were found using either PubMed, Google scholar, or through using the University of Pittsburgh Health Sciences Library System by using a combination of search terms, including "ice hockey", "women's", "men's", "injuries", "epidemiology", "incidence of injury", "collegiate sport", "NCAA", "Canadian", and "contact sports".

Results: Injury rates in ice hockey range from 2.0 injuries per 1000 Athlete Exposures (AEs) to 27.0 injuries per 1000 AEs. Data collected shows a variety in the mechanism and diagnosis of injury. Contact with another player is a common mechanism of injury in both women's and men's ice hockey, regardless of age or level of competition. Strains and sprains are a common diagnosis of injury for both women's and men's ice hockey, and concussions tend to be more common in women's ice hockey when compared to men's ice hockey at a similar level.

Conclusion: In conclusion, this narrative review highlights the need for ongoing research into the mechanism, incidence, and rate of injuries in women's ice hockey, particularly when compared to men's ice hockey. The results of the study suggest that injury rates in ice hockey vary greatly and that contact with another player is a common mechanism of injury in both women's and men's ice hockey. Strains, sprains, and concussions are common diagnoses in both women's

and men's ice hockey. Further research is needed to better develop effective injury prevention strategies.

Table of Contents

List of Tables

List of Figures

1.0 Introduction

Since the inaugural competition of Olympic Women's Hockey in 1994, there has been a steady increase in female hockey registration[1]. The United States Department of Commerce stated that from 2004 to 2014, women's hockey was the fastest growing women's sport in the world, with registration increasing by more than 400%[2]. In the past 10 years, in the United States alone, girls' and women's hockey participation has grown by 34%[3]. Despite this increase, there are still fewer Women's Hockey teams at the collegiate levels when compared to the male counterpart[1]. During the 2021-2022 season, there were 41 NCAA Division I women's teams and 59 Division I Men's teams. There were 90 Division II/III men's teams and only 71 women's teams in Division II/III[4]. In Canada, there are 36 women's hockey teams and 36 men's hockey teams at the USports level[5,6]. There is limited research on women's hockey injuries. Hockey-related injuries are normally reviewed solely in men's hockey[7]. As female participation in ice hockey increases, so does the need for sex-specific research[1]. Within a systematic review done by MacCormick, Best, and Flanigan, of 22 chosen studies, only 6 included data for injuries occurring in women's hockey[2]. Though, non-contact injuries are common, ice hockey players are in the category of athletes at a high risk for traumatic injuries because of the aggressive nature of the sport[8].

There is a lack of current research into the mechanism, incidence, and rate of all injuries within the game of Women's Hockey[9]. Athlete sex might be one of the most important factors to consider when looking at injury epidemiology, but is often neglected[10]. Research is an important aspect of any athletics program. Research drives injury prevention and training programs; including practice and game schedules, rule adaptations, and the general wellness of athletes. The risk, type, mechanism, and severity at specific levels have not been well studied[11]. Within the

limited research concerning women's ice hockey, it has been shown that despite the differences in rules of the game, women's ice hockey injuries are most commonly caused by body contact[2,12].

1.1 The History of Women's Ice Hockey

The first-ever documented game of women's hockey was played in 1892, two years prior to the first Stanley Cup being awarded, in Barrie, Ontario. Two years later, in defiance of the Archbishop, Queen's University formed a female club team called "the Love-Me-Littles", with teams at McGill University and in the Ottawa Valley forming another two years later in 1896. By 1916 competitions had been held across eastern Canada, with the first international tournament held in Cleveland, Ohio. This tournament featured teams from both the United States and Canada[13]. The first women's game was reported in the United States around 1920[14]. The first-ever intercollegiate championship was held in 1921, where the University of Toronto defeated McGill University[13]. In the 1930s, women's hockey gained popularity but eventually disappeared during World War II. Post war, hockey was seen as a men-only sport, and it took time for the women's game to gain popularity again[14].

By the 1970s, numerous women's tournaments had been established across Canada, as well as in the Midwest and Northeast of the US, and teams were formed in Sweden, Finland, Japan, China, Korea, Norway, Germany, and Switzerland. In 1987, the first-ever invitational world women's championship was held in Mississauga, ON, hosting teams from Canada, the US, Sweden, Japan, Switzerland, and the Netherlands[13]. The first International Ice Hockey Federation (IIHF) Women's European Championship was held in Germany in 1989[14]. Just one year later, the first-ever IIHF women's world championship was held, where team Canada beat the US. In 1992,

it was announced that women's hockey would be joining the list of full medal sports at the Olympics at the 1998 Winter Games in Nagano, Japan. At the 1998 winter games, the US beat Canada despite four straight gold medal losses at the IIHF World Women's Championships[13]

At the collegiate level, women's hockey joined the Canadian Intersport Sport (now USport) system in 1997 and the National Collegiate Athletics Association (NCAA) established the women's hockey championship in 2001[14]. Within the NCAA, women's hockey began with 63 teams and expanded to 73 from 2000-2010[7]. USport is the home of 36 women's hockey programs, 32 of which are at institutions that also have a men's program[5,6]. In north America, USport and NCAA hockey are considered the highest level of competition for female hockey players, behind only national team participation. Numerous regional, national, and cross border professional leagues were founded in the 1990s and 2000s, such as the Canadian Women's Hockey League (CWHL) and National Women's Hockey League (now Premier Hockey League)[14]. The CWHL disbanded in 2019 due to an "unsustainable business model"[15].

The rules of the game are the same for both men's and women's hockey with only one difference; body contact is permitted yet body checking receives a minor two-minute penalty in the women's game[15]. Despite the no-checking rule, the women's game is a very physical game[2]. The size of the rink, goal net, and the duration of the game is the same[7]. In terms of equipment both teams wear the same gear, with only a few alterations. Genital protection, use of a neck guard, and face protection differ between women and men[15]. In the women's game, a neck guard is required at all levels of play, whereas it is only sanctioned up until the junior level for men. This is similar to face protection. Women are required to wear either a cage, a metal grid that covers the whole face, or a bubble, a full plastic covering with a grid near the mouth for breathing. Men are required the same level of facial protection only until the junior level, and then it is up to each

player to choose the extent of facial protection for themselves. Many players choose a simple plastic visor, as it is believed to block an athlete's vision the least[16]. Since the inaugural Olympics, women's ice hockey has gained popularity. From 2007 through 2018, the number of registered players worldwide increased by more than 30% from 153,665 to 205,674[14].

1.1.1 The Impact of Title IX on Women's Collegiate Sports

In the 1960's Dr. Bernice (Bunny) Sandler was applying for a full-time faculty position at her alma mater, the University of Maryland, where she had received her doctoral degree in psychology. Application after application got rejected, and when she approached her department chair about her rejections, he responded that she "came on too strong for a woman". Bunny Sandler began to record what was happening: sexism. A phenomenon not exclusive only to women in academics, nor a term yet part of the lexicon, was a prominent experience for women and girls going to school[17,18]. Female students were required to have higher test scores and grades to be accepted into universities. Sandler spent a week testifying to convince Representative Edith Green to sponsor a congressional hearing. Eventually President Nixon signed Title IX to the law and title IX became a part of the Educational Amendments Act of 1972[18].

Title IX uses a three-part test to assess gender equality in the athletic population. 1) Is the percentage of participation offered to female and male athletes proportional to the percentage of female and male athletes in the undergraduate student body? OR 2) Is there a history and continuing effort of expansion within the athletic department to demonstrate growth in the under-represented population? OR 3) Has the Athletic Department exhausted their efforts to satisfy the needs of the underrepresented population[18,19]?

Ideally, the athletic population would be 50% female athletic opportunities and 50% female undergraduate students, but due to fluctuations in enrollment and team participation, there is some flexibility[18]. Without any flexibility it would be challenging for schools to have to adjust every academic year resulting in difficulties of having a viable team[19]. Satisfaction of the second step is achieved by demonstrating a history of program expansion such as adding new teams, upgrading to Division I status, or increasing participation opportunities. The final step is fulfilled by having periodic reviews to confirm that the needs of the underrepresented population are being considered[18].

Athletic opportunities increased substantially after the implementation of Title IX. Women have twelve times as many athletic opportunities than they did before Title IX[20]. This growth was not without trial, in 1974, an amendment to exempt athletics was proposed. Though the amendment was never approved, there had been a widespread belief that applying Title IX to the NCAA would bring on the demise of men's college sports[21-23].

For decades, Title IX compliance was lax, and finally in the 1990's, removal of federal funding was a consequence of non-compliance. With the necessity of complying with Title IX looming, athletics departments began to trim budgets by eliminating both men's and women's teams. Many schools used a lack of accessible resources as the justification for only cutting the women's team[21]. With a lack of resources, athletes in women's sports may not be provided access to athletic trainers, strength and conditioning staff and other necessary resources to remain healthy and competitive. Despite this, the number of women who enrolled in a four-year college or university and participated in collegiate sports teams grew from 30,000 in the 1970's to 180,000 students in the 2010's. Progress can also be seen outside of collegiate sports in women's professional leagues, where 40 years ago, women competing at a professional level seemed all but

farfetched. Despite women gaining entry into the world of competitive sport, there is still the presence of sexism, homophobia, and misogyny that must be combated[24].

1.2 The Application of the Injury Surveillance System in American Collegiate Ice Hockey

The NCAA injury surveillance system (ISS) was created in 1988 with data from 16 sports. The 17th sport, women's ice hockey, wasn't added until the 2000-2001 season. To be included in the ISS, the reportable injury had to meet three criteria: (1) The injury occurred as a result of participation in an organized intercollegiate practice or contest; (2) The injury required medical attention by a certified athletic trainer or team doctor; and (3) the injury caused a reduction in athlete's participation or performance for more than 1 day following the injury[25].

Melvin et al., studied the epidemiology of upper extremity (UE) injuries in NCAA Men's and Women's Ice Hockey athletes. UE injuries were the focus of this study due to the lack of focus on UE injuries in the literature, though many studies had described the common injuries in hockey. Athletic trainers would submit information on an injury to the surveillance program. The information was verified and included body sublocation, mechanism of injury, type of injury, and the timing of injury. Athlete exposure (AE) is when a single student athlete participated in a single NCAA-sanctioned practice or competition[12]. Melvin et al. hypothesized that male hockey players would sustain UE injuries more often than their female counterparts, based on the difference in body checking rules. Using the NCAA injury surveillance program, UE injury data from 2004-2014 was examined. From the 2004-2005 season until the 2008-2009 season, the athletic trainers from 19 men's hockey teams and 10 women's teams recorded the injury data. Following the 2008-2009 season to the completion of the study in 2014, only 18 men's teams and 9 women's teams

data was recorded[12]. Between 1988 and 2004, participation in NCAA championship sports has increased among both sexes. Female participation increased by 80% and male participation creased by 20%[25].

During the academic years 2004-2005 through 2013-2014, 1304 UE injuries were recorded for 552,623 AEs in men's ice hockey. Of all injuries reported, 88% occurred during the regular season (256.94 injuries per 100,000 AEs), with pre-, off-, and post season only accounting for 12% (142.73 injuries per 100,000 AEs). Most AEs were during practice (76%), yet 73% of all injuries occurred during competition, Division I had the highest total of UE injury, representing 47.5% of all UE injuries yet Division III had the greatest overall injury rate with 260 UE injuries per 100,000 AEs. Forwards sustained UE at the greatest frequency (55.1% of all injuries), but injuries seemed to be proportionate to the number of players on the ice in each position[12].

During the academic years 2004-2005 through 2013-2014, 289 UE injuries were recorded for 231,923 AEs in women's ice hockey. 75% of all AEs were practices (n = 172,910), but 62% of injuries were sustained during competition (303.30 injuries per 100,000 AEs). Division III athletes had the highest amount of UE injuries (n = 148), but division II had the greatest overall injury rate (148.23 per 100,000 AEs). Most UE injuries (92%) were sustained during the regular season (n = 265). Forwards sustained UE at the greatest frequency (50.5%), but injuries seemed to be proportionate to the number of players on the ice in each position[12].

When compared to other sports, Hootman found that both men's and women's ice hockey were among the sports with the lowest rates of any injury occurring during practice; 2.0 per 1000 AEs for men and 2.5 per 1000 AEs[25]. Conversely, Melvin et al. found that the overall rate of UE injury was significantly higher in men's hockey than in women's hockey and remained higher when comparing injury rate in the preseason, regular season, and the post season among the

sexes[12]. Men had a three times higher chance compared to women of any injury in the pre- or postseason, at 149.09 and 142.73 injuries per 100,000 AEs respectively whereas women only had 52.67 and 49.01 injuries per 100,000 AEs. Men's hockey had a higher injury rate in Division I (231.51) and Division III (260.07) than women's hockey Division I (115.22) and Division III (126.82)[12].

