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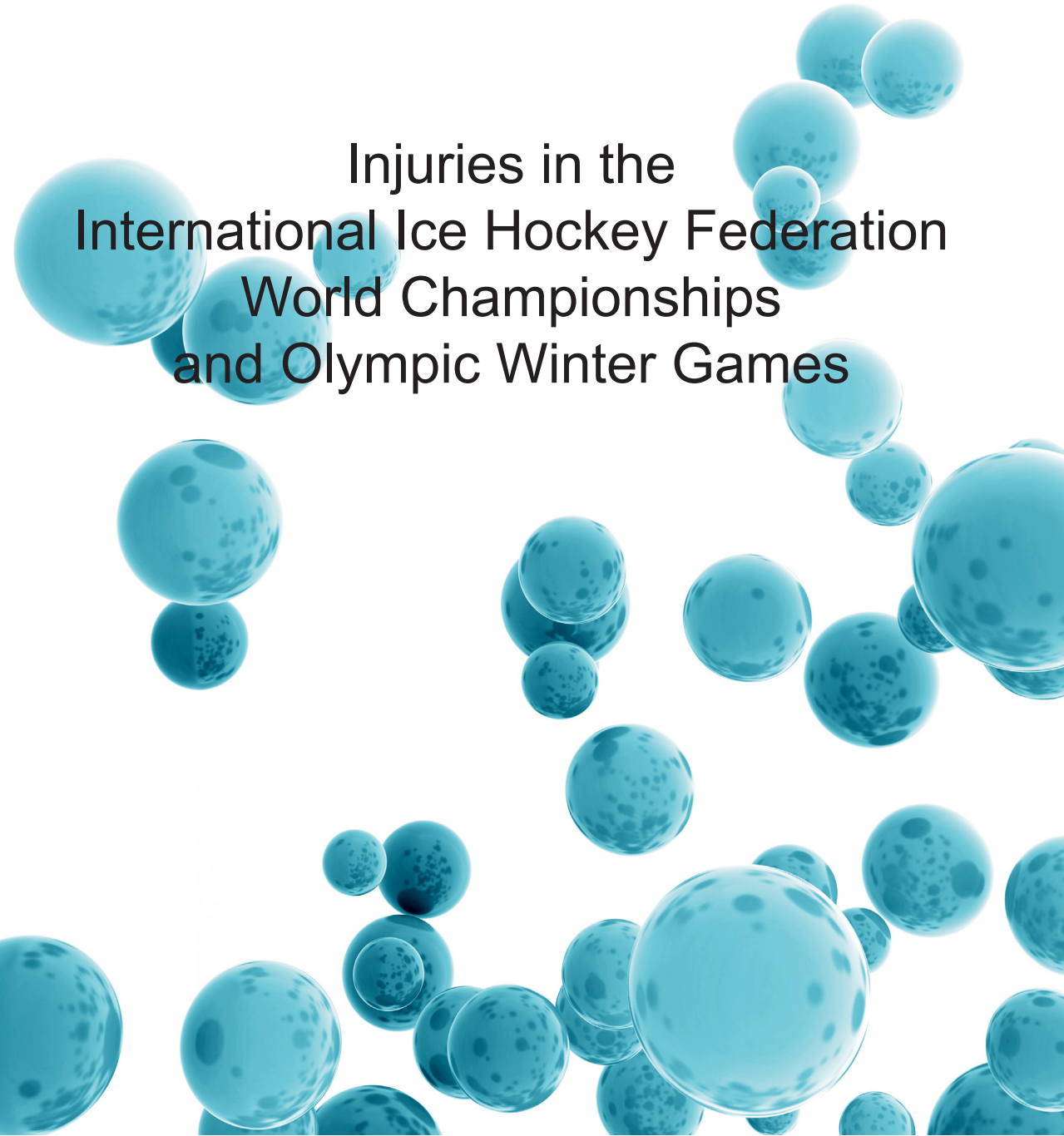
MARKKU TUOMINEN

Injuries in the International Ice Hockey Federation World Championships and Olympic Winter Games



MARKKU TUOMINEN

Injuries in the International Ice Hockey Federation World Championships and Olympic Winter Games

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ACADEMIC DISSERTATION
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of the University of Tampere,
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MARKKU TUOMINEN

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To my family and

hockey family

ABSTRACT

An understanding of the epidemiology of injuries in ice hockey is the prerequisite for successful injury prevention, treatment and rehabilitation. The purpose of this dissertation was to investigate the incidence, type, severity and risk factors of injuries, including concussions in men, women and junior players competing in international tournaments.

Ice hockey injuries in the International Ice Hockey Federation (IIHF) World Championship tournaments and the Olympic Winter Games were prospectively registered in 2006-2015. A total of 3293 games were played in the 169 tournaments by 1212 teams comprising 142244 athletic game exposures.

We found the highest risk for injury in the men's tournaments. Incidence of injury varied from 12.2 to 17.5 per 1000 player-games and from 44.7 to 64.2 per 1000 player-game hours. Head and especially face injuries were common in men's and male junior under-20 tournaments where full-facial protection is not mandatory. The risk of knee injury was two times higher in men's and female under-18 tournaments compared with male junior and women's tournaments. Shoulder injury rate was highest in the male junior under-18 championships and in men's tournaments. Further studies are needed to explain differences in the knee injury risk between the age groups. These injuries may be prevented with proper neuromuscular training. Mandatory use of full-facial protection is a great opportunity to reduce the risk of facial injuries, especially for male junior under-20s who have the highest injury rate.

One of our major findings was that flexible boards and glass significantly decreased the risk for those shoulder injuries and concussions that occurred during board contact. Installation of flexible boards and glass and the elimination of illegal hits are highly recommended for all future tournaments, especially in men's and male

under-18 tournaments where a high number of injuries occurred with board contact.

TIIVISTELMÄ

Jääkiekkovammojen epidemiologinen tutkimus on tärkeää loukkaantumisia ehkäisevien ratkaisujen löytämiseksi. Epidemiologinen tutkimus auttaa vammojen hoidossa, vammojen jälkeisen kuntoutuksen suunnittelussa ja sen kehittämisessä. Tämän väitöskirjatyön tarkoituksena oli tutkia loukkaantumisriskiä ja tyyppivammoja miesten, naisten ja juniorien huipputason jääkiekko-otteluissa, tutkia loukkaantumisten riskitekijöitä sekä vertailla tuloksia sukupuolten ja eri ikäryhmien välillä.

Väitöskirjatyössä kerättiin loukkaantumistiedot kansainvälisen jääkiekkoliiton maailmanmestaruus turnauksissa ja talviolympialaisissa vuodesta 2006 alkaen yhdeksän vuoden ajan. Kaikkiaan seuranta-aikana pelattiin 3293 ottelua 169 turnauksessa. Turnauksiin osallistui 1212 joukkuetta. Näistä muodostui yhteensä 142244 ottelukohtaista pelaaja-altistumista.

Tutkimusjakson aikana korkein loukkaantumisriski oli miehillä. Pään alueen vammojen ja erityisesti kasvovammojen esiintyvyys oli korkeinta miesten ja alle 20-vuotiaiden juniorien turnauksissa. Osakasvosuojan käyttö on heillä sallittu. Polvivamman riski oli kaksinkertainen miesten turnauksissa verrattuna poikien ja naisten turnauksiin. Alle 18-vuotiaiden tyttöjen polvivammariski vastasi kuitenkin miesten polvivammariskiä. Olkapäävammoja sattui eniten alle 18-vuotiaiden poikien ikäryhmässä ja miesten turnauksissa.