The shoulder (n = 709, 54.4% for men and n= 121, 41.9% for women) was the most common anatomical area of injury amongst both sexes. For men, the hand followed the shoulder (n = 246, 18.9%) then finally the wrist (n = 180, 13.8%). The wrist was second for women (n = 57, 19.7%), followed by the hand (n = 55, 19%) in women. A sprain (men, 40.4%; women, 29.4%) was the most common type of injury followed by a contusion for both sexes (men, 19.9%; women, 23.2%). The third most common type was a strain for women (12.5%), and a fracture for men (9.5%). The most common mechanism of injury for both sexes was contact with an object, such as the glass, boards, goal, or another player's stick (women, 38.8%; men, 41.6%). The next-most common mechanism was body contact for both sexes (women, 24.9%; men, 38.3%), but men had a higher proportion of injury. For both the men and women, the third most common mechanism was contact with a playing surface (women, 17.3%; men, 9.7%). Women had a higher proportion of injuries sustained by non-contact, contact with the playing surface, and overuse/gradual onset[12].

In a 7-year review of men's and women's ice hockey injuries within the NCAA, Agel and Harvey found that men experienced a steady decrease in injury rates for both practices and games throughout a season, the women had higher injury rates for practices and games during the season than the preseason. The differences could be based on the use of pre-season practices by coaches. Men's hockey coaches tend to use the preseason to pick their team as the men's system has a larger

pool of players to pull from. This creates a highly competitive environment where the players need to 'prove' their toughness to the coach during the full-contact drills and scrimmages[7].

The utilization of the NCAA injury surveillance program with injury reporting by ATs was sufficient for the Melvin et al. study, but the underrepresentation of the women's game could be a limitation. It is possible that women's teams and even Division II/III teams may not have a fulltime AT providing care[12]. This could lead to a lack of reporting and even a lack of consistent treatment. Since the creation of the National Athletic Trainer's Association (NATA) in 1950, medical coverage has increased and improved for athletes in NCAA sport. From 1995 to 2005, ATs working in the collegiate setting increased by 86%[25]. This increased availability of AT's has improved injury monitoring. Data from athletic therapists and athletic trainers, including the information about the team roster will be utilized to describe injury incidence.

1.2.1 Risk Factors in Ice Hockey

There are risks that accompany participation in sport, especially when participating in contact sports like ice hockey. A risk factor is a characteristic that increases the likelihood of a person becoming injured. Protective factors are characteristics that decrease the likelihood of a person becoming injured[26]. Risk factors are classified as either intrinsic or extrinsic.

1.2.1.1 Intrinsic Risk Factors

Intrinsic factors are those individual biological and psychosocial characteristics that may predispose an athlete to injury. Intrinsic factors are characteristics like age, sex, psychology, skill level, and experience in the sport[27].

As athletes age and gain more experience within their sport, they are exposed to more activity and greater risks[28]. In contrast, De Loes and Goldie found that most injuries in any sport occurs most during adolescent and young adulthood, with the risk of injury tending to decrease with increasing age[29]. The relationship between age and injury seems to depend on the type and intensity of activity.

An athlete's psychological skills, like coping with adversity, mental preparation, peaking under pressure, and motivation, have been shown to increase sport ability. Yet, the knowledge of and implementation of these skills has a higher presence in experienced athletes. This suggests that these psychological skills are required in order to be successful within sport[30].

As athletes age and gain experience within a sport, a variety of physical skills have been acquired. More skilled athletes tend to have fewer overuse injuries, but skill level has little to no impact on the occurrence of traumatic injury. Additionally, injury severity to recreational athletes and professional athletes do not differ when the athlete is unable to return to play for more than one week, thus skill level has little to no impact on injury severity[31].

Intrinsic factors also include biomechanical factors like joint mobility, dynamic and static strength, ligamentous laxity, and muscle tightness[27]. Athletes with ligamentous laxity and joint hypermobility are at an increased risk of injury. Commonly, there is an imbalance between the agonist and antagonist muscle groups, and thus if a joint is put into an unnatural position, the surrounding muscles may struggle to protect the joint from injury[32]. Research has shown that stronger athletes are at a lower risk of getting injured[33].

Each of these factors have varying levels of importance, depending on which position the athlete plays. A goalie requires far more hip joint mobility than a forward, but forwards require

greater lower limb power capacity[34]. Forwards require speed to be considered competent at their position, but numerous other factors also impact the skill level of the athlete[35].

1.2.1.2 Extrinsic 2 Factors

Extrinsic factors are those that are independent or outside of the athlete and make up much of their physical and socio-cultural environment. Exposure to the sport, position on the team, level of competition, playing time, and protective equipment influence how an athlete competes. Their training, coaching, and refereeing also impact the athlete, just as the opponent they are competing against does. Does the team practice in the morning but is playing a game late in the evening? Endurance training should take place at the same time of day that competition is scheduled[36].

In ice hockey, there are three forwards, two defense, and one goaltender on the ice during regular play. Forwards tend to sustain the most injuries when compared to their defensive or goaltending counterparts, yet injury rates are proportional to the number of athletes in each position on the ice[12].

A difference in physical environment also changes how athletes competes; is the arena warmer or colder than what they are used to? The temperature in most arena rinks is maintained around 10°C or 50°F, but hockey athletes wear layers of protective equipment while performing repeated sprints at high skating speeds, which leads to high sweat loss volumes[37]. Thus differences in rink temperatures can impact hydration levels and may reduce aerobic performance[38].

1.2.2 Anatomical Locations Commonly Injured in Ice Hockey

In the early years of ice hockey, protective equipment was uncommon, even for the goalies. Helmets were thought to impair vision and be a greater risk factor than a protective factor and thus

were not mandated within the National Hockey League until 1979. Even with the implementation of protective equipment and rule changes ice hockey has the second highest incidence of concussion per athlete exposure at 1.20 per 1000 AEs, following only rugby at 4.18 per 1000 AEs, according to a study on concussion in youth[39]. Head and neck injuries made up nearly 40% of all injuries in ice hockey[40]. The upper body sustained approximately 22% of all injuries, with 50% of upper body injuries occurring at the shoulder. 11% of upper extremity injuries were to the wrist and the fingers sustained 25% of the upper body injuries. The lower body endured over 30% of all injuries, with the knee being the most injured sustaining 47% of all lower body injuries. The ankle and thigh followed the knee for injury rate. Only 8% of injuries in ice hockey occurred to the spine or trunk[41].

1.2.3 Types of Injuries in Ice Hockey

Ice hockey is a high speed, dynamic, and skilled sport that is played on thin blades of steel, using carbon fiber sticks to move a frozen vulcanized rubber puck around on an ice surface that is surrounded by wooden boards and tempered glass. This environment is ideal for a variety of injuries from minor injuries, such a superficial laceration to more severe injuries such as fractures and traumatic brain injuries. At the collegiate level, protective equipment includes shin, elbow, chest and shoulder pads, hockey socks and pants, a neck guard, padded gloves and groin protection. The athlete's helmet must also include a full face covering for women (such as a bubble or cage) and a visor for men, which only covers the eyes. Despite this equipment, there are still some exposed areas that are subject to injuries like contusions, abrasions, and lacerations. Joints are highly susceptible to overuse, subluxation, and traumatic dislocation injuries[42].

Morrissey et al., looked at injury trends in adult recreational ice hockey athletes that went to an emergency department over ten years (2007-2016). Lacerations were the most common diagnosis for college aged athletes at 27.9% (n = 8,750). Sprains and strains followed at 19% of all injuries (n = 5,963). Contusions and abrasions accounted for 14.2% (n = 4,456), and fractures accounted for 11.2% (n = 3,515). Concussions accounted for 10.1% of all injuries presented in emergency departments (n = 3,574), this may be due to the education of ATs in concussion assessment, leading to increased awareness of concussions. Internal organ injuries made up 6.8% of injuries (n = 2,134), followed only by dislocations (n = 1,255)[42].

When researching UE injury epidemiology in women's and men's hockey, Melvin et al., described injury types across a ten-year period (2004-2014). Women's hockey only reported 85 sprains over the ten-year period, making up 29.4% of all injuries reported. Contusions had the next highest occurrence with 67 injuries reported, 23.2% of all injuries. Strains accounted for 12.5% of injuries reported (n = 36), with only ten fewer subluxations recorded (n = 26, 9.0%). There were 20 fractures reported (6.9%) and only 7 dislocations (2.4%). Lacerations only accounted for 2.8% of injuries (n = 8) and no abrasions. Women had a greater proportion of miscellaneous injuries (n = 13, 4.5%), than that recorded by the men's team (n = 22, 1.7%)[12].

Men had the greatest proportion of sprains (n = 527, 40.4%), followed by contusions (n = 260, 19.9%) and fractures (n = 124, 9.5%). Strains accounted for 7.9% of all injuries (n = 103) and lacerations only accounted for 3.8% of injuries (n = 49). There were 25 more subluxations (n = 78) than dislocations recorded (n = 53), a nearly 2.0% difference (4.1% and 6.0% respectively). Over the ten year period, only one abrasion was recorded for men's hockey[12].

1.2.4 Injury Rates in other Collegiate Sports

Hootman et al., looked at the epidemiology of injuries in collegiate athletes across 15 sports from the late 1980s until the early 2000s. Sport to sport comparison was only focused on concussions, ankle ligament sprains, and anterior cruciate ligament, but Hootman et al., did describe the overall game and practice injury rates[25]. Men's football had the highest game injury rate at 35.9 injuries per 1000 AEs. Men's wrestling and soccer followed with rate at 26.4 and 18.8 injuries per 1000 AEs, respectively. Women's soccer had 16.4 game injuries per 1000 AEs which was nearly equal to men's ice hockey, who had 16.3 game injuries per 1000 AEs. Women's gymnastics had 15.2 injuries per 1000 AEs. Women's ice hockey and men's lacrosse were equal at 12.6 injuries per 1000 AEs[25].

Injury rates at practices were far less compared to games. Women's gymnastics had more injuries during practice than most other sports, at 6.1 injuries per 1000 AEs, following only men's spring football (9.6 per 1000 AEs). Men's wrestling had 5.7 injuries per 1000 AEs. Women's soccer had 5.2 per 1000 AEs whereas men's soccer only had 4.3 injuries per 1000 AEs. Women's and men's ice hockey had low injury rates, but women's hockey had more practice injuries than men's hockey at 2.5 per 1000 AEs and 2.0 injuries per 1000 AEs respectively[25].

Kerr et al., used the NCAA's ISS to report college sports-related injuries from 2009 to 2014[43]. Similar to the study by Hootman et al., men's football and wrestling had the highest competition injury rate with 40 and 39 injuries per 1000 AEs, respectively[25,43]. Men's hockey was the next sport with 27 injuries per 1000 AEs. Women's and men's soccer had similar injury rates with 17 and 18 injuries per 1000 AEs[43]. Interestingly, men's basketball had more competition injuries per AE (15 per 1000 AEs) in this study period, than when Hootman et al., had explored NCAA injury rates nearly 20 years prior, when men's basketball rates were only 9.9 injuries per

1000 AEs[25,43]. Women's gymnastics (13 per 1000 AEs) and men's lacrosse (14 per 1000 AEs) were the other sports to have greater competition injury rates than women's ice hockey. Women's ice hockey had a rate of 11 injuries per 1000 AEs. Women's field hockey and basketball followed with 10 injuries per 1000 AEs for both sports[43].

Just as when Hootman et al., studied NCAA injury rates, women's gymnastics had the highest rate of injuries during practice at 10 injuries per 1000 AEs, matching the rates for men's wrestling[25,43]. Men's basketball had 7 injuries per 1000 AEs, and men's football had 6 per 1000 AEs. Similar to competition injury rates, women's and men's soccer had the same practice injury rate of 5 injuries per 1000 AEs, the same rate as men's lacrosse and women's field hockey. Women's ice hockey and men's ice hockey, and all shared the same practice injury rate of 4 injuries per 1000 AEs[43].

The increase in injury rates from the late 1980s to the early 2010s can be attributed to the increase in participation in collegiate sports. In 2015, there were over 480,000 student athletes competing in the NCAA, and in 2020 there were over 500,000 student athletes.[44] With more athletes, there is a greater need for athletes to "prove" themselves and their toughness in order to making the starting lineup, keep their position in the lineup, and even to remain an active participant on a teams' roster in the following season. This increased pressure to succeed and be the best, can create a highly competitive environment, which leads to riskier play and higher intensity training, resulting in injuries.

1.3 The Public Health Model

The Public Health Model outlines a systematic, evidence-driven approach to the prevention and control of any public health issue, including injuries. The Public Health Model strives to benefit a large number of people and can be targeted towards populations or groups with health issues affecting numerous members of the community, such as concussion rates in contact sports. Input comes from health, education, social services, justice, policy, and from the private sector[26]. This integration of discipline and community leaders allows for a shift from reacting to disease and injury to addressing the causes, a core value of public health. An example of this in collegiate sports is the shift from treating injured athletes, to most universities implementing an injury prevention strategy into their athlete training programs[26].

The public health model can be used to identify what puts the populations at risk and what protects it. This can help guide focus areas for prevention efforts[26]. The public health model is an evidence based four-step process. The four steps are (1) define and monitor the problem, (2) Identify the risk and protective factors, (3) develop and test prevention strategies, and (4) assure widespread adoption[26].

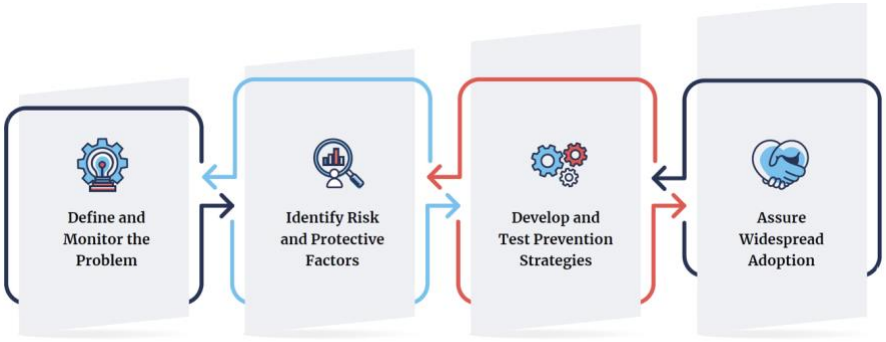

Figure 1. The Public Health Model

This study will focus on the first step of the public health model; define and monitor the problem. To define the problem, the "who, what, when, where, and how's" must be identified. In

the instance of this study, the "who" has been identified as Canadian collegiate ice hockey athletes. The "what" that will be focused on is the injury occurrence for these athletes throughout one season (the "when"). The final aspect of the first step that this study will focus on is how the injuries are occurring; as a result of body contact, non-body contact, or contact with another object/player. Without the identification and definition of these factors, it would be difficult complete the subsequent steps of the public model.

Describing the risk and protective factors is step two of the public health model. A risk factor is a characteristic that increases the likelihood of a person becoming injured, whereas a protective factor is a characteristic that decreases the likelihood of a person becoming injured or that provides a buffer against injury. Without the first step of the public health model, these factors would be useless to direct where prevention efforts need to be focused. This causes a domino effect, and the development and testing of prevention strategies are misled (step three), meaning widespread adoption is unlikely (step four).

Research has shown that altering the environment is more likely to be effective than targeting changes in individual behaviours, making this a core concept of the public health model[45]. A change in the rules of the game has a greater chance of reducing injuries and dangerous play rather than solely educating athletes to "play safer". Furthermore, when trying to solve the problem at hand, multiply strategies are needed and must be directed to towards each of the risk factors are essential[45]. For example, if the target problem is head injuries in ice hockey, there cannot only be rule changes, but also equipment adjustments, and extensive education of the athletes, coaching, and medical staff on safe play.

1.4 Study Problem, Purpose, Specific Aims, and Significance

1.4.1 Study Problem

Research is an important aspect of any injury prevention program, rule adaptations, and general wellness of athletes. In the sport of ice hockey, a limited amount of research has explored injuries to both male and female athletes, especially among women's collegiate ice hockey athletes. This narrative review will describe the epidemiology of injuries among collegiate ice hockey athletes and to build a foundation on which further research about prevention, potential interventions, and injury mitigation programs can be conducted.

1.4.2 Study Purpose

The purpose of this narrative review is to review the epidemiology of injuries and compare the incidence of injuries between Collegiate women's and men's ice hockey leagues, and with other sports.

1.4.3 Specific Aims

The aim of this study was to conduct a narrative review of literature about injuries in female and male collegiate ice hockey athletes and expanded to related research as the amount of data pertaining to women's ice hockey was limited.

Specific Aim #1: To review anatomic locations and sublocations for injuries in women's and men's ice hockey.

Specific Aim #2: To review common mechanisms of injury women's and men's ice hockey.

Specific Aim #3: To review injury types in women's and men's ice hockey.

Specific Aim #4: To review the rate of injury in women's and men's ice hockey.

Specific Aim #5: To review the rate of injury in women's and men's ice hockey compared to other contact sports.

Specific Aim #6: To review the rate of injury in women's and men's ice hockey compared to other ice-based sports.

1.4.4 Study Significance

The proposed project is needed to compare injuries between women's and men's ice hockey players. With the narration of mechanism of injury, anatomical location of injury, diagnosis of injury, incidence of injury, and the comparison of injury incidence in ice hockey with other sports, a foundation for injury prevention programs was developed. This review describes the incidence of injury across all ages, levels of play, and in both genders. Athletic Trainers/Therapists, Physiotherapists, team doctors, coaches and strength and conditioning professionals will gain insight into the extent of injuries. Knowledge about the diagnoses of injuries, the mechanism of injury, and the anatomical location will allow for comprehensive rehabilitation plans to be solidified, proper body contact education to be implemented, and injury prevention strategies to be created.

2.0 Methods

2.1 Experimental Design

A narrative review of previous literature pertaining to ice hockey injuries was performed.

2.1.1 Independent Variables

This study is a narrative review with no *a priori* hypothesis.

The independent variables observed in this study include:

- Age: youth or adult
- Gender: women's or men's
- Level of Play: youth, junior, college, international tournaments, Olympic competition or recreational
- Source of injury data: emergency department, insurance company, athletic trainer/therapist, or survey

2.1.2 Dependent Variables

The dependent variables observed in this study include:

- Incidence of injury

- Setting of the Injury: During a game, practice, training session, warm up, cool down or otherwise.
- How the injury occurred: Contact with another player (body contact), contact with the boards due to a hit, contact with the boards NOT due to a hit, contact with the puck, contact with a stick, non-contact (ie. tripping, during a workout, etc.), or otherwise
- What the location of the injury was: upper extremity, lower extremity, or concussion
- What the sublocation of the injury was: fingers/hand, wrist, forearm, elbow, shoulder/clavicle, toes/foot, ankle, lower leg, knee, thigh, hip/glute, or otherwise
- The type of injury: strain, sprain, fracture, contusion, etc.

2.2 Studies Reviewed

2.2.1 Search Strategy

All articles included in this review were found using either PubMed, Google scholar, or through the University of Pittsburgh Health Sciences Library System. A few of the articles were found by reviewing the cited references and searching for them using the University of Pittsburgh Health Sciences Library System. Search terms used to search for relevant articles included; “injuries in ice hockey”, “injuries in NCAA ice hockey”, “injuries in NCAA sports”, “incidence of injury in ice hockey”, “epidemiology of injuries in collegiate ice hockey”, “injuries in women’s ice hockey”, “injuries in men’s ice hockey”, “incidence of injuries in ice hockey”, “incidence of injury in women’s ice hockey”, “incidence of injury in women’s hockey”, “incidence of injury in women’s sports”, “epidemiology of injury in women’s hockey”, “epidemiology of injury in

women's ice hockey", "epidemiology of injury in women's sports", "incidence of injury in women's collegiate ice hockey", "incidence of injury in women's collegiate sports", "injuries in Canadian women's hockey", "injuries in Canadian men's hockey", and "injuries in Canadian ice hockey".

2.2.2 Inclusion Criteria

The following inclusion criteria were used to select relevant studies: (1) injuries sustained in the sport of hockey, (2) female or male athletes, (3) athletes participating at any level of competition, primarily those in the collegiate level, (4) original data (cross-sectional, prospective surveillance, prospective cohort, prospective observational, retrospective cohort, and retrospective comparison), (5) English language, (6) peer reviewed reports and/or articles.

2.2.3 Exclusion Criteria

Exclusion criteria was as follows: studies that focused on (1) one injury, (2) the burden of injury, (3) the psychological impact of injuries, (4) exclusively risk factors of injury, (5) performance factors, (6) the impact of title IX, (7) the effect of a treatment on return to play, (8) systematic reviews, (9) return to play criteria, (10) non-English articles (11) review articles, case studies and/or reports, experimental studies, review studies and commentaries or (12) did not provide data related to injury rates, mechanism of injury, or anatomical location of injury. Each of the papers were reviewed in full to determine if the article was relevant.

2.3 Data Processing

After reading the abstract for an article and deciding that the article could have relevant information, each article was downloaded as a PDF. The article was uploaded into the EndNote application along with the corresponding citation. This minimized the chance of mislabelling or mis-citing an article. The article was reviewed in full to determine if the information included was applicable to the topic of interest. Notes and highlights were added for the important points to refer to.

2.4 Data Analysis

The articles were reviewed in full a second time to determine if the information was relevant to one of the five subtopics: anatomical location, mechanism of injury, diagnosis of injury, incidence of injury in hockey, incidence of injury in other contact and winter sports; and that the information was reported in such a way that data could be extracted. If the article did have relevant information; the title, author, year, and population of interest was input to a excel spreadsheet in the corresponding topic of interest. This was repeated with all articles for each topic. Once in the excel spreadsheet, the data was extracted and entered into a excel table and was organized based on the topic of interest.

3.0 Results

3.1 Incidence of Injury in Ice Hockey

Table 1. Incidence of Injury in Women's Ice Hockey

Study	Year	Injury Location	Gender	Age	Duration of Study in Years	Total number of Injuries	IR/1000 AE
Tuominen et al.	2016	All	W	Over 20	8	168	6.4
Dryden et al.	2006	All	W	Adolescent and Adults	1	128	7.5
Decloe et al.	2014	All	W	Youth	1		1.9
Agel et al.	2010	All	W	College	7	767	5.12
Schick & Meeuwisse	2003	All	W	College	1	66	7.77
Soligard et al.	2015	All	W, M	Adults	1	19	11.3*

* per 100 participating athletes

3.1.1 Women's Ice Hockey

Women's ice hockey had injury rates of 5.12/1000 AEs in the NCAA[7]. Shick and Meeuwisse found that in Canadian collegiate ice hockey, women had an injury rate of 7.77/1000 AEs[9]. In women's recreational ice hockey athletes across the span of one year, there was 128 injuries and the injury rate was 7.5 injuries per 1000 AEs[46]. In youth hockey, Decloe et al., found an injury rate of 1.9 injuries per 1000 AEs in girls youth ice hockey[47],[11]. At the 2014 winter Olympic games, women's ice hockey had 19 injuries in 168 athletes and an injury rate of 11.3

injuries per 100 participating athletes[48], this is higher than at the 2010 winter Olympic games where women's ice hockey had a total of 38 injuries in 168 athletes[49].

Table 2. Incidence of Injury in Men's Ice Hockey

Study	Year	Injury Location	Gender	Age	Duration of Study in Years	Total number of Injuries	IR/1000 AE
Agel et al.	2007	All	M	College	16	6639	16.3
Tuominen et al.	2017	All	M	Under 20	9	633	11
Tuominen et al.	2015	All	M	Over 20	7	528	14.2
McKay et al.	2014	All	M	Adults	6	5184	15.6
Lorentzon et al.	1988	All	M	Adults	3		79.2
Flik et al.	2005	All	M	College	1	113	4.9
Agel et al.	2010	All	M	College	7	2828	5.95
Schick & Meeuwisse	2003	All	M	College	1	161	9.19
Soligard et al.	2015	All	M	Adults	1	32	10.7*

* per 100 participating athletes

3.1.2 Men's Ice Hockey

Shick and Meeuwisse found that in Canadian collegiate ice hockey men had an injury rate of 9.19/1000 AEs, for a total of 161 injuries in one year[9]. Men's NCAA ice hockey had the highest injury rate in the research at 16.3 injuries per 1000 athlete exposures (AEs), with a total of 6,639 injuries across 16 years[50]. Flik et al., found that in NCAA men's ice hockey, there was a total of 113 injuries with an injury rate of 4.9/1000 AEs[51]. The NHL had a total of 5,184 injuries across a six-year span, with an injury rate of 15.6/1000 AEs[52]. 633 injuries occurred in nine years in the men's world junior championships and injuries occurred at a rate of 11.0/1000 AEs[53]. 528 injuries

happened during a seven-year span with an injury rate of 14.2/1000 AEs, at men's international tournaments and Olympic competition[40,48]. Men's ice hockey had a total of 44 injuries in 276 athletes[49].

Table 3. Incidence of Injury in Ice Hockey - Both Genders Combined

Study	Year	Injury Location	Gender	Age	Duration of Study in Years	Total number of Injuries	IR/1000 AE
Melvin et al.	2018	Upper Extremity	W, M	College	10	1593	M: 1304 W: 289
Mölsä et al.	2003	Upper Extremity	W, M	All	1	760	14.8*
Forward et al.	2014	All	W, M	Youth	14	33233	
Morrissey et. al	2020	All	W, M	Adults	9	8,201	
Deits et al.	2010	All	W, M	All	16	21092	
Agel et al.	2010	All	W, M	College	7	3595	M: 5.95 W: 5.12
Krutsch et al.	2018	All	W, M	Adults	15	127	
Engebretsen et al.	2010	All	W, M	Adults	1	82	
Kujala et al.	1995	All	W, M	All	4	16,836	94†

* per 1000 player-years
† per 10000 person years of exposure

3.1.3 Women's and Men's Ice Hockey

Some studies combined injury data from women and men. In a study by Agel et al. that investigated both women's and men's ice hockey injuries, the authors noted that there were 3595 injuries in 7 years. Melvin et al. looked at upper extremity injuries and found that there were 1593 injuries to the upper extremity in men's and women's ice hockey across a 10 year span, with women's ice hockey accounting for 289 injuries and men's ice hockey accounting for 1,304 injuries[12]

In a study that observed adults who presented to emergency departments, there was a total of 8,201 injuries across the 9 years of data collection[42]. Deits et al. reported on injuries to all patients that were in the emergency department for an ice hockey injury and found that there were 21,092 injuries over 16 years, from 1990 until 2006[54]. Similarly, Forward et al. reviewed youth patients with ice hockey injuries who sought attention at an emergency department, and reported 33,233 injuries over 14 years[55].