Jatkotutkimuksia tarvitaan selvittämään, mistä johtuvat polvivammariskin erot miesten ja poikien sekä tyttöjen ja naisten välillä. Nykytiedon valossa heikko polven liikehallinta on yleistä etenkin naisurheilijoilla. Kehon hallintaa ja alaraajojen liiketaitoa tulee kehittää kaikilla jääkiekkoilijoilla jo lapsuudesta lähtien. Kasvovammojen esiintyvyyttä jääkiekossa voidaan vähentää merkittävästi alle 20-vuotiaiden poikien otteluissa muuttamalla sääntöjä siten, että kokokasvosuojan käyttö on pakollista alle 18-vuotiaiden tapaan.

Väitöskirjatyön yksi päähavainto oli, että joustokaukalon käyttö vähensi merkittävästi laitakontaktissa tapahtuvia olkapäävammoja ja aivotärähdyksiä. Joustokaukalon käyttö onkin suositeltavaa vähentämään niin olkapäävammoja kuin aivotärähdyksiä. Joustokaukalo olisi erityisen hyödyllinen varsinkin miesten ja alle 18-vuotiaiden poikien otteluissa, joissa kyseisten vammojen esiintyvyys laitakontaktissa on suuri.

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ORIGINAL PUBLICATIONS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by their Roman numerals.

I 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. Tuominen M, Stuart MJ, Aubry M, Kannus P, Parkkari J. British Journal of Sports Medicine 2015; 49 (1): 30-36.

II Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. Tuominen M, Stuart MJ, Aubry M, Kannus P, Tokola K, Parkkari J. British Journal of Sports Medicine 2016; 50 (22): 1406-1412.

III Injuries in World Junior ice hockey Championships between 2006-2015. Tuominen M, Stuart MJ, Aubry M, Kannus P, Parkkari J. British Journal of Sports Medicine 2017; 51 (1): 36-43.

IV Concussions in the international ice hockey World Championships and Olympic Winter Games between 2006 - 2015. Tuominen M, Hänninen T, Parkkari J, Stuart MJ, Luoto T, Kannus P, Aubry M. British Journal of Sports Medicine 2017; 51 (4): 244-252.

Study IV is also a part of the doctoral thesis of M.D. Timo Hänninen (thesis title: The Sport Concussion Assessment Tool in the Management of Concussion in Professional Ice Hockey).

ABBREVIATIONS

AC	Acromioclavicular joint
ACL	Anterior cruciate ligament
AE	Athlete exposure
FIFA	Fédération Internationale de Football Association
GIR	Game Injury Report
IIHF	International Ice Hockey Federation
IOC	International Olympic Committee
IR	Injury Rate
IRS	Injury Report System
MCL	Medial Collateral Ligament
NCAA	National Collegiate Athletic Association
NHL	National Hockey League
OWG	Olympic Winter Games
RTP	Return to Play
SCAT	Sport Concussion Assessment Tool
SHL	Swedish Hockey League
SRC	Sport-related Concussion
WC	World Championship
WJ	World Junior
WJ U18	World Junior Under-18 Championship

WJ U18 A-pool	World Junior Under-18 Championship top level
WJ U20	World Junior Under-20 Championship
WJ U20 A-pool	World Junior Under-20 Championship top level
WS	Men's World Senior Championship
WS A-pool	Men's World Senior Championship top level
WW U18	World Women Under-18 Championship
WWC	Women's World Championship
WWC A-pool	Women's World Championship top level
All WWC	WWC and WW U18 tournaments together

1 INTRODUCTION

Ice hockey is a major winter team sport. Number of registered players in the world is currently about 1.8 million. The International Ice Hockey Federation (IIHF), founded on 15 May 1908 in Paris, is the governing body of international ice hockey and inline hockey. The IIHF is comprised of 72 member associations, each of which is the national governing body for the sport of ice hockey. The IIHF also presides over ice hockey in the IIHF World Championships (WC) at all levels - that is, men, women, junior under-20, junior under-18 and women under-18, and the Olympic Winter Games. The teams are qualified for the divisions and groups according to the IIHF world ranking. Ice hockey is the biggest team sport in the Olympic Winter Games (OWG).

Each ice hockey team typically consists of 20 - 22 players, including two wingers, one centre, two defensemen and a goalkeeper who are usually on the ice at the same time. The active playing time is three periods of 20 minutes each. In ice hockey, body contact is common. Body checking is not permitted in the female game. Ice hockey is also associated with many other potential risk factors, such as unintended collisions, high velocity, rapid changes in direction and trauma from the boards, sticks or a puck. As a result, a wide variety of injuries ensue. Facial injuries and concussions have been reported in epidemiological studies at other levels of the sport, including in the National Hockey League (NHL; USA and Canada).

Most of the epidemiological research of ice hockey is done at the minor, youth, high school or collegiate level in North America. There are very few studies published from the NHL. In Europe, most of the studies have been conducted at the end of the 1980s or in the 1990s. However, in the new millennium, the game has become faster, and the board materials, rules, as well as players' equipment, have changed. These changes may well have affected the type, incidence and severity of ice hockey injuries. The IOC wants to promote injury and disease

prevention as well as the improvement of the physical health of the athlete (Engebretsen et al. 2014).

2 REVIEW OF THE LITERATURE

2.1 Epidemiology in sports medicine

Epidemiology assesses relationships among the various factors determining the frequency and distribution of diseases and/or injuries in a human community. The basic elements of epidemiology have been applied to the study of the frequent consequences of practicing a sport. Understanding the incidence and prevalence of injuries based on variables such as the type and nature of the injury, age group, the nature of the sport, gender and time since the onset of symptoms, amongst others, has contributed to the development of programmes aimed at the prevention and treatment of injured athletes (Walter & Hart 1990). Most importantly, these studies have resulted in the identification of risk factors for sports injuries (Macera et al. 1989) and modifications in the competitive rules within various sports (Frontera 2003).

Epidemiological research in sports medicine is essential to the development of preventive interventions. Understanding the risk factors associated with sports injuries is necessary in the design of rehabilitation strategies, which can result in a lower incidence and severity of injuries. The study of the epidemiology of sports injuries is also as valuable to rehabilitation as it is to prevention. Many injuries may occur because the rehabilitation of a previous injury was not complete (Frontera 2003).

The study of the patterns of disease and injuries in international sports competitions can help local medical staff and team physicians plan the composition of the health care teams as well as the necessary equipment and medical supplies for a tournament. (Frontera et al. 1997).

2.2 Theoretical model of injury prevention research

Van Mechelen, Hlobil and Kemper (1992) developed a four-step sequence model of injury prevention research. This model has been modified by Frontera (2003), with the inclusion of rehabilitation programmes. At first, (1), the magnitude of injury issues within a certain population are identified and described according to incidence and severity. Establishing the risk factors and injury mechanisms that affect the occurrence of sports injuries is the second step (2). The third step is to provide preventive measures (3a) and/or rehabilitation (3b) programmes that have the potential to reduce the risk of injuries, which is based on the information gathered in the second phase. Finally, (4), the efficiency of the preventive action should be assessed in a randomised clinical trial and/or epidemiological study (repeat Step 1). In addition, when a number of studies have been carried out, conclusions are determined by means of meta-analysis (van Mechelen et al. 1992, Frontera, 2003).