German emergency departments reported only 127 hockey related injuries across 15 years[56]. Elite Swedish ice hockey athletes had an injury rate of 79.2/1000 AEs[57]. In Finland, Mölsä et al. looked at ice hockey injuries reported to insurance companies and found an injury rate of 14.8 per 1000 player years, with a total of 760 injuries in one year[58]. Kujala et al. looked at the national finish registry data and reported that ice hockey had rate of injury at 94 injuries per 1,000 person years of experience and had 16,836 injuries[59].

3.2 The Anatomical Location of Injury

Anatomical location of injury was categorized in a variety of different ways. Some studies report only anatomic location (e.g., head and neck, upper extremity, lower extremity, trunk, and other), whereas others describe specific sublocations). These sublocations include head, neck, face and mouth, shoulder and clavicle, elbow and wrist, hand and fingers, trunk, thigh, knee, lower leg and ankle, foot and toes, and other or unknown. The first part of this narrative will review the broad categories of anatomical sites of injuries and will be followed by a review of more specific sublocations.

Table 4. Anatomical Location of Injury

Study	Year	Population of Interest	Anatomical Location of Injury (% of all injuries)				
			Head/Neck	*Upper Extremity*	*Trunk*	*Lower Extremity*	*Other/ Unknown*
Dryden et al.	2006	Women's Recreational Ice Hockey Athletes	15.2	27.2	26.4	31.2	
Agel et al.	2007	NCAA Men's Hockey: Games	15.4	34.4	14.3	34.3	1.6
		NCAA Men's Hockey: Practices	10.3	24.9	26.4	35.9	2.5
Forward et al.	2014	Canadian Youth - Girls	28.4	39.2	10.7	23.2	0.4
		Canadian Youth - Boys	25.1	45.2	9.7	21.4	0.4

3.2.1 The Head and Neck

The head and or neck was the anatomical location for 15.2% of injuries in women's recreational ice hockey athletes[46]. In Canadian youth hockey players under the age of 18, 28.4% of injuries for girls were sustained at to the head and or neck, whereas only 25.1% of injuries for boys were sustained to the head and or neck[55]. Comparatively, for women's international tournaments and Olympic competitions, 17.2% of injuries were to the head, 11.9% to the neck, and only 3.6% to the face and/or mouth[11]. The minimal injury to the face and/or mouth can be attributed to the requirement of full-face coverage in women's hockey by means of a cage or bubble, compared to the choice of coverage in men's hockey[16].

Deits et al. looked at patients who presented to emergency departments with ice hockey injuries and found that the head was the sublocation of injury for 9.7% of injuries, the neck for 2.6% of injuries, and the mouth was the sublocation of injury for 22.4% of injuries[54]. In adults who presented to emergency departments with ice hockey injuries, the head was the location of injury for 14.8% of injuries, 1.9% the injury was to the neck, and 22.4% of injuries were to the face and/or mouth[42]. For youth who presented to emergency departments with ice hockey injuries, the head and/or neck was the location of injury for 16.3% of injuries reported, and 10% were to the face and/or mouth[60].

In NCAA men's ice hockey, 19.0% of injuries were to the head[43]. Agel et al. researched injuries that occurred in NCAA men's ice hockey and found that 15.4% of game injuries and 10.3% of practice injuries occurred to the head and or neck region[50]. For men's international tournaments and Olympic competition, injuries to the head accounted for 11.6% of injuries, the neck 6.6% of injuries, and the mouth 28.1% of injuries[40]. Another example of this is when looking

at men's world junior championships, where face and/or mouth injuries accounted for 26.2%, the neck 7.4% and the head accounted for 12.3%[53]. In the NHL, the head was the sublocation of injury for 17.0% of injuries and the neck was the location for 3.0% of injuries[52]. Krutsch et al., looked at ice hockey injuries to patients who presented to a German emergency department, and found that the head was the sublocation of injury for 19.7% of injuries, and the neck 3.1% of injuries[56].

3.2.2 The Upper Extremity

The location that had the greatest percentage of injuries was the upper extremity. Canadian youth hockey players under the age of 18 had high percentages upper extremity injuries at 45.2% of all injuries in boys and 39.2% in girls[55]. 43.8% of injuries in youth who presented to emergency departments with an ice hockey injury was classified as an upper extremity injury[60]. In NCAA men's ice hockey, 34.4% of injuries occurred to the upper extremity in the game setting and 24.9% in the practice setting[50]. For injuries that presented to a German emergency department and were classified as an ice hockey injury, 34.6% of them were to the upper extremity[56]. Dryden et al. found that the upper extremity could account for 27.2% of injuries in women's recreational ice hockey athletes[46].

3.2.3 The Trunk

Injuries to the trunk were the more common in NCAA men's ice hockey practices at percentages of 26.4% and were much lower in the game setting, at 14.3%[50]. In men's NCAA ice hockey, the trunk was the injured sublocation 9.0% of the time, and this only slightly increased in the NHL to be 11.0% of injuries[43,52]. For Canadian youth hockey players under 18 years old, boys

sustained injuries to the trunk 9.7% of the time, and girls sustained injuries to the trunk 10.7% of the time[55]. In women's recreational ice hockey athletes, the trunk was the location of injury for 26.4% of injuries[46]. On the international stage, women's and men's international tournaments and Olympic competitions showed the trunk to be injured 6.5% and 5.5%, respectively[11,40]. For men's world junior championship tournaments, the trunk was the injury sublocation of only 3.0% of injuries[53]. The trunk was the sublocation of injury for 9.3% of injuries in ice hockey athletes who presented to emergency departments, 13.8% in youth who presented to an emergency department with an ice hockey injury, 13.4% in ice hockey injuries in German emergency departments, and 9.4% of adults who presented to emergency departments with an ice hockey injury[42,54,56,60].

3.2.4 The Lower Extremity

The lower extremity was the location of injury for 35.9% of injuries in men's NCAA ice hockey practices, and 34.3% of injuries in men's NCAA ice hockey games[50]. In women's recreational ice hockey, lower extremity injuries accounted for 31.2% of injuries[46]. Forward et al. found that in Canadian youth hockey players, boys had lower extremity injuries at percentages of 21.4% and girls at 23.2% of all injuries[55]. 16.1% of injuries were to the lower extremity in youth who present to emergency departments with an ice hockey injury[60]. In German emergency departments, of injuries that were sustained during ice hockey, 29.1% of injuries were sustained to the lower extremity[56].

Table 5. General Anatomical Sublocation of Injury

Study	Year	Population of Interest	Anatomical Sublocation of Injury (% of all injuries)									
			Head	*Neck*	*Face/ Mouth*	*Shoulder/ Clavicle*	*Elbow/ Forearm*	*Wrist/ Hand/ Fingers*	*Trunk*	*Thigh/ Knee*	*Lower Leg/ Foot*	*Other/ Unknown*
Deits et al.	2010	Ice Hockey Athletes Presenting to Emergency Departments	9.7	2.6	23.0	13.8	8.1	14.1	9.3	8.0	11.1	0.3
Hostetler et al.	2004	Youth Emergency Department visits	16.3		10	43.8			13.8	16.1		-
Krutsch et al.	2018	Injuries at a German Emergency Department	19.7	3.1	-	34.6			13.4	29.1		-
Kerr et al.	2005	NCAA Men's Hockey	19	-	-	15	-	7	9	9	12	7

Table 6. Specific Anatomical Sublocation of Injury

Study	Year	Population of Interest	Anatomical Site of Injury (%)											
			Head	*Neck*	*Face/ Mouth*	*Shoulder/ Clavicle*	*Elbow/ Forearm*	*Wrist*	*Hand/ Fingers*	*Trunk*	*Thigh*	*Knee*	*Ankle/ Lower Leg*	*Foot/ Toes*	*Other/ Unknown*
Morrissey et. al	2020	Adults presenting to Emergency Departments	14.8	1.9	22.4	14.0	4.0	4.0	4.3	9.4		5.1	7.8	1.8	10.5
Tuominen et al.	2015	Men's international tournaments & Olympics	11.6	6.6	28.1	11.2	2.3	2.5	5.9	5.5	4.2	14.4	4.7	3.0	
Tuominen et al.	2016	Women's international tournaments & Olympics	17.2	11.9	3.6	7.1	6.0	4.2	4.8	6.5	3.6	20.8	12.5	1.8	
Tuominen et al.	2017	Injuries at the men's world junior championships between 2006-2015	12.3	7.4	26.2	16.7	3.2	2.4	6.5	3.0	5.2	7.9	7.0	2.2	
McKay et al.	2014	NHL injuries	17	3		16	3	2	7	11	14	13	8	6	

3.2.5 The Shoulder and Clavicle

The shoulder and/or clavicle was the sublocation of injury for 16.7% of injuries at the men's worlds junior championships between 2006 and 2015[53]. In the NCAA men's ice hockey league, the shoulder and/or clavicle was the injury sublocation for 15.0% of injuries[43], and was only slightly higher at 16.0% of injuries in the NHL[52]. At the men's international tournaments and Olympic competition, the shoulder and/or clavicle was the sublocation of 11.2% of injuries[40], whereas for women's international tournaments and Olympic competition the shoulder and/or clavicle was the sublocation for only 7.1%[11]. Morrissey et al. looked at adults presenting to emergency departments and found that 14.0% of injuries were to the shoulder and/or clavicle[42]. The shoulder and/or clavicle was the sublocation of 13.8% of injuries in ice hockey athletes that presented to emergency departments[54].

3.2.5.1 The Elbow and Forearm

Injuries to the elbow and/or forearm are uncommon, with percentages under 8.1% across all the research reviewed. Injuries to the elbow and/or forearm occurred in 8.1% of injuries in athletes who presented to emergency departments with ice hockey injuries[54]. In adults that presented to emergency departments with ice hockey injuries, injuries to the elbow and/or forearm made up only 4.0% of all injuries reported[42]. In the NHL, the elbow and/or forearm was the location for 3.0% of injuries and the location for 3.2% of injuries at the men's world junior championships from 2006 to 2015[52,53]. At women's international tournaments and Olympic competition, 6.0% of injuries were to the elbow and/or forearm, compared to only 2.3% of injuries at men's international tournaments and Olympic competition[11,40].

3.2.5.2 The Hand, Wrist, and Fingers

The wrist was the location of injury for 4.0% of injuries in adults who presented to emergency departments, and the hand and/or fingers was the sublocation of injury for 4.3% of injuries[42]. According to Deits et al., 14.1% of ice hockey injuries that presented to emergency departments occurred to the wrist, hand and/or fingers[43]. Within NCAA men's ice hockey 7.0% of injuries occurred to the wrist, hand and/or fingers[43,54]. In the NHL, 2.0% of injuries were to the wrist and 7.0% of injuries to the hand and/or fingers[52]. For athletes competing at the men's world junior championships, 2.4% of injury sublocations were at the wrist, and 6.5% at the hand and/or fingers[53]. 4.2% of injuries at women's international tournaments and Olympic competitions were to the wrist, and 4.8% to the hand and/or fingers[11]. For men's international tournaments and Olympic competitions, the sublocation of injury was at the wrist 2.5% of the time, and to the hand and/or wrist 5.9% of the time[40].

3.2.5.3 The Thigh and Knee

Of injuries in ice hockey athletes who presented to emergency departments, 8.0% of injuries occurred at the thigh and/or knee whereas 11.1% of injuries were at the lower leg and/or foot[54]. Of adults who presented to emergency departments with ice hockey injuries, the knee was injured in 5.1% of injuries[42].

For women's international tournaments and Olympic competition, the thigh was the injured sublocation in 3.6% of injuries, and the knee was the injured sublocation in 20.8% of all injuries reported[11]. The thigh was the injured sublocation of 4.2% of injuries reported at the men's international tournaments and Olympic competition. The knee was injured more often in men's international tournaments and Olympic competition and made up 14.4% of injuries sustained[40]. In

the men's world junior championships between 2006 and 2015, the knee was the sublocation of 7.9% of injuries and the thigh was the injured sublocation in 7.9% of injuries[53].

In elite level ice hockey athletes, specifically in NHL players, the thigh was the injury sublocation for 14.0% of injuries and the knee was the location of 13.0% of injuries[52]. Kerr et al. found that in NCAA men's ice hockey the thigh and/or knee was the injured sublocation of 9.0% of injuries reported and the lower leg and/or foot was the injured of 12.0% of injuries[43].