Clearly-defined methodologies are essential to use in order to receive reliable and comparable information on sports injury research. Conflict conclusions can be reached, depending on how the data are collected and analysed. Injury definition, recurrent injury definition, the method of reporting injuries and the method of calculating incidences have played a pivotal rule. There has to be an unambiguously and universally-defined term for sports injuries based on the present recommendations or consensus statements (van Mechelen et al. 1992, Brooks & Fuller 2006).

What is important is that incidence of injuries reflect the true magnitude of the problem and is reported in a way that allows it to be compared to injury rates in different sports and populations. Epidemiological studies have commonly reported the absolute number of injuries or number of injured individuals, the relative proportion of injuries or the incidence of injuries. The incidence of injury is dependent upon the definition of an injury and the population at risk. Injury incidence is enunciated as the number of injuries per 1000 hours of sports participation, including the time an athlete is

actually at risk of injury. Injury incidence based on athletic -exposure requires that sports participation is clearly defined. Counting the incidence of injury from training and competition combined reflect more often the results from training injuries, but the distribution of injuries reflects more of the game injuries (van Mechelen et al. 1992, Brooks & Fuller 2006).

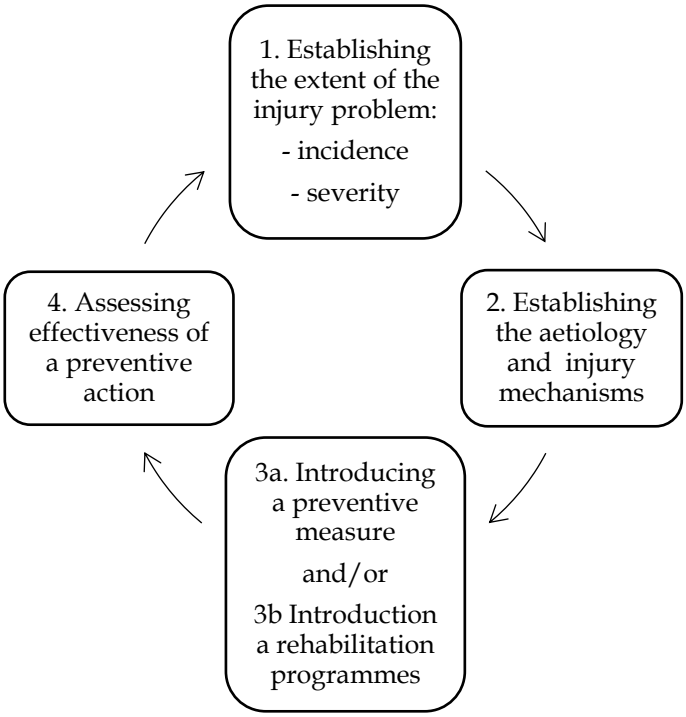


FIGURE 1 The sequence of injury prevention research, modified from van Mechelen, Hlobil & Kemper (1992).

The chosen study design and the methodology, as well as the representativeness of the sample, affect the results of sports injury research (van Mechelen et al. 1992).

2.3 Sports injuries

An injury occurs when the stress applied to a tissue is greater than its ability to 'absorb' the stress acutely or chronically. This results from complex interactions between internal and external risk factors (Meeuwisse 1994, McBain et al. 2012) as well as protective factors. All types of injuries that occur during a sporting activity are generally considered as sports-related injuries. However, for research purposes, the criteria of sports injuries need to be clearly and consistently defined (Brooks & Fuller 2006, Fuller et al. 2006). Currently, a number of consensus statements on injury definitions and data collection have been published. Some of them are based on the definition of diagnosis and some of them are sport-specific consensus statements (Fuller et al. 2006, Fuller et al. 2007, Pluim et al. 2009, McCrory et al. 2013a, Timpka et al. 2014, Weir et al. 2015, Mountjoy et al. 2016).

2.3.1 Definition of an injury

There have been considerable methodological variations in injury definitions, thus making comparisons between studies difficult. Consensus statements have been suggested in team sports such as rugby, soccer and multi-sport events (IOC). Individual sports such as tennis, track and field, and aquatic sports have proposed their own definitions and statements. These statements make injury surveillance more sport-specific. This helps to compare the results of the studies with each other, but does not help compare risk of injury between various sports events.

The definition of an injury in rugby and soccer includes any physical complaint that is associated with training or a match within the sport, that needs medical attention or results in a player being unable to take full part in ordinary training or matches ("medical attention" or "time-loss" definitions) (Fuller et al. 2006, Fuller et al. 2007). The combination of time-loss and medical attention injuries is probably the best combination to collect reliable and comparable data regarding sport injuries.

Because in some studies a previous injury is connected to an increased risk of subsequent injury, recurrent injuries are necessary to

define and collect. A recurrent injury is an injury of the same type and at the same site as an index injury and which occurs after a player's return to full participation from the index injury (Hägglund et al. 2006, Hamilton et al. 2011).

2.3.2 Acute injuries

An injury occurs when the stress applied to a tissue is greater than its ability to 'absorb' the stress acutely or chronically (Meeuwisse 1994, McBain et al. 2012). An acute injury was defined as 'trauma resulting from a specific and identifiable event' (Yang et al. 2012, Fuller et al. 2006). Two widely-used and acceptable injury definitions for acute injuries are based on medical attention and a time-loss from sports participation (Brooks & Fuller 2006, Fuller et al. 2006). An injury that results in a player receiving medical attention is referred to as a ''medical attention'' injury. An injury is referred as a "time-loss" injury if an athlete is unable to take full part in training or competition (Fuller et al. 2006).

In high-speed sports, acute injuries are common. Sudden changes of direction, rapid accelerations, decelerations, stops and jump landings characterise them. Especially in team sports, contact with opponents or teammates is very common (Wennberg 2004, Wennberg 2005, Darrow et al. 2009, Yang et al. 2012, Tranaeus et al. 2016).

Acute injuries are classified within practice or competition injuries. There can be contact with another player or another object (Fuller et al. 2007). Contact injuries are divided into injuries caused by direct contact to the injured body part or indirect contact injuries. A direct impact to the knee, causing an MCL rupture, is an example of direct contact injury. A hit to an opponent's shoulder that results in a concussion is an example of an indirect contact injury. Injuries that occur without contact with any outside object are classified as non-contact injuries. Indirect contact injuries and non-contact injuries are often the result of a loss of adequate movement control.

2.3.3 Overuse injuries

Approximately 50% of all sports injuries are due to overuse as a result of repetitive microtrauma (Frontera 2003). An overuse injury is defined as a gradual-onset injury caused by repeated microtrauma without a single, identifiable event responsible for the injury. (Fuller et al. 2006, Yang et al. 2012). Overuse injuries are common in sports that include monotonous training sessions (endurance sports) (Clarsen et al. 2010, Ristolainen et al. 2010, Andersen et al. 2013) or repetitious movement patterns (technical sports) (Jacobsson et al. 2013). In team sports, most of the injuries are acute injuries. From 17% to 30% of all injuries in high-speed sports are overuse injuries (Wikström & Andersson 1997, Starkey 2000, Snellman et al. 2001, Deitch et al. 2006, Pasanen et al. 2008, Drakos et al. 2010). In team sports, repeated competing and the high training activity are factors, that are associated with the risk of overuse injury (Lian et al. 2005, Myklebust et al. 2011, Visnes & Bahr 2013).