3.2.5.4 The Lower Leg and Ankle

For women's international tournaments and Olympic competition, the ankle and/or lower leg was the sublocation of injury in 12.5% of all injuries reported[11]. On the men's side, 4.7% of injuries occurred to the ankle and/or lower leg[40]. Seven percent of all injuries recorded at the men's world junior championships were at the ankle and/or lower leg[53]. Injury to the ankle and/or lower leg was only slightly more common in the NHL, with percentages of 8.0%[52]. In adults who presented to emergency departments with ice hockey injuries, the ankle and/or lower leg was the injured sublocation in 7.8% of those reported[42].

3.2.5.5 The Foot and Toes

Foot and toe injuries were reported to be uncommon, with percentages below 6.0%. Foot and toe injuries were most common in the NHL at 6.0% of injuries reported[52], followed by 3.0% of injuries reported in men's international tournaments and Olympic competition[40]. At the men's world junior championship between 2006 and 2015, the foot and toes were the injured sublocation in 2.2% of all injuries[53]. 1.8% of injuries in women's international tournaments and Olympic competition and in adults who presented the emergency department with an ice hockey injury, occurred in the foot or toes[11,42].

3.3 The Diagnosis of Injury

Table 7. The Diagnosis of Injury

Study	Year	Population of Interest	Diagnosis of Injury (%)								
			Laceration	*Contusion/ Abrasion*	*Fracture*	*Sprain/ Strain*	*Concussion*	*Dislocation/ Subluxation*	*Other/ Unknown*	*Dental Injury*	*Internal Organ Injury*
Deits et al.	2010	Ice Hockey Athletes Presenting to Emergency Departments	27	23.6	17.3	16.9	7.0	2.7	5.1	0.3	
Morrissey et. al	2020	Adults presenting to Emergency Departments	26.4	13.5	14.7	17.7	7.0	4.9	9.2		6.6
Tuominen et al.	2015	Men's international tournaments & Olympics	26.1	15.0	14.0	21.8	9.9		13.2		
Forward et al.	2014	Canadian Youth - BoysMale:	5.8	32.6	27.1	17.6	14.5	2.4	3.8		
Tuominen et al.	2017	Injuries at the men's world junior championships between 2006-2015	24.0	22.0	10.0	18.0	10.0	~7.0	9.0		
Melvin et al.	2018	UE injuries in NCAA men's hockey	3.6	20.5	9	47.1		10.3	9.4		
Lorentzon et al.	1988	Injuries in Elite Swedish Hockey Players	2.6	32.9	13.2	32.9	5.3		8.1		
Lorentzon et al. 2	1988	A comparison of injuries in international and Swedish hockey players	5.3	36.8	10.5	47.4					
Hostetler et al.	2004	Youth Emergency Departments visits	15.3	26.9	17.5	17.3	14.1		8.9		

Table 8. Diagnosis of Injury in Women's Ice Hockey

Study	Year	Population of Interest	Diagnosis of Injury (%)								
			Laceration	*Contusion/ Abrasion*	*Fracture*	*Sprain/ Strain*	*Concussion*	*Dislocation/ Subluxation*	*Other/ Unknown*	*Dental Injury*	*Internal Organ Injury*
Tuominen et al.	2016	Women's international tournaments & Olympics	5.4	28.0	6.5*	32.7	15.5	7.0†	4.0‡		
Forward et al.	2014	Canadian Youth - Girls:	2.4	39.8	18.2	21.1	17.8	1.7	3.5		
Dryden et al.	2006	Women's Recreational Athletes		30.4	2.4	52	5.6	0.8	8.8		

* Date pulled from figure.
† Date pulled from figure.
‡ Date pulled from figure.

3.3.1 Contusions and Abrasions

Contusions and abrasions together make up the highest percentage of all injuries sustained in ice hockey. Dryden et al. looked at women's recreation hockey athletes and showed that contusions/abrasions made up of 30.4% of all injuries[46]. In youth athletes, athletes under the age of 18 years old, who presented to an emergency department and were recorded to have a hockey injury, contusions/abrasions made up 26.9%[60]. Among injuries that were recorded at the men's world junior championships between 2006-2015, contusions/abrasions accounted for 22.0% of injuries, and lacerations made up 24.0%[53]. So, while most studies show that contusions/abrasion are the most common injury type, there are a few studies that reported that other injuries are more frequent.

3.3.2 Lacerations

Lacerations occurred more often than contusions and abrasions in patients with ice hokcey injuries that presented to US emergency departments; 27% for lacerations compared to 23.6% for contusions and abrasions[54]. Similarly, Tuominen et al. found, that when looking at men's ice

hockey at international tournaments and Olympic competitions, lacerations were more common than contusions/abrasions (26.1% and 15.0% respectively)[40]. In research by Morrissey et al., lacerations occurred more often than contusions and abrasions, with the percentage of lacerations being 26.4% and 13.5% for contusions/abrasions[42]. Interestingly, when Tuominen et al. looked at women's international tournaments and Olympic competitions, contusions/abrasions were more

common than lacerations which had a percentage of 5.4%[11]. Yet, Melvin et al., Forward et al., and Lorentzon et al. reported that lacerations were the least common injury, with percentages of 3.6%, 2.4% for girls and 5.8% for boys, and 5.3%, respectively.[12,55,61].

3.3.3 Fractures

The percentage of fractures ranges from 10-20% of all injuries. In Canadian youth under the age of 18 years old, over 27% of injuries affecting boys were fractures while about 18% of injuries affecting girls were fractures[60]. When looking at research that can compare women's and men's players, fractures, were significantly lower in women's ice hockey at ~6.5% than in men's ice hockey of 14%[11,40]. Dryden et al. explored injuries in Canadian women's recreational ice hockey athletes and fractures had percentages of only 2.4%[46]. Similarly, when Tuominen et al. looked at women's international tournaments and Olympic competitions, fracture percentages were around 6.5%[11].

3.3.4 Sprains and Strains

Sprain and strain percentages were shown to be highest in the study of elite international

hockey players by Lorentzon et al. at 47.4%[61]. Melvin et al. provided similar percentages at 47.1% although Melvin et al. explored injuries sustained to the upper extremity, thus strains and sprains at percentages of nearly half of all injuries sustained was logical, especially since AC joint sprains and wrist sprains were in the top 5 injuries for both the women's and men's side[12]. When Tuominen et al. looked at women's international and Olympic competition, sprains and strains were reported

at percentages of 32.9% of all injuries sustained[11]. This could be considered high, since most other research show sprain/strains at percentages closer to 16.9-21.8%[40,42,46,53-55,60].

3.3.5 Concussions

Concussions are a topic that is researched and discussed often. Of all hockey injuries presented to emergency departments, for both youth and adults, concussions had percentages of around 7% of all injuries recorded[42,54]. There was only one group of hockey players that had lower concussion percentages; women's recreation hockey athletes where the percentage of concussions were only 5.6% of all injuries sustained[46]. One reason for this might simply be due to the lack of medical coverage at recreational games. Without this support, it is unknown how many concussions are never diagnosed and treated. Conversely, for the women's international and Olympic competition, concussion percentages were around 15.5%[11]. At the men's world junior tournaments, from 2006-2015, concussions made up 10% of all injuries sustained and this only slightly decreased at the adult competition[53]. At the men's international and Olympic competition level, concussion percentages were at nearly 10%[40]. This difference concussion percentages between women's and men's ice hockey are also reflected in youth hockey. Girls had concussion percentages of 17.8%, yet the boys had percentages near 14.5%[55]. Hostetler et al. found that

concussions for 14.1% of youth hockey injuries that presented to emergency departments[60].

3.3.6 Dislocations and Subluxations

Dislocations and subluxations could be considered rare, as most studies present percentages below 5.0% of all injuries sustained. In women recreational ice hockey athletes, dislocations/subluxations only accounted for 0.8% of injuries reported[46]. International tournaments and Olympic competition for women, dislocations/subluxations made up around 7.0% of all injuries, which was the same as at the men's world junior championships[11,53]. In Canadian youth hockey players, girls experienced dislocations/subluxations at percentages of 1.7% and boys at percentages of 2.4%[55]ice hockey athletes presenting to emergency departments, dislocations/subluxations account for only 2.7% of injuries recorded, yet for exclusively adults the percentage is closer to 4.9%[42,54]. Melvin et al., looked at injuries sustained only to the upper extremity, and so it would make sense that dislocations/subluxations would represent a higher percentage of injuries; 10.3%[12].

3.3.7 Other and Unknown

Dental injuries make up only 0.3% of all injuries[54]. Morrissey et al. found that 6.6% of all injuries could be accounted internal organ injuries[42]. At the men's international tournaments and

Olympic competition, the category of other/unknown made up 13.2% of all injuries[40]. For upper extremity injuries in the NCAA, Melvin et al., found that other/unknown could account for 9.4% of injuries[12]. Similar numbers were shown for adults who presented to emergency departments, at 9.2% of all ice hockey injuries[42], for youth, under the age of 18 years old who present at emergency departments at 8.9%[60], and for all hockey athletes presenting to emergency departments (5.1%)[54].

For men's world junior championship other and unknown made up 9.0% of all injuries recorded[40]. Forward et al., reported other/unknown at 3.5% for girls and 3.8% for boys[55]. For women's international tournaments and Olympic competition, other/unknown accounted for around 4.0% of all injuries[11], but for recreation athletes the percentages were higher, at 8.8%[46].

3.4 The Mechanism of Injury

Table 9. The Mechanism of Injury in Ice Hockey

Study	Year	Population of Interest	Mechanism of Injury (%)										
			Fall	*Contact with Boards*	*Contact with Stick*	*Player-Player Contact*	*Contact with Puck*	*Contact with Skate*	*Other/ Unknown*	*Acute Non-contact*	*Contact with Apparatus*	*Contact with playing surface*	*Overuse*	*Fighting*
Morrissey et. Al	2020	Adults with Ice Hockey Injuries Presenting to an Emergency Department	20.2	7.7	7	16.8	15.5	3.4	29.3					
Melvin et al.	2018	Upper Extremity Injuries in NCAA							5.0	3.9	41.7	11.1	3.1	
Deits et al.	2010	Patients with Ice Hockey Injuries Presenting to an Emergency Department	16.5	13.6	13.0	11.5	10.5	3.7	31.1					
Lorentzon et al.	1988	Injuries in Elite Swedish Hockey Athletes	6.6	6.6	11.8	57.9	14.5	2.6						

Table 11. The Mechanism of Injury in Women's Ice Hockey

Study	Year	Population of Interest	Mechanism of Injury (%)										
			Fall	*Contact with Boards*	*Contact with Stick*	*Player-Player Contact*	*Contact with Puck*	*Contact with Skate*	*Other/ Unknown*	*Acute Non-contact*	*Contact with Apparatus*	*Contact with playing surface*	*Overuse*	*Fighting*
Forward et al.	2014	Canadian Youth - Girls	25.3			54.3			20.4					
Dryden et al.	2006	Women's Recreational Ice Hockey Athletes	7.2	20	16	40	7.2			9.6				
Tuominen et al.	2016	Women's International Tournaments & The Olympics				24.6	12.0		26.3					

Table 10. The Mechanism of Injury in Men's Ice Hockey

Study	Year	Population of Interest	Mechanism of Injury (%)										
			Fall	*Contact with Boards*	*Contact with Stick*	*Player-Player Contact*	*Contact with Puck*	*Contact with Skate*	*Other/ Unknown*	*Acute Non-contact*	*Contact with Apparatus*	*Contact with playing surface*	*Overuse*	*Fighting*
Agel et al.	2007	NCAA Men's Hockey		21.6	6.4	47.7	7		1.1	9.3	1.1	5.9		
Tuominen et al.	2017	Injuries at the Men's World Junior Championship Tournaments between 2006-2015			13.0	32.0	13.0							
McKay et al.	2014	Injuries in the NHL		4.6		50.3	13.5		10.6	14.8		2.7		3.6
Kerr et al.	2005	NCAA Men's Hockey	6	18.6	1.8	36.3	6.2	3.5	18.7				8	
Forward et al.	2014	Canadian Youth - Boys	14.8			67.4			17.8					

3.4.1 Player-to-player Contact

Across the research, player-to-player contact seems to be the most common mechanism of injury. For women's recreational ice hockey, player-to-player contact was the mechanism of 40% of the reported injuries[46]. In Canadian youth hockey athletes under the age of 18 that presented to emergency departments, player-to-player contact could account for 54.3% of injuries for girls and 67.4% of injuries in boys[55]. Yet, when looking at women's and men's international tournaments and Olympic competitions, both leagues recorded similar proportions for player-to-player contact as the mechanism of injury, at 24.6% and 27.2% [11,40].

When looking at all patients who presented to an emergency department with a hockey injury, player-to-player contact could only account for 11.5% of the mechanisms[54], whereas when looking exclusively at adults who presented to an emergency department with a hockey injury, player-to-player contact could account for 16.8% of mechanisms[42]. As previously stated, the slight differences in percentages can most likely be attributed to the difference in body checking rules at different age levels.

In elite Swedish and international hockey athletes, player-to-player contact was the mechanism of injury for 73.7% of injuries[61]. In NCAA men's ice hockey, Kerr et al. recorded percentages at 36.3% for player-to-player contact[43], but Agel et al., recorded percentages of 47.7[50].

These proportions are similar to those seen at the men's world junior championships which recorded player-to-player contact as the mechanism of injury for 32.0% of injuries[40]. Lorentzon et al., found that in elite Swedish athletes, player-to-player contact was the cause for 57.9% of

injuries[57]. When looking at the National Hockey League (NHL), McKay et al., reported that 50.3% of injuries could be attributed to player-to-player contact[52].

3.4.2 Contact with the Boards

Due to the nature of the sport, and the culture of body checking within hockey, one might think that contact with the boards would be a common mechanism of injury. Contact with the boards could only account for 4.6 – 21.6% of mechanisms, dependent on the level of play. In NCAA men's ice hockey, Agel et al. found that contact with the boards was the mechanism responsible for 21.6% of injuries[50] and Kerr et al., found proportions slightly lower at 18.6%[43]. Similar percentages of player-to-player contact injuries were seen in women's recreational hockey players, Dryden et al., found that contact with the boards could account for 20% of injuries, one of the highest found the research[46]. Contact with the boards accounted for 13.6% of injuries in patients who present to emergency departments with ice hockey injuries[54], but only 7.7% in exclusively adults who presented to the emergency department with ice hockey injuries[42]. In the professional side of ice hockey, contact with the boards was the mechanism of injury for 4.6% of injuries in the NHL[52], and 6.6% in elite Swedish ice hockey athletes[57].

3.4.3 Contact with a Puck

Contact with a puck was responsible for 5.3 – 15.5% of injuries in ice hockey. Women's ice hockey athletes in a recreational league found that puck contact made up 7.2% of injuries[46]. Tuominen found that contact with the puck represented similar percentages when looking at women's and men's international tournaments and Olympic competitions, as well as the men's world junior championships. Contact with the puck made up 12.0% of injuries in the women's competitions but represented 12.3% for the men's competition[53,59]. For injuries at the world junior

championship tournaments, puck contact could account for 13.0% of injuries[53]. McKay et al., looked at injuries in the NHL and found that puck contact could explain 13.5% of injuries[52].

For injuries when comparing elite international ice hockey athletes from Sweden to other international athletes, contact with a puck could account for 5.3% of all injuries reported[56]. Lorentzon et al., also looked at just elite Swedish ice hockey players, and saw that puck contact causes 14.5% of injuries[57]. In the NCAA men's ice hockey league, Agel et al. reported that contact with a puck could account for 7.0%[50], whereas Kerr et al., found the percentage to be lower at 6.2%[43]. When looking at patients who presented to emergency departments with ice hockey injuries, puck contact caused 10.5% of injuries[54]. Yet, when Morrissey et al. looked exclusively at adults, 15.5% of injuries could be attributed to contact with the puck[42].

3.4.4 Contact with Skates

Seeing as ice hockey is a sport played on metal blades, injuries due to contact with skates are not very common. Within the NCAA, skate contact only accounts for 3.5% of injuries[52]. Adults who presented to emergency departments with ice hockey injuries had similar percentages, at 3.4%[42], yet when looking at all patients who reported to emergency departments due to an ice hockey injury, Deits et al., reported that skate contact accounted for 3.7%[54]. International elite ice hockey athletes could contribute 5.3% of their injuries to skate contact[61], but when looking at exclusively Swedish ice hockey athletes, contact with a skate counted for percentages of 2.6%[57].

3.4.5 Contact with a Stick

Contact with a stick could account for 13.0% of injuries at the men's world junior championship but 21.2% of injuries at men's international tournaments and Olympic competitions[40,53]. On the international stage, in Swedish ice hockey players, contact with a stick made up 11.8% of injuries[57]. For adults who presented to emergency departments, stick contact made up only 7.0% of injuries, yet for all patients who presented to emergency departments with ice hockey injuries, stick contact made up 13.0%[42,54]. In the NCAA, the research credits 1.8 – 6.4% of injuries to contact with a stick[43,50]. Dryden et al. found that in women's recreational ice hockey athletes, stick contact accounts for 16.0% of all injuries reported[46].

3.4.6 Falls

Falls could be credited for 20.2% of injuries in adults who presented to emergency departments with ice hockey injuries[42], but only 16.5% in Deits et al.'s research into all patients who presented to emergency departments with ice hockey injuries[54]. In Canadian youth hockey players under the age of 18, girls ice hockey players had 25.3% of all injuries attributed to falls and boys had only 14.8%[55]. 7.2% of all injuries in women's recreational athletes could be credited to falls[46]. In the NCAA, falls could account for only 6.0% of injuries in men's ice hockey[50]. Similarly, Lorentzon et al. looked at elite Swedish hockey players and found that falls were responsible for 6.6% of injuries reported[57].

3.4.7 Contact with an Apparatus

Melvin et al., credited contact with an apparatus for 41.7% of injuries to the upper extremity in NCAA ice hockey[12], whereas Agel et al. found that contact with an apparatus only accounted for 1.1% of all injuries[50]. Melvin et al. did attribute 11.1% of upper extremity injuries to contact with the playing surface, and this is unclear if this includes the boards, glass, and/or ice[12]. Similarly, McKay et al. found that contact with the playing surface accounted for 2.7% of injuries in the NHL[52]. Contact with the playing surface made up 5.9% of injuries in NCAA men's hockey, according to Agel et al.[50]. Overuse was responsible for 8.0% of injuries in NCAA men's ice hockey[43], and 3.1% in upper extremity injuries the NCAA[12]. McKay found that fighting was the cause of 3.6% of injuries in the NHL[52].

3.4.8 Acute Non-Contact, Other, and Unknown

Acute non-contact injuries made up 14.8% of injuries in the NHL, 9.3% in men's NCAA ice hockey, 9.6% in women's recreational ice hockey, and 3.9% of upper extremity injuries in NCAA women's and men's ice hockey[12,46,50,52]. Finally, other/unknown was the mechanism of injury for 29.3% of injuries in adults who presented to emergency departments with ice hockey injuries[42]. Similarly, Deits et al. found that 31.1% of all injuries could be attributed to other/unknown for all patients presenting to emergency departments with ice hockey injuries[54]. For women's international tournaments and Olympic competitions, other/unknown was the mechanism of injury for 26.3% of injuries[11]. Canadian ice hockey athletes under the age of 18 had percentages of 20.4% for girls and 17.8% for boys[55]. In the NHL, 10.6% of injuries were categorized as other/unknown, which is one of the lower percentage in the research[52].

Unknown/other was the mechanism of injury recorded for 18.7% of injuries in NCAA men's ice hockey according to Agel et al.[50]

3.5 Ice Hockey Injury Rates Compared to Other Contact Sports

Table 12. Injury Rates in Other Collegiate Sports

Study	Year	Population of Interest	Sport	Game Injury Rate per 1000 AEs	Practice Injury Rate per 1000 AEs
Kerr et al.*	2015	Injuries in college sports	Men's football	40	
			Men's Wrestling	38	
			Men's Ice Hockey	27	
			Men's Basketball	15	
			Men's Soccer	18	
			Women's Soccer	17	
			Women's Field Hockey	11	
			Women's Ice Hockey	12	
			Women's Gymnastics	13	
			Women's Basketball	11	
Hootman et al.	2007	Injuries in college sports	Men's football	35.9	3.8
			Men's Wrestling	26.4	5.7
			Men's Ice Hockey	16.3	2.0
			Men's Soccer	18.8	4.3
			Women's Soccer	16.4	5.2
			Women's Field Hockey	7.9	3.7
			Women's Gymnastics	15.2	6.1
			Women's Ice Hockey	12.6	2.5
			Women's Basketball	7.7	4

* Data from this study was estimated based off a figure.

3.5.1 Women's contact sports in a collegiate setting

In women's sports, women's soccer had the highest game injury rate at 16.4 injuries per 1000 athlete exposures, yet in the practice setting, women's soccer had rates of 5.2/1000 AEs[25]. In another study looking at American collegiate sports, women's soccer had the highest game injury rate with approximately 17 injuries per 1000 athlete exposure, but only had a practice injury rate of about 5 injuries per 1000 AEs[43]. The sport with the next highest injury rates, was a non-contact sport, but had higher rates than the other women's sports so it was included here. Women's gymnastics had a game injury rate of 15.2/1000 AEs and, in the practice, setting women's gymnastics had an injury rate of 6.1/1000 AE[25]. According to Kerr et al. women's gymnastics had high practice injury rates at about 10/1000 AEs but had game injury rates lower than women's soccer at around 13 injuries per 1000 AEs[43].

In a study by Hootman et al., women's field hockey had a lower game injury rate than women's ice hockey, at 7.9/1000 AEs compared to 12.6 injuries per 1000/AEs, yet women's field hockey had a higher practice injury rate. The rate for injury in women's field hockey practice was 3.7/1000 AEs, whereas the practice injury rate for women's ice hockey was only 2.5/1000 AEs[25]. According to Kerr et al., women's ice hockey had a high game injury rate at approximately 12/1000 AEs but a low practice injury rate with only about 4 injuries per 1000 AEs[43]. Additionally, women's field hockey and women's basketball had identical game and practice injury rates. The game injury gate for both sports was around 11 injuries per 1000 AEs and the practice rate was around 5 injuries per 1000 athlete exposures[43]. Hootman et al. found the trend of lower injury rates in practices when compared to games was similar in women's basketball. The practice injury rate was lower that the game injury rate at 4.0/1000 AEs compared to 7.7 per 1000 athlete exposures[25].

3.5.2 Men's contact sports in a collegiate setting

Hootman et al. reported on injuries that occurred in the collegiate sport setting, and men's football, had a game injury rate of 35.9/1000 AEs and a practice injury rate of 3.8/1000 AEs[25], yet Kerr et al. found rates to be higher at 40 injuries per 1000 athlete exposures and practice injury rates at around 6/1000 AEs[43]. Krutsch et al. found that American football had the lowest number of injuries at only 49 injuries reported in German emergency departments[56]. Kerr et al. found that men's wrestling had the highest practice injury rates at rates near 10/1000 AEs and followed closely behind men's football with game injury rates near 38/1000 AEs[43]. These rates are much higher than what Hootman et al. described. Men's wrestling had a game injury rate at 6.4/1000 AEs yet had a practice injury rate of 5.7/1000 AEs[25].

Men's soccer had a higher injury rate in the game setting, with rates at 18.8 and but lower in the practice setting at 4.3 per 1000 AEs[25]. Men's soccer had a game injury rate of around 18 injuries per 1000 AEs and had a high practice injury rate at about 5 injuries per 1000 AE[43]. According to Kerr et al. men's basketball has practice injury rates higher than both men's soccer and men's ice hockey at around 7/1000 AEs, but had a lower game injury rate of 15/1000 AEs[43], yet for Hootman et al. men's basketball had a practice injury rate with 1.9/1000 AEs but had a much lower game injury rate of 9.9/1000 AEs[25].

Table 13. Injury Rates in Other Sports

		Olympic Games 2014	Men's Ice Hockey	10.7	32
			Women's Figure Skating	13.5	10
			Men's Figure Skating	13.3	10
			Women's Speed Skating	3.6	3
			Men's Curling	14	7
Engebretsen et al.	2010	Injuries and Illnesses at the Winter Olympic Games 2010	Women's Ice Hockey		38
			Men's Ice Hockey		44
			Women's Figure Skating		12
			Men's Figure Skating		9
			Women's Speed Skating		5
			Men's Curling		4
Kujala et al.	1995	Injuries in Finland[2]	Soccer	89	26330
			Volleyball	60	5,235
			Judo	117	1,163
			Basketball	88	3,472
			Karate	142	1,150
Krutsch et al.	2018	Injuries presenting to a German Emergency Departments	Soccer		2762
			Volleyball		413
			Basketball		363
			Team Handball		156
			American Football		49

[1] per 100 participating athletes
[2] per 10000 person years of exposure

3.5.3 Other Winter sports on Ice

Engebretsen et al. recorded injuries at and illnesses at the 2010 winter Olympic games. On ice sports other than ice hockey, had much lower injury numbers, but also had a lower number of athletes. Women's figure skating had a total of 12 injuries in 73 athletes and men's figure skating had only 9 injuries in 73 athletes. Women's speed skating only reported 5 injuries in 83 athletes, but no data was recorded for the 93 men's speed skaters. Men's curling had 4 injuries in 50 athletes, but no data was recorded for the 50 women's curlers[49].

Similar to Engebretsen et al., Soligard et al. looked at injuries and illnesses at the 2014 winter Olympic games. Injury rates were reports as per 100 participating athletes, instead of the typical per 1000 athlete exposures. Figure skating had higher injury rates with women's figure skating reporting a rate of 13.5 injuries per 100 participating athletes and men's figure skating reporting a rate of 13.3 injuries per 100 participating athletes, yet both women's and men's figure skating only had 10 injuries each in 74 and 75 athletes respectively. Women's speed skating had only 3 injuries in 83 athletes with a injury rate of only 3.6 injuries per 100 participating athletes. Men's speed skating had 5 injuries in 94 athletes, with an injury rate of 5.3 injuries per 100 participating athletes. Men's curling had 7 injuries in 50 athletes for an injury rate of 14 injuries per 100 participating athletes, whereas women's curling had 5 injuries in 50 athletes for an injury rate of 10 injuries per 100 participating athletes[48].