2.3.4 Recurrent injuries

A recurrent injury can be defined as an injury of the same type and anatomical site as the initial injury after a person has returned to full participation from the index injury (Fuller et al. 2006). A recurrent injury occurring within 2 months of a player's return to full participation is referred to as an 'early recurrence'; one occurring from 2 to 12 months after a player's return to full participation as a 'late recurrence'; and one occurring more than 12 months after a player's return to full participation as a 'delayed recurrence' (Fuller et al. 2006, Fuller et al. 2007).

2.3.5 Incidence of injury

The incidence of injury is highly dependent upon the definition of injury and the population at risk. In epidemiological sports injury research, the incidence of injury is usually the main outcome, expressed as a ratio between the adequate numerator and denominator

data. The number of injuries or the number of injured players during a defined period is the common numerator data. The number of athletes at risk and the time of sports participation, or the number of athlete -exposures belongs to the denominator data. Injury incidence is usually expressed in team sports as the number of injuries per 1000 player-hours, per 1000 athlete -exposures, per 1000 player-games (player-matches) or per 1000 matches. The injury incidence reported in a study thus fully depends on the definitions of injury and exposure used (Hägglund et al. 2010).

2.3.6 Severity of sports injuries

Sports injury severity can be described on the basis of 6 criteria: (1) the nature of the injury; (2) the duration and nature of treatment; (3) sport participation time lost; (4) work time lost; (5) permanent damage; and (6) financial cost. Uniform definitions are important in order to enhance the comparability of the research data (van Mechelen et al. 1992).

The definition for the severity of sports injuries is the number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection (Fuller et al. 2006, Fuller et al. 2007). The severity of time-loss injuries are usually classified into four to six categories based on the number of days lost from full participation in training and competition (van Mechelen et al. 1992, Fuller et al. 2006, Fuller et al. 2007, Yang et al. 2012).

2.4 Ice hockey injuries

Ice hockey is associated with many injury risk factors, such as unintended collisions, high velocity, rapid changes in direction and contact with the boards. The fast-moving puck, swinging sticks and 6 players per team in a small space contributes to the risk of injury (LaPrade et al. 2014).

The active playing time is 60 minutes in all World Championship tournament games, including three 20-minute periods. Intermission is usually 15 minutes between the periods. The main difference between male and female ice hockey rules is that body checking is legal in the men's game. Intentional body checking is not permitted in any level of women's ice hockey (Dick 2009, Brainard et al. 2012, Delaney et al. 2014, Wilcox et al. 2014, Covassin et al. 2016). The equipment is similar for all ice hockey players, except for facial protection. All female and male under-18 (U18) players must use full-facial protection (full cage or shield), but male players over 18 years of age are allowed to wear partial-facial protection (visor) only. In addition, a mouth guard is mandatory for players in the World Junior U20 category who wear a visor (Asplund et al. 2009).

The exact size of an ice hockey rink and its sections (offensive zone, neutral zone and defensive zone) varies among arenas within the limits of variation of the IIHF rulebook but not between gender, age groups or levels of tournament. Modern rink materials have the flexibility and capacity to absorb the energy of players colliding with the boards and perimeter glass. This has led to the gradual replacement of traditional rinks with modern flexible materials (Poutiainen et al. 2014).

2.4.1 Definition of an injury in ice hockey

To improve the understanding of injuries within a specific sport is the target of sports injury research in order to facilitate prevention and rehabilitation. Comprehension of epidemiology principles is necessary to design research protocols that are both accurate and pragmatic. The definitions usually used in previous ice hockey studies have been a combination of time-loss and medical attention injuries. A recommended injury definition is any ice hockey related injury occurring on the rink or the player's bench or during team practice that keeps (or would keep) a player at least out of the next practice or competition or has required medical attention (other than icing or wrapping) and all concussions, lacerations, fractures, dental, eye and nerve injuries. Consistent use of the exact definition of the injury will allow more meaningful comparisons between studies of ice hockey injuries (Stuart & Smith 2000).

2.4.2 Population at risk

Only the participating players are at risk for injury and are included in the denominator when calculating incidences. In Europe, the population at risk is determined by including only the players who are on ice at the same time. This definition takes out the players who are on the bench during a game. When calculating the incidence of injury estimated, collective playing time is used (Lorentzon et al. 1988, Mölsä et al. 1997). However, in North America, the population at risk belongs all the players who take part in a practice or a game, regardless of the duration of the practice or game (Flik et al. 2005, Agel & Harvey 2010). In some studies, only one goalie is counted in the population at risk in a game (Benson et al. 2011). In some studies, the measurement of individual player exposure time is used to count the incidence of game injuries. Individual practice time is not possible to use for counting the incidence of practice injuries. The results of this research were closer to the results of studies conducted in Europe (estimated player-game hours). The use of individual playing time also gives an opportunity to compare the risk of injury between the different playing times (Stuart & Smith 2000, Izraelski 2014, McKay et al. 2014).

2.4.3 Incidence of injury

The concept of athlete -exposures, which reports the injury rate with reference to 1000 player-practice hours and 1000 player-game hours, estimates the risk of injury in a clearly-defined sample (Stuart & Smith 2000). Injury incidence rates were usually estimated by collective playing time, since individual on-ice exposure was not being measured. In addition, it has been assumed that each game was played for 60 minutes. This approach did not take penalties and overtime into consideration. When the results were given from the games only, the injury incidence per 1000 player-game hours was equal to the 1000 player-games or 1000 athlete -exposures, when the population at risk was defined the same way. Usually, the total duration of a game is between 2 to 2.5 hours, including intermissions and breaks during the periods. Differences in the duration of games, breaks and penalties give the ability for coaches to use players in different ways.

In ice hockey, most of the studies conducted in Europe expressed injury incidence as the number of injuries per 1000 player-hours, where the population at risk was the six players who were on the ice at the same time in each team (Lorentzon et al. 1988, Mölsä et al. 1997). In North-America, injury incidence was usually counted per 1000 athlete-exposures, where the players of an entire team were at risk for an injury (Agel & Harvey 2010, Benson et al. 2011). In this definition, all players of the team participating in a game had an impact on the game and were at risk for injury during every moment of the game.

Today, the greater number of players on a team has increased the speed of the game. This gives a little bit longer rest period and better recovery for players between the shifts. This also means that players have more intensive shifts when they are on the ice.

If training and game injuries are combined, the incidence of injury is more likely to reflect the incidence of training injuries, but the distributions of injuries are more likely to reflect the distributions of game injuries (Brooks & Fuller 2006).

2.4.4 Injuries in men's ice hockey

Most of the studies of men's ice hockey have been carried out in North America. There are only a few studies from Europe, and most of them occurred at the end of the 1980s or at the beginning of the 1990s. There are also only a few published studies from the NHL. Most of the studies were reported from collegiate players. In previous studies from the international level in each research conducted, only one team was followed or ice hockey injuries were collected within part of the Olympic Winter Game's (OWG) medical research. Most of the studies have used the definition of injury, which included time-loss injuries and medical attention, but there have been differences in the definitions. There have also been differences in defining the population at risk.

2.4.4.1 Incidence of injury

The injury rates for ice hockey injuries reported for North American collegiate players were from 13.8 to 18.7 injuries per 1000 athlete-exposures (AEs) (McKnight et al. 1992, Flik et al. 2005, Agel et al. 2007a, Agel & Harvey 2010). In the prospective study from six NHL seasons (2006-2012) on the basis of the estimated AEs, the overall regular season incidence density was 15.6 injuries per 1000 AEs. Based on individual time on ice, the injury rates were 49.4 injuries per 1000 player-game hours. There was a reduction in injury rates over the 6-year period, with the greatest reduction between the 2007-2008 and 2008-2009 seasons (McKay et al. 2014).

The result was similar with the reported injury rates of 66–79.2 per 1000 estimated player-game hours in the elite European leagues and in the Japanese ice hockey league (Lorentzon et al. 1988, Mölsä et al. 1997, Mölsä et al. 2000, Kuzuhara et al. 2009). In Finnish and Swedish ice hockey leagues the injury rate was 66 - 78.4 per 1000 player-game hours (Lorenzon et al. 1988). In Finland in the second highest level (Division I), the league incidence of injury was 36 per 1000 player-game hours (Mölsä et al. 1997). The risk of injury was very low during practices compared to the games.

2.4.4.2 Type of injury, period and cause

Contusions were the most common diagnosis of the injury. Facial lacerations were also a very common type of injury in studies from the European leagues. In that time, under half of the players used a facial protection. There were fewer injuries in first period, while most of them occurred during the third period. Body checking, unintended contact with another player or contact with the boards and glass were the main causes of an injury. Most of the facial lacerations were caused by a hockey stick (Lorentzon et al. 1988, Mölsä et al. 1997, Mölsä et al. 2000). In North American collegiate studies, a concussion was one of the most common diagnosis together with shoulder and knee ligament injuries (Flik et al. 2005, Agel et al. 2007a, Agel & Harvey 2010).

2.4.4.3 Differences between decades

In another study from the Finnish ice hockey league, the injury rate increased significantly from 54 per 1000 player-game hours in the 1970s to 83 per 1000 player-game hours in the 1990s. The rate of contusions, sprains and strains increased significantly with each decade (Mölsä et al. 2000). Injuries were classified as major in 5% of the patients, and there were fractures in 8% and head or facial involvement in 18% of them (Mölsä et al. 1997). Checking and unintentional collisions with an opponent were the common mechanisms of injury regardless of decade (Mölsä et al. 2000).

McKay et al. (2014) reported in an NHL study that the most commonly injured body regions were the head (16.8%), thigh (14.0%) and knee (13.0%). Together, these body regions also accounted for the greatest number of man-game lost, resulting in 16.7%, 10.5% and 15.5% of total man-game lost, respectively. Of the cases where the mechanism was reported, body checking accounted for the largest proportion. Compared with the forwards, the defensemen were more likely to report a game-related time-loss injury. Injuries were significantly more frequent in the first period (48.1%) than in the second (25.4%) or third (24.4%) periods. Only a few injuries occurred during the pregame warm-up and during overtime (McKay et al. 2014).

2.4.5 Injuries in women's ice hockey

Almost all female studies have been carried out in North America using same methods as in men's ice hockey (Agel et al. 2007a, Agel et al. 2007b, Agel & Harvey 2010). Most of them are from the collegiate level. There has been no specific research from injuries in women's international-level ice hockey. Only some results were given from OWGs. Most of the studies have used a definition of injury, which included time-loss injuries and medical attention, but there were study-to-study differences in the definitions.

2.4.5.1 Incidence of injury

In the women's National Collegiate Athletic Association (NCAA), ice hockey game injury rates were reported to be from 12.1 to 12.6 per 1000 athlete –exposures (AEs). The athlete –exposure was determined by the number of athletes participating in a game or practice, regardless of duration or type of exposure (Agel et al. 2007b, Agel & Harvey 2010). Schick and Meeuwisse (2003) reported that the injury rate for female ice hockey was 7.77 per 1000 athlete-exposures (AEs) and for game injuries 10.43. In all studies, the game injury rate was significantly higher compared to the practice injury rate (MacCormick et al. 2014).

In women's ice hockey, the risk of injury was greater with increasing age and at the more elite levels to play as well as an increase in injury severity (Keightley et al. 2013). Agel and Harvey (2010) reported a non-significant average annual decrease (2.9%) for injury rate (IR) in women's ice hockey. In turn, the practice injury rate for women had a 7.2% nonsignificant increase (Agel & Harvey 2010). The injury rate in female ice hockey was lower than that in men's ice hockey, but the differences between the sexes were smaller at the collegiate level (MacCormick et al. 2014).

2.4.5.2 Type and causes of injury

Most of injuries in women's ice hockey were lower-body injuries. Sprains and strains were main types of injury. Concussions were the most common diagnosis followed by hip/groin and ankle injuries (Schick & Meeuwisse 2003, Agel et al. 2007b, Agel & Harvey 2010). The average rate of concussion over 7-year period was 0.82/1000 athlete - exposures (Agel & Harvey 2010) and the concussion rate for game injuries was 2.72 (Agel et al. 2007b). In women's collegiate ice hockey, the injury rate for concussions was reported to be higher than in men's ice hockey. Body checking and unintentional collisions with an opponent were the common mechanisms of injury in female ice hockey (Agel & Harvey 2010). Ninety-six percent of injuries were related to contact mechanisms (Schick & Meeuwisse 2003).

2.4.6 Injuries in juniors' ice hockey

Most of the research from juniors' (under-18 and under-20) ice hockey have been carried out in USA or Canada. Most of them are from high school, college or junior A-level.

2.4.6.1 Incidence of injury

In North American collegiate-level ice hockey, the incidence of injury was reported to be from 13.8 to 18.7 per 1000 athlete -exposures. There were differences in the definition of injury. The majority of them included both time-loss injuries and injuries that required medical attention (McKnight et al. 1992, Flik et al. 2005, Agel et al. 2007a, Agel & Harvey 2010). Stuart and Smith (1995) reported an injury rate of 96.1 per 1000 player-game hours in Elite Junior A (from 16 to 21 years) ice hockey in North America. The injury rate for laceration was 32.4 per 1000 player-game hours. The anatomical region most often injured was the face (IR 38 per 1000 player-game hours) (Stuart & Smith 1995). At the high school level, the injury rate was lower compared to the Junior A-level: IR 34.4 per 1000 player-game hours (Smith et al. 1997). The injury rate for games was significantly higher in all studies compared to the risk of injury during practices (a 6.3 to 25 times higher risk of injury during a game) (McKnight et al. 1992, Smith et al. 1997, Pinto et al. 1999, Flik et al. 2005, Agel et al. 2007a, Agel & Harvey 2010, Matic et al. 2015).

2.4.6.2 Injured anatomical region, cause, and position

Players competing at the minor hockey, high school and Junior A levels of competition sustained most of their injuries to the upper extremity, head and face and the lower extremity, respectively (Benson & Meeuwisse 2005). In earlier studies, the face was the most common location of injury, and lacerations were the most common diagnosis before full-facial protection was mandated in the United States Hockey League for players age 18 and older (Stuart et al. 2002).