3.5.4 Other Sports with High risk of Injury

On the international stage, Kujala et al. looked at injuries reported to the national insurance registry in Finland to both genders. Karate has the highest injury rate at 142 injuries per 1,000 person years of exposure. Karate had a total number of 1,150 injuries. Judo had a greater number of injuries with 1,163 injuries, but only had an injury rate 142 injuries per 1,000 person years of exposure. Soccer had the highest number of injuries with 26,330 injuries reported. Furthermore, Krutsch et al. reported on injuries that presented to German emergency departments and found that soccer had the highest number of injuries at 2,762 injuries, followed by volleyball with 413 injuries[56]. In the data presented by Kujala et al. volleyball had the lowest injury rate of only 60 injuries per 1,000 person years of exposure but had a total of 5,235 injuries. Basketball had a total of 3,472 injuries reported and an injury rate of 88 injuries per 1,000 person years of exposure[59]. Team handball had a total of 363 injuries and ice hockey had 127 injuries[56].

3.6 Comparison of Injuries in Women's and Men's Collegiate Ice Hockey

In the United States, women's ice hockey had injury rates of 5.12/1000 AEs in the NCAA[7], but men's ice hockey in the NCAA had the highest injury rate in the research at 16.3 injuries per 1000 AEs[50]. In Canadian collegiate ice hockey, women had an injury rate of 7.77/1000 AEs and once again, men had higher injury rates at 9.19/1000 AEs[9]. Flik et al., found that in the NCAA men's ice hockey, had an injury rate of 4.9/1000 AEs[51].

In NCAA men's ice hockey, 19.0% of injuries were to the head[43]. Agel et al. looked at injuries that occurred in NCAA men's ice hockey and found that 15.4% of game injuries and

10.3% of practice injuries occurred to the head and or neck region[50]. There was no data found for women's NCAA ice hockey.

Melvin et al., looked at injuries sustained only to the upper extremity. Men's ice hockey had higher percentages for injuries to the AC joint (29.1% for men, but only 13.8% for women), yet had smaller percentages for hand and finger contusions, wrist sprains, and anterior subluxation. Hand and finger contusions were showed at 8.0% for women and only 6.1% for men. Sprained wrists accounted for 8.7% of women's ice hockey upper extremity injuries but only 5.7% in men's. Anterior subluxation was the diagnosis of injury for 4.8% of upper extremities injuries in women's ice hockey, and 3.7% for men's ice hockey[12].

In men's NCAA ice hockey, the trunk was the injured sublocation 9.0-27% of the time[50]. There was no data for NCAA women's ice hockey. The lower extremity was the location of injury for approximately 35.% of injuries in men's NCAA ice hockey[50]. There was no data recorded for NCAA women's ice hockey. In NCAA men's ice hockey 7.0% of injuries occurred to the wrist, hand and/or fingers[43,54]. There was no data recorded for NCAA women's ice hockey.

In NCAA men's ice hockey, 36-47% of injuries could be attributed to player-to-player contact[43,50]. No data was recorded for women's NCAA ice hockey. In NCAA men's ice hockey, contact with the boards was the mechanism responsible for 18-21% of injuries[43,50]. There was no data recorded for NCAA women's ice hockey In the NCAA men's ice hockey league, Agel et al. reported that contact with a puck could account for 6.0-7.0%[43,50]. There was no data recorded for NCAA women's ice hockey. In NCAA men's ice hockey, the research credits 1.8 – 6.4% of injuries to contact with a stick[43,50]. There was no data recorded for NCAA women's ice hockey. In the NCAA, falls could account for only 6.0% of injuries in men's ice hockey[50]. There was no data recorded for NCAA women's ice hockey. Contact with an apparatus for 41.6% of injuries to the

upper extremity in NCAA men's ice hockey, and 38.8% of injuries to the upper extremity in NCAA women's hockey[12].

Contact with the playing surface made up 5.9% of injuries in NCAA men's hockey[50]. There was no data recorded for NCAA women's ice hockey. Overuse was responsible for 8.0% of injuries in NCAA men's ice hockey[43], 5.9% in upper extremity injuries for women's ice hockey and 2.5% in upper extremity injuries for men's ice hockey in the NCAA[12].

4.0 Discussion

Ice hockey is a high contact, high collision sport, with multiple players, hockey sticks, and a puck all moving around a confined ice space at one time. Because of this, the mechanism of an injury can be attributed to a wide variety of moving parts. Player-to-player contact is a common mechanism of injury in both women's and men's ice hockey, across all ages and levels of play. It is probable that any difference in percentages between genders can be attributed to the difference in body checking rules between the women's and men's game. The overall rules of the game are the same for both men's and women's hockey with only one difference; body contact is permitted yet body checking receives a minor two-minute penalty in the women's game[15]. Since body checking is prohibited in women's games, though it does still occur, this could be the cause in the gap in percentages. This difference between genders is also seen in youth hockey, under the age of 18, collegiate hockey, and even at the Olympics, as the difference in rules spans all ages and competition levels.

Ice hockey injury rates differ between men and women as well as across different levels of competition. The injury rate in men's ice hockey is generally higher than in women's ice hockey. Canadian collegiate ice hockey has a higher injury rate in both men's and women's categories compared to the NCAA. As seen in both genders, injury rates increase with age. This is shown in recreational women's ice hockey, the injury rate is 7.5 injuries per 1000 AEs, while in youth girl's ice hockey it is only 1.9 injuries per 1000 AEs. The difference between recreational and professional sports, is the access to an athletic trainer or therapist. Athletes at international women's ice hockey tournaments have a lower injury rate of 6.4/1000 AEs across eight years. Lorentzon et al. recorded an injury rate of 79.2, which is high compared to other studies. Lorentzon

et al. recorded rates this high because the injuries were reported as injuries per 1,000 player game hours for each athlete[61]. At the 2014 Winter Olympics, women's ice hockey had a higher injury rate compared to the 2010 Winter Olympics. Men's NCAA ice hockey had the highest injury rate at 16.3 injuries per 1000 AEs across 16 years, and the NHL had a 15.6/1000 AEs injury rate across six years. Men's ice hockey had a lower injury rate per participating athlete than women's ice hockey at the 2014 and 2010 Winter Olympics.

The most common anatomical location of injury in ice hockey was highly dependent on the age, level, and gender. As players age and enter more competitive levels, the rules become less protective, most specifically in terms of body contact and equipment. In the women's game, a neck guard is required at all levels of play, whereas it is only sanctioned up until the junior level for men. This is similar to face protection. Women are required to wear either a cage or a "bubble", but men are only required the same level of facial protection until the junior level, and then it is up to each player to choose the extent of facial protection for themselves. Most men's ice hockey players choose to wear a visor which only directly protects the eye, though no face protection is seen in leagues like the NHL. This was seen in the disparities in face and mouth injuries reported during international tournaments and Olympic competition when comparing women and men[11,40]. Since women have to wear a full-face covering, the face and mouth injuries were at percentages much lower than in men's competitions.

Interestingly, the injuries to the head accounted for a higher percentage of injuries in women's ice hockey than in men's in the youth and Olympic competition levels[11,40,55]. There are numerous possible reasons for this difference. One explanation may be the difference in training in youth hockey players. Since body checking is not permitted in women's hockey[15], girls are not always educated on how to hit, how to take a hit, how to fall, and even how to go into the boards

safely. This is reflected in the percentage of head and neck injuries recorded in Canadian youth hockey players, with the girls' head and neck injuries being higher than in boys[55]. All other injuries are comparable between women and men.

As seen with both mechanism and anatomical location of injury, the diagnosis of injury was dependent on the age and gender of the athlete, as well as the level of play. Lacerations were common in highly competitive men's hockey, such as in the NCAA, international tournaments, and the Olympics, yet are fairly uncommon in boys' youth hockey[11,40,53,55]. For women's hockey sprains and strains are common in both recreational, international, and Olympic athletes[11,46]. As with mechanism and diagnosis, the differences can be attributed to the distinctions in rules. Women's hockey involves generally less body contact than men's hockey, which means there may be fewer opportunities for the skin to tear due to trauma from body contact or contact with an object. Consequently, female hockey players have to rely more on their skills and speed rather than their body size to gain or maintain control of the puck. However, this increased reliance on skill and speed, coupled with an all-too-common lack of funding and support could result in having to skip warm-up, the muscles being overworked and undertrained, ultimately leading to sprain and strain injuries.

In women's ice hockey, the injury rates vary considerably. It's important to note that the data in this text come from different sources who recorded injury rates differently. These sources include studies of collegiate ice hockey in the United States and Canada, as well as reports on recreational and international competition. The data suggest that injury rates may be higher in more competitive contexts, such as Olympic competition, where players may be pushing themselves to their absolute limit.

Yet, the research does show that men's ice hockey tends to have higher injury rates than women's ice hockey. The studies reveal a range of injury rates and numbers across different levels of play, with men generally having higher injury rates than women[15]. The results highlight the importance of understanding the prevalence and types of injuries in ice hockey, as well as the need for injury prevention strategies across different levels of play. This review shows that injury rates can vary widely depending on the population being studied and the level of play, emphasizing the need for targeted injury prevention efforts.

There are numerous reasons why Kerr et al. found higher injury rates in collegiate athletes compared to Hootman et al.[25,43]. Hootman et al., looked at injuries in a 16-year period ending in the 2003-2004 athletic season, whereas Kerr et al. looked at injuries in a 5-year period ending in the 2013-2014 athletic season, a whole decade later[25,43]. The culture surrounding injuries changed significantly from the early 2000s to the early 2010s, especially with the growth of the athletic training profession.

Since the creation of the National Athletic Trainer's Association (NATA) in 1950, medical coverage has increased and improved for athletes in NCAA sport. From 1995 to 2005, ATs working in the collegiate setting increased by 86%[25]. In 2000 NATA had just over 27,000 members, and by 2010 NATA nearly 34,000 members with approximately 25% of members working in a college setting[62,63]. This increase allowed athletes to access care quicker and easier, possibly increasing reporting.

4.1 Limitations

This study has some limitations. The first being publication bias. Academic authors often submit articles containing "positive" findings, such as new exposure-disease associations, while neglecting to report statistically insignificant or "negative" results. This tendency is often encouraged by organizations, peer reviewers, and editors, which can lead to publication bias and an incomplete understanding of the research literature[64].

There was a limited amount of research to pull relevant data from. There are relatively few descriptive epidemiology studies in the populations, and there were many studies that looked at specific injuries that occurred in ice hockey players or explored the effect a return-to-play protocol on ice hockey athletes, or even how a training program effects these athletes.

Additionally, every article seemed to report the data in a different way. There was no consensus on how to present injury incidence, how to categorize an anatomical location, or how to define mechanisms of injury. Finally, there was a lack of current and up to date research within the topic of injuries in ice hockey, especially in women's hockey, that did not focus solely on a single injury, RTP, or performance enhancement.

4.2 Conclusions and Future Research Needs

In the ever-evolving world of sports, safety has become a top priority for athletes, coaches, and sports organizations. Ice hockey, a high-intensity sport that involves physical contact, speed, and agility, is no exception. Due to this nature, there is a wide variety of injuries that varies by age, level, and gender. However, despite the advancements in protective gear and rule changes, injuries

in ice hockey remain a prevalent issue, particularly among women, youth, and collegiate players. To address this issue, there is a pressing need for comprehensive research that delves into various aspects of ice hockey injuries. This research needs to focus on injury rates, incidence of injury, mechanism of injury, anatomical location, and diagnosis of injury in the specific demographics mentioned above. Furthermore, a meta-analysis or systematic review would be advantageous in the development of rehabilitation plans, proper body contact education implementation, injury prevention strategies, and the overall care provided to ice hockey athletes of all levels of play.

Through this research experts can gain a better understanding of the nature and severity of injuries in ice hockey, as well as identify potential areas of improvement in terms of player safety. This knowledge can inform the development effective preventative measures, training programs, as well as treatment and return to play protocols, ultimately increasing the career longevity of ice hockey players and enhancing the overall safety of the sport. Moreover, such research can provide invaluable insights into the unique challenges faced by women ice hockey players, which may differ from those experienced by men’s ice hockey players. By recognizing these differences, sports organizations can implement tailored policies and guidelines that promote gender and age inclusivity and safeguard the physical and mental well-being of all players.

It is imperative that research prioritize investigation on injuries in women's, youth, and collegiate ice hockey to ensure the longevity and safety of the sport. Understanding the prevalence and types of injuries in ice hockey is critical to developing targeted injury prevention strategies. This research can inform evidence-based interventions that not only reduce the incidence and severity of injuries but also foster a culture of health and well-being for ice hockey players of all ages and genders.

Bibliography

1.Abbott K. Injuries in women's ice hockey: special considerations. *Current sports medicine reports*. 2014;13(6):377-382. doi:10.1249/JSR.0000000000000102

2.MacCormick L, Best TM, Flanigan DC. Are There Differences in Ice Hockey Injuries Between Sexes?: A Systematic Review. *Orthopaedic Journal of Sports Medicine*. 2014;2(1):2325967113518181-2325967113518181. doi:10.1177/2325967113518181

3.Content Search. Accessed November 3, 2021, 2021.

4.Online UCH. Directory of all men's and women's NCAA college hockey teams. US College Hockey Online. Accessed July 5, 2022, 2022. https://www.uscho.com/teams/

5.Teams: Men's Hockey. USports. Accessed July 5, 2022, https://usports.ca/en/sports/hockey/m/teams

6.Teams: Women's Hockey. Accessed July 5, 2022, https://usports.ca/en/sports/hockey/f/teams

7.Agel JMA, Harvey EJMDM. A 7-year review of men's and women's ice hockey injuries in the NCAA. *Canadian journal of surgery*. 2010;53(5):319-323.

8.Dwyer T, Petrera M, Bleakney R, Theodoropoulos JS. Shoulder instability in ice hockey players: incidence, mechanism, and MRI findings. *Clinics in sports medicine*. 2013;32(4):803-813. doi:10.1016/j.csm.2013.07.013

9.Schick DM, Meeuwisse WH. Injury Rates and Profiles in Female Ice Hockey Players. *The American journal of sports medicine*. 2003;31(1):47-52. doi:10.1177/03635465030310011901

10.Frank RM, Romeo AA, Bush-Joseph CA, Bach JBR. Injuries to the Female Athlete in 2017: Part II: Upper and Lower-Extremity Injuries. *JBJS reviews*. 2017;5(10):e5-e5. doi:10.2106/JBJS.RVW.17.00031

11.Tuominen M, Stuart MJ, Aubry M, Kannus P, Tokola K, Parkkari J. Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. *British journal of sports medicine*. 2016;50(22):1406-1412. doi:10.1136/bjsports-2015-094647

12.Melvin PR, Souza S, Mead RN, Smith C, Mulcahey MK. Epidemiology of Upper Extremity Injuries in NCAA Men's and Women's Ice Hockey. *The American journal of sports medicine*. 2018;46(10):2521-2529. doi:10.1177/0363546518781338

13.Female Hockey History. Hockey Canada. Accessed June 12, 2022, https://cdn.hockeycanada.ca/hockey-canada/Hockey-Programs/Female/Downloads/Female-Hockey-History.pdf

14.Women's Ice Hockey. Internation Ice Hockey Federation. Updated 2022. Accessed June 12, 2022, 2022. https://www.iihf.com/en/static/5068/women-s-hockey

15.Syrén J. CWHL & Canadian Women`s Hockey: The History of Famous Awards, League and Championship. Canadian Women's Hockey League. Accessed June 14, 2022, 2022. https://cwhl.ca/

16.Ferderation IIH. IIHF Official Rule Book 2021/2022. 1.1 ed. https://blob.iihf.com/iihf-media/iihfmvc/media/downloads/rule%20book/2021_22_iihf_rulebook_v1_1.pdf: IIHF; 2021.

17.Sandler BR. "Too Strong for a Woman"-The Five Words that Created Title IX. *Equity & excellence in education*. 2000;33(1):9-13. doi:10.1080/1066568000330103

18.Staurowsky EJ. The impact of Title IX and other equity laws on the business of women's sport. 1 ed. Routledge; 2019:23-35.
19.Rights USDoEOfC. *Clarification of intercollegiate athletics policy guidance: The three-part test*. Department of Education, Office for Civil Rights; 1996.
20.Druckman JN, Rothschild JE, Sharrow EA. Gender policy feedback: Perceptions of sex equity, Title IX, and political mobilization among college athletes. *Political Research Quarterly*. 2018;71(3):642-653.
21.Staurowsky E. Title IX in its third decade: The Commission on Opportunity in Athletics. *Entertainment Law*. 2003;2(3):70-93.
22.Jurewitz RA. Playing at even strength: Reforming Title IX enforcement in intercollegiate athletics. *Am UJ Gender Soc Pol'y & L*. 2000;8:283.
23.Byers W, Hammer CH. *Unsportsmanlike conduct: Exploiting college athletes*. University of Michigan Press; 1997.
24.Cooky C, Lavoi NM. Playing but losing: Women's sports after Title IX. *Contexts*. 2012;11(1):42-46.
25.Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *Journal of athletic training*. 2007;42(2):311-319.
26.The Public Health Approach to Violence Prevention. Updated Janurary 18, 2022. Accessed July 9, 2022, https://www.cdc.gov/violenceprevention/about/publichealthapproach.html
27.Gissane C, White J, Kerr K, Jennings D. An operational model to investigate contact sports injuries. *Medicine and science in sports and exercise*. 2001;33(12):1999-2003. doi:10.1097/00005768-200112000-00004
28.Taimela S, Kujala UM, Osterman K. Intrinsic risk factors and athletic injuries. *Sports Medicine*. 1990;9(4):205-215.
29.De Loes M, Goldie I. Incidence rate of injuries during sport activity and physical exercise in a rural Swedish municipality: incidence rates in 17 sports. *International journal of sports medicine*. 1988;9(06):461-467.
30.Young PR, Knight EL. Use of psychological skills by risk sport athletes. *Journal of Human Performance in Extreme Environments*. 2014;11(2):2.
31.Koch M, Zellner J, Berner A, et al. Influence of preparation and football skill level on injury incidence during an amateur football tournament. *Archives of orthopaedic and trauma surgery*. 2016;136(3):353-360.
32.Wolf JM, Cameron KL, Owens BD. Impact of joint laxity and hypermobility on the musculoskeletal system. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*. 2011;19(8):463-471.
33.Lauersen JB, Bertelsen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. *Br J Sports Med*. Jun 2014;48(11):871-7. doi:10.1136/bjsports-2013-092538
34.Quinney HA, Dewart R, Game A, Snydmiller G, Warburton D, Bell G. A 26 year physiological description of a National Hockey League team. *Applied physiology, nutrition, and metabolism*. 2008;33(4):753-760. doi:10.1139/H08-051
35.Geithner CA, Lee AM, Bracko MR. PHYSICAL AND PERFORMANCE DIFFERENCES AMONG FORWARDS,DEFENSEMEN, AND GOALIES IN ELITE WOMEN'S ICE HOCKEY. *Journal of strength and conditioning research*. 2006;20(3):500-505. doi:10.1519/00124278-200608000-00007

36.Cappaert TA. Time of day effect on athletic performance: An update. *The Journal of Strength & Conditioning Research*. 1999;13(4):412-421.
37.Palmer MS, Spriet LL. Sweat rate, salt loss, and fluid intake during an intense on-ice practice in elite Canadian male junior hockey players. *Applied physiology, nutrition, and metabolism*. 2008;33(2):263-271.
38.Sawka M, Latzka W, Matott R, Montain S. Hydration effects on temperature regulation. *International journal of sports medicine*. 1998;19(S 2):S108-S110.
39.Pfister T, Pfister K, Hagel B, Ghali WA, Ronksley PE. The incidence of concussion in youth sports: a systematic review and meta-analysis. *British journal of sports medicine*. 2016;50(5):292-297. doi:10.1136/bjsports-2015-094978
40.Tuominen M, Stuart MJ, Aubry M, Kannus P, Parkkari J. Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *British journal of sports medicine*. 2015;49(1):30-36. doi:10.1136/bjsports-2014-093688
41.Mosenthal W, Kim M, Holzshu R, Hanypsiak B, Athiviraham A. Common Ice Hockey Injuries and Treatment: A Current Concepts Review. *Current sports medicine reports*. 2017;16(5):357-362. doi:10.1249/JSR.0000000000000402
42.Morrissey PJ, Maier SP, Zhou JJ, et al. Epidemiology and trends of adult ice hockey injuries presenting to United States emergency departments: A ten-year analysis from 2007–2016. *Journal of orthopaedics*. 2020;22:231-236. doi:10.1016/j.jor.2020.04.015
43.Kerr ZY, Marshall SW, Dompier TP, Corlette J, Klossner DA, Gilchrist J. College Sports–Related Injuries — United States, 2009–10 Through 2013–14 Academic Years. *MMWR Morbidity and mortality weekly report*. 2015;64(48):1330-1336. doi:10.15585/mmwr.mm6448a2
44.Estimated probability of competing in college athletics. Accessed August 22, 2022
, 2022. https://www.ncaa.org/sports/2015/3/2/estimated-probability-of-competing-in-college-athletics.aspx
45.Powell EC, Sheehan KM, Christoffel KK. Firearm Violence Among Youth: Public Health Strategies for Prevention. *Annals of emergency medicine*. 1996;28(2):204-212. doi:10.1016/S0196-0644(96)70063-X
46.Dryden DM, Francescutti LH, Rowe BH, Spence JC, Voaklander DC. Epidemiology of women's recreational ice hockey injuries. *Medicine and science in sports and exercise*. 2000;32(8):1378-1383. doi:10.1097/00005768-200008000-00004
47.Decloe MD, Meeuwisse WH, Hagel BE, Emery CA. Injury rates, types, mechanisms and risk factors in female youth ice hockey. *British journal of sports medicine*. 2014;48(1):51-56. doi:10.1136/bjsports-2012-091653
48.Soligard T, Steffen K, Palmer-Green D, et al. Sports injuries and illnesses in the Sochi 2014 Olympic Winter Games. *British journal of sports medicine*. 2015;49(7):441-447.
49.Engebretsen L, Steffen K, Alonso JM, et al. Sports injuries and illnesses during the Winter Olympic Games 2010. *British journal of sports medicine*. 2010;44(11):772-780.
50.Agel J, Dompier TP, Dick R, Marshall SW. Descriptive epidemiology of collegiate men's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *Journal of athletic training*. 2007;42(2):241-248.
51.Flik K, Lyman S, Marx RG. American Collegiate Men's Ice Hockey: An Analysis of Injuries. *The American journal of sports medicine*. 2005;33(2):183-189. doi:10.1177/0363546504267349

52.McKay CD, Tufts RJ, Shaffer B, Meeuwisse WH. The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. *British journal of sports medicine*. 2014;48(1):57-62. doi:10.1136/bjsports-2013-092860
53.Tuominen M, Stuart MJ, Aubry M, Kannus P, Parkkari J. Injuries in world junior ice hockey championships between 2006 and 2015. *British journal of sports medicine*. 2017;51(1):36-43. doi:10.1136/bjsports-2016-095992
54.Deits J, Yard EE, Collins CL, Fields SK, Comstock RD. Patients with ice hockey injuries presenting to US emergency departments, 1990-2006. *Journal of athletic training*. 2010;45(5):467-474. doi:10.4085/1062-6050-45.5.467
55.Forward KE, Seabrook JA, Lynch T, Lim R, Poonai N, Sangha GS. A comparison of the epidemiology of ice hockey injuries between male and female youth in Canada. *Paediatrics & child health*. 2014;19(8):418-422. doi:10.1093/pch/19.8.418
56.Krutsch W, Krutsch V, Hilber F, et al. 11.361 sports injuries in a 15-year survey of a Level I emergency trauma department reveal different severe injury types in the 6 most common team sports. *Sportverletzung, Sportschaden*. 2018;32(2):111-119. doi:10.1055/s-0583-3792
57.Lorentzon R, Wedrèn H, Pietilä T. Incidence, nature, and causes of ice hockey injuries: A three-year prospective study of a Swedish elite ice hockey team. *The American journal of sports medicine*. 1988;16(4):392-396. doi:10.1177/036354658801600415
58.Mölsä J, Kujala U, Myllynen P, Torstila I, Airaksinen O. Injuries to the Upper Extremity in Ice Hockey: Analysis of a Series of 760 Injuries. *The American journal of sports medicine*. 2003;31(5):751-757. doi:10.1177/03635465030310051901
59.Kujala UM, Taimela S, Antti-Poika I, Orava S, Tuominen R, Myllynen P. Acute injuries in soccer, ice hockey, volleyball, basketball, judo, and karate: analysis of national registry data. *BMJ*. 1995;311(7018):1465-1468. doi:10.1136/bmj.311.7018.1465
60.Hostetler SG, Xiang H, Smith GA. Characteristics of Ice Hockey-Related Injuries Treated in US Emergency Departments, 2001-2002. *Pediatrics (Evanston)*. 2004;114(6):e661-e666. doi:10.1542/peds.2004-1565
61.Lorentzon R, Wedren H, Pietilä T, Gustavsson B. Injuries in international ice hockey: A prospective, comparative study of injury incidence and injury types in international and Swedish elite ice hockey. *The American journal of sports medicine*. 1988;16(4):389-391. doi:10.1177/036354658801600414
62.Members by Setting. Accessed 04/10/2023

, 2023. https://members.nata.org/members1/documents/membstats/2014EOY-stats.htm
63.Growth in Total Number of Members 1974-2014. Accessed 04/10/2023, https://members.nata.org/members1/documents/membstats/2014EOY-stats.htm
64.Nair AS. Publication bias - Importance of studies with negative results! *Indian J Anaesth*. Jun 2019;63(6):505-507. doi:10.4103/ija.IJA_142_19