More than half of the injuries were caused by collision with another player or the boards and glass followed by stick and puck contact. Injuries caused by contact with another player or the boards and glass were more common during games than practices. Forwards and defensemen had the highest injury rates for injury and the position of goalie had the lowest rate of injuries compared to the other positions (Benson & Meeuwisse 2005).

2.4.6.3 Type of injury, period

In Junior A hockey, the three most commonly reported types of injuries were sprains and strains (20.5–41%), contusions (18–45.8%), and lacerations (9.6–24%). Similarly, the most frequent types of injuries in high school hockey were contusions (29–58.6%), sprains and strains (6.8–37%), lacerations (10.3–13%), and concussions (3.7–13.8%). In most of the studies, the third period had the highest risk of injury (Benson & Meeuwisse 2005). Flik et al. (2005) reported injury risk by periods: 36.5% in the first and second period and 27% in last period. In this study, only time-loss injuries were included in the definition.

Concussions were one of the most common diagnosis in junior ice hockey. The overall injury rate for concussions in high school was reported to be from 0.54 per 1000 AEs to 0.64 per 1000 AEs, and the game injury rate was higher compared to the concussion rate for practices (Clay et al. 2013, Matic et al. 2015). Agel et al. (2007a) reported (NCAA) that the injury rate for concussions in games was 1.47 per 1000 AEs.

2.4.6.4 Full face protection

Facial protection reduces overall head injuries in ice hockey. Stuart et al. (2002) reported the incidence of injury at 158.9 per 1000 player-game hours occurred in players wearing no facial protection, 73.5 per 1000 player-game hours in players wearing partial facial protection (half shield), and 23.2 per 1000 player-game hours in players wearing full-facial protection (full cage or shield). Facial protection showed a statistically significant reduction in the number and type of facial

injuries. In studies evaluating full-facial protection versus half-facial protection, full-facial protection offered a significantly higher level of protection against facial injuries and lacerations than half facial protection. Both full and partial facial protection significantly reduced injuries to the eyes and face without increasing the risk of neck injuries and concussions. In those players with full-facial protection who sustained a concussion, they returned to practice or games sooner than players with partial facial protection (Benson et al. 2002, Asplund et al. 2009).

There is now good evidence that full-facial protection reduces the number and risk of overall head and facial injuries in ice hockey compared with partial facial protection and no facial protection (Asplund et al. 2009).

2.4.7 Concussions in ice hockey

Concussions are a known problem at all levels of the game and have been reported to account for 3-22% of all ice hockey injuries. Concussions in sport have been defined as a clinical syndrome of a traumatically-induced transient disturbance of normal brain function. The lateral and temporal areas of the head are the most common areas to be struck, resulting in concussion. In ice hockey, concussion impacts are more likely to occur from contact with another body part or object rather than with another head. Differences in the mechanisms of injuries have been found between males and females, which may be of importance when planning the prevention of concussions (Noble & Hesdorffer 2013, Delaney et al. 2014). Concussive injury is believed to result from a series of metabolic events within the brain and have been summarised in detail by Giza and Hovda (2001 and 2014) as well as Barkhoudarian et al. (2016).

The diagnosis of a concussion relies on the clinician's evaluation. Injury mechanics, visible signs, reported symptoms, changes in cognitive and/or physical performance and the exclusion of a more severe neurotrauma are the fundamentals of clinical assessment (Aubry et al. 2002, McCrory et al. 2005, McCrory et al. 2009, Harmon et al. 2013, McCrory et al. 2013a). The systematic collection of all ice hockey injuries shows that, in both genders, a concussion is one of the

most common injury types resulting in missed participation (Schick & Meeuwisse 2003, Flik et al. 2005, Agel et al. 2007a and 2007b, Agel & Harvey 2010, Keightley et al. 2013, Matic et al. 2015). Furthermore, growing concerns about the possible lingering detrimental effects of concussions have addressed the need for preventive measures (McCrory et al. 2013b).

2.4.7.1 Definition of a concussion

The 1st International Consensus Conference on Concussion in Sport was organised by the IIHF, FIFA and IOC in Vienna in 2001. The 2nd was in Prague in 2004; the 3rd and 4th in Zurich in 2008 and 2012, respectively. The definition of a concussion was updated after the 5th International Conference on Concussion in Sport which was held in Berlin in 2016.

A sport-related concussion (SRC) is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilised in clinically defining the nature of a concussive head injury include: (McCrory et al. 2017):

1. A sport-related concussion (SRC) may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head (McCrory et al. 2017).
2. SRC typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, signs and symptoms evolve over a number of minutes to hours (McCrory et al. 2017).
3. SRC may result in neuropathological changes, but the acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies (McCrory et al. 2017).
4. SRC results in a range of clinical signs and symptoms that may or may not involve the loss of consciousness. Resolution of the clinical and cognitive features typically follows a sequential course. However, in some cases symptoms may be prolonged (McCrory et al. 2017).

The clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc) or other comorbidities (eg,

psychological factors or coexisting medical conditions) (McCrory et al. 2017).

2.4.7.2 Symptoms and signs of a concussion

The diagnosis of an acute sport-related concussion (SRC) involves the assessment of a range of domains including clinical symptoms, physical signs, cognitive impairment, neurobehavioral features and sleep/wake disturbance. Furthermore, a detailed concussion history is an important part of the evaluation both in the injured athlete and when conducting a pre-participation examination. The suspected diagnosis of SRC can include one or more of the following clinical domains: 1. Symptoms: somatic (e.g., headache), cognitive (e.g., feeling like in a fog) and/or emotional symptoms (e.g., lability); 2. Physical signs (e.g., loss of consciousness, amnesia, neurological deficit); 3. Balance impairment (e.g., gait unsteadiness); 4. Behavioural changes (e.g., irritability); 5. Cognitive impairment (e.g., slowed reaction times); 6. Sleep/wake disturbance (e.g., somnolence, drowsiness). If symptoms or signs in any one or more of the clinical domains are present, an SRC should be suspected and the appropriate management strategy instituted. (McCrory et al. 2013a, McCrory et al. 2017).

2.4.7.3 Sideline evaluation

No single diagnostic test exists for a concussion. The sideline evaluation is based on the recognition of an injury, assessment of the symptoms, cognitive and cranial nerve function, and balance. Serial assessments are often necessary (re-evaluation). Because SRC is often an evolving injury, and signs and symptoms may be delayed, erring on the side of caution (i.e., keeping an athlete out of participation when there is any suspicion of injury) is important. The player should be evaluated by a physician or other licensed healthcare provider on-site using standard emergency management principles, and particular attention should be given to excluding a cervical spine injury (McCrory et al. 2017).

The Sideline Concussion Assessment Tool 5rd Edition (SCAT5) was developed during the 5th International Conference on Concussion in Sport (Berlin 2016) (Attachment VII) (developed by the Concussion in Sport Group 2017). The recognition of a suspected SRC is therefore best approached using multidimensional testing guided via expert consensus. The SCAT5 currently represents the most well-established and rigorously developed instrument available for sideline assessment. There is published support for using the SCAT and Child SCAT in the evaluation of SRC. The SCAT is useful immediately after an injury in differentiating concussed from non-concussed athletes, but its utility appears to decrease significantly 3–5 days after the injury. The symptom checklist, however, does demonstrate clinical utility in tracking recovery. (McCrory et al. 2017).

2.4.7.4 Concussion management and return to play protocol

The process of recovery and then a return to sports participation after an SRC follows a graduated stepwise rehabilitation strategy (table 1). A brief period (24-48 hours) of cognitive and physical rest is appropriate for most patients. Following this, patients should be encouraged to gradually increase activity while staying below a cognitive and physical exacerbation threshold (Stage 1). The exact amount and duration of rest are not yet well defined (Schneider et al. 2017). Once concussion-related symptoms have resolved, the athlete should continue to proceed to the next level if he or she meets all the criteria (e.g., activity, heart rate, duration of exercise, etc.) without a recurrence of concussion-related symptoms. Generally, each step should take 24 hours, so that athletes would take a minimum of 1 week to proceed through the full rehabilitation protocol once they are asymptomatic at rest. However, the time frame for Return to Sport (RTS) may vary with player age, history, level of sport, etc., and management must be individualised. In athletes who experience prolonged symptoms and resultant inactivity, each step may take longer than 24 hours, simply because of limitations in the physical conditioning and recovery strategies outlined above. If any concussion-related symptoms occur during the stepwise approach, the athlete should drop back to the previous asymptomatic level and

attempt to progress again after being free of concussion-related symptoms for a further 24-hour period at the lower level (table 1) (McCrory et al. 2017).

Stage	Aim	Activity	Goal of each step
1.	Symptom-limited activity	Daily activities that do not provoke symptoms	Gradual reintroduction of work or school activities
2.	Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training	Increase heart rate
3.	Sport-specific exercise	Running or skating drills. No head impact activities	Add movement
4.	Non-contact training drills	Harder training drills, eg. passing drills. May start progressive resistance training	Exercise, coordination and increase thinking
5.	Full-contact practice	Following medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6.	Return to sport	Normal game play	

TABLE 1. Graduated return to sport protocol adopted from McCrory et al. (2017)

2.4.7.5 Incidence of concussions

2.4.7.5.1 Men's college ice hockey

At the North American collegiate level, concussion incidence rates have varied between studies, ranging from as low as 7.9% to as high as 18.6% overall, and from as low as an overall concussion rate of 0.22 per 1000 athletic -exposures to as high as 0.79 per 1000 athletic -exposures. The reported game injury rates for concussion varies between studies - from 1.47 to 2.49. Injury rates for concussions were a few times higher in games compared to practices. Part of the large variance can be explained by different methods and measures employed (McKnight et al. 1992, Flik et al. 2005, Agel et al. 2007a, Hootman et al. 2007, Agel & Harvey 2010, Clay et al. 2013, Ruhe et al. 2014, Zuckerman et al. 2015).

2.4.7.5.2 European and Japanese ice hockey

Concussions in the Swedish Hockey League (SHL) have been studied previously. During the seasons 1982 to 1985, 5.3% of all recorded injuries in one observed team were concussions (Lorentzon et al. 1988). From 1988 to 1992, a study of all SHL teams found that 6% of all recorded injuries were concussions, and the injury rate was 6.5 per 1000 player-game hours (Tegner & Lorentzon 1996). The concussion incidence rates (IRs) have also been reported, and during the period 1982 to 2001, it ranged from 12 per 1000 games to 53 per 1000 games in SHL teams. Pauelsen et al. (2016) has shown an increase in the concussion rate over a 29-season period - a shift in the injury pattern toward relatively more concussions and an increased concussion severity. In previous studies from the Finnish league and Mestis (First Division), Mölsä reported a 3% to 5% proportion of concussions from all injuries (Mölsä et al. 1997; Mölsä et al. 2000).

In a Japanese elite team over a period of 3 seasons, an overall injury rate during games of 74 per 1000 player-hours was found. The concussion rate for games was 1.6 per 1000 player-hours for that team (Kuzuhara et al. 2009).

2.4.7.5.3 The NHL

Benson and colleagues (2011) reported that the estimated incidence of concussions in the NHL was 1.8 per 1000 game player-hours, where the athlete -exposure time was estimated based on a roster of 18 skaters and one goalie playing in each team per game.

Wennberg and Tator (2008) evaluated concussions in the National Hockey League (NHL). They analysed the concussion incidence and time lost from play due to concussions during the ten NHL seasons 1997-1998 through 2007-2008. Data were obtained from a complete review of injury reports from two different sports media sources. The incidence of concussions reported in the regular season ranged from a high of 1.81 per 1000 athlete -exposures in 1998-99 to a low of 1.04 per 1000 athlete -exposures in 2005-06. The mean incidence for concussions over the ten seasons was 1.45 per 1000 athlete -exposures (Wennberg & Tator 2008).

Hutchison et al. (2015a) reported a total of 260 regular season concussions to have occurred during the data collection period from the beginning of the 2006-2007 season to the end of December 2009, or 6.05 injuries per 100 games.

2.4.7.5.4 Women's ice hockey

Studies from women's ice hockey were usually done from the collegiate level in North America. The overall injury rate for concussions varied between studies from 0.75 to 0.91 per 1000 athlete-exposures. The game injury rate for concussions was higher than that of men's games (from 2.01 to 2.72 per 1000 athlete-exposures), but the difference between game and practice injury rates was not as high as in men's ice hockey. The proportion of concussions from all injuries ranged from 15.2% to 21.6% (Schick & Meeuwisse 2003, Agel et al. 2007b, Zuckerman et al. 2015). In previous studies, the concussion rate for female ice hockey players has been higher than that for male ice hockey players, regardless of the fact that female players sustain fewer impacts and impacts resulting in lower head acceleration than males (Schick & Meeuwisse 2003, Hootman et al. 2007, Agel et al. 2007b, Agel & Harvey 2010, Brainard et al. 2012, Zuckerman et al. 2015).

2.4.7.5.5 Juniors' ice hockey

In high school ice hockey, the concussion rate was from 1.2 to 1.5 per 1000 athlete -exposures for games, and the overall incidence has been from 0.54 to 0.64 per 1000 athlete-exposures (Marar et al. 2012, Clay et al. 2013, Matic et al. 2015, Pfister et al. 2016). Echlin et al. (2010) reported the concussion rate as high as 21.52 per 1000 athlete -exposures in one junior physician-observed concussion study. The results differed considerably from the other studies made before or after the Echlin et al.'s (2010) work. The percentage of concussions from all injuries has been lower at the junior and high school level compared to men's and women's results (from 1.3% to 13.2%) (Pinto et al. 1999, Marar et al. 2012, MacCormick et al. 2014).

2.4.7.6 Causes of concussions

In a systematic video analysis of the National Hockey League (NHL), 88% of concussions occurred due to contact with an opponent and 5% involved contact with a teammate. The most common body part initially contacted by the hitter was the player's head (68%), with 22% of direct head contact from the shoulder, elbow or gloves. Eight percent of concussions were due to fighting (Hutchison et al. 2015 a, Hutchison et al. 2015b). Previous research at the collegiate and high school levels reported that player-to-player collisions accounted for 63%-73% of concussions in male ice hockey. It should be noted that 10% to 25% of concussions involved direct head contact with the boards or glass (Dick 2009, Agel & Harvey 2010, Marar et al. 2012, Zuckerman et al. 2015). The most common injury mechanism was checking.

In women, 41%-49% of the concussions sustained in games resulted from player contact. Overall, 35%-47% of the injuries sustained by women were the result of player contact (Agel et al. 2007b, Agel & Harvey 2010). In women's ice hockey, more of the concussions occurred with player-surface contact than in men's ice hockey. Concussions due to sticks and the puck accounted for only 10% to 16% (Tegner & Lorentzon 1996; Pauelsen et al. 2016).

2.4.7.7 Period

The majority of concussions in ice hockey are sustained during games. Most of the concussions at the men's highest level of competition occurred during the first period, when the players are maximally energised and able to apply more force with greater acceleration to contacts (Benson et al. 2011, Hutchison et al. 2015a). In the studies done in Sweden, more concussions were sustained in the second period compared to the first and third periods (Tegner & Lorentzon 1996; Pauelsen et al. 2016). These findings are contrary to the traditional view that concussions in hockey often occur when players are more fatigued or at points later in the game when emotions run high and the game gets 'out of hand'.

2.4.7.8 Position, zone, and penalty

Sixty-five percent of the concussions in the NHL were sustained by forwards, 32% by defensemen and 3% by goalies. The proportion of concussions sustained by a centre was about twice that of defensemen and wingers (Benson et al. 2011). In Swedish ice hockey, 47% of the concussions occurred to wings, 34% to defensemen, 11% to the centre, and 8% to the goalie (Pauelsen et al. 2016).

Forty-five percent of concussions occurred in the defensive zone, 34% in the offensive zone, and 21% in the neutral zone. A penalty was called in 29% of concussions (Hutchison et al. 2015 a).

2.4.7.9 Recovery time after a concussion

In female ice hockey, the higher concussion incidence rates and severity compared to men have been exhibited (Agel et al. 2007b, Dick 2009, Agel & Harvey 2010). However, physical contact is not allowed in female ice hockey, and body checking, a significant injury risk factor, is illegal at all ages and skill levels making this statistic particularly perplexing (Emery et al. 2010, Emery et al 2017). The average time lost from play per concussion has increased in men's ice hockey (Wennberg & Tator 2008, Benson et al. 2011, Hutchison et al. 2015a, Pauelsen et al. 2016).

In total, 80% of the reported concussions in women required fewer than 10 days of lost activity. Seventy-seven percent of those concussions occurred during a game. For concussions severe enough to keep an athlete out of scheduled practices or games for 10 or more days, 75% of these severe concussions sustained by women occurred during games (Agel & Harvey 2010). Benson et al. (2002) reported that full-facial protection will decrease the severity of a concussion (length of time to return to play).

2.4.8 Effect of ice surface size and dasher boards

Wennberg (2005) compared collision rates and head impacts in elite junior hockey between games played on the small North American ice

surface, an intermediate-size Finnish ice surface, and the large standard international ice surface. There was a significant inverse correlation between ice size and collision rates in elite hockey, including direct, indirect, and severe head impacts. Thus, in order to decrease the occurrence of collisions and head impacts in ice hockey, larger international rinks could be preferred (Wennberg 2004, Wennberg 2005).

Dasher board materials and structures had a clear effect on the impact characteristics. Compared to the reference dasher board, flexible protective shielding material resulted in 17% and 16% lower peak forces, 110% and 136% greater stopping distances and 62% and 56% lower stiffness values in the straight and the corner parts of the dasher board, respectively. The shielding support posts were much stiffer compared to the protective shielding. The single-framed dasher board was found to be 29% and 11% more flexible than its dual-framed counterpart, and heavier protective shielding resulted in 33% and 19% higher element stiffness in the straight and the corner parts of the dasher board, respectively. The safest dasher board would be single-framed with a light and flexible protective shielding material, and would not include shielding support posts (Poutiainen et al. 2014).

3 PURPOSE OF THE STUDY

The goals of this dissertation were to investigate the incidence of ice hockey injuries, especially concussions, in international top-level ice hockey, and to determine the risk factors of injuries, including differences between the gender and age groups. The specific study aims were:

1. To examine the risk, type, mechanism and severity of injuries at the elite level of men's international ice hockey. (*Study I*)
2. To investigate the incidence, type, mechanism and severity of injuries at the international female ice hockey. (*Study II*)
3. To identify the incidence, type, mechanism and severity of injuries in males under ages 18 and 20 at the junior ice hockey. (*Study III*)
4. To describe the incidence, injury characteristics and time trends of concussions in international ice hockey. (*Study IV)*

4 RESEARCH METHODS

4.1 Research process and dissertation structure

This dissertation is based on four independent research articles published in a prestigious peer-reviewed journal. The first three original articles described the incidence, severity and potential risk factors of ice hockey injuries in men, women and juniors. The fourth article is an analysis of specific diagnosis, concussion and identified risk factors for it. All the studies were based on the IIHF Injury Report System since 2006 (Medhockey, Medisport Ltd, Finland) (figure 2).

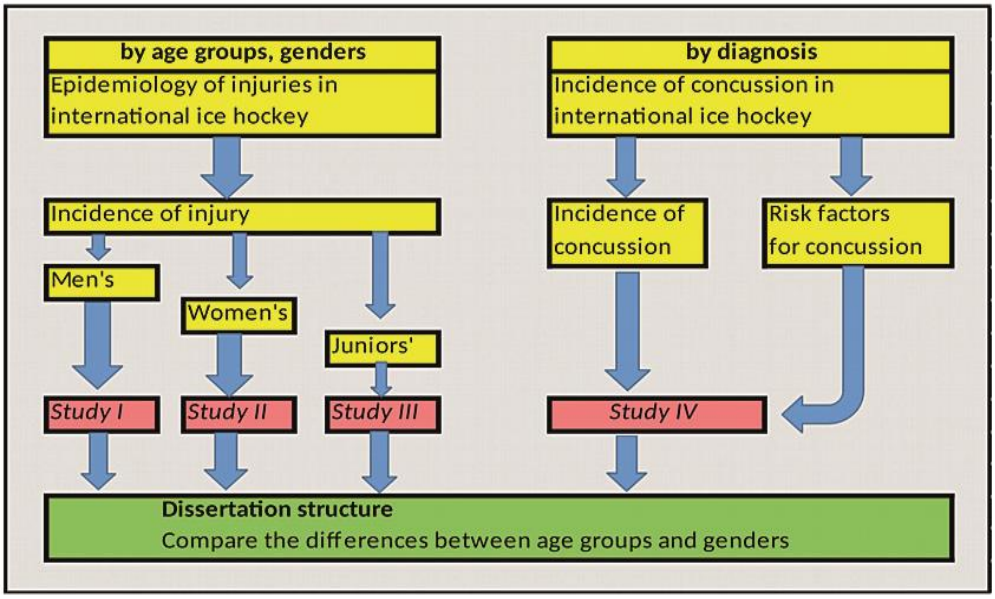


FIGURE 2. The dissertation structure

4.2 Epidemiology and risk factors of injuries

4.2.1 Study design

The dissertation contains data from the IIHF Injury Report System. The International Ice Hockey Federation has had an Injury Report System (IRS) since 1998. Since 2006, the IIHF has used Medhockey software (Medisport Ltd, Finland) to collect all injuries in a computer-based data register. All the studies were done with permission from the International Ice Hockey Federation.

For *Study I,* during the seven ice hockey seasons between 2006 and 2013 (from 1 July 2006 to 30 June 2013), all ice hockey injuries were analysed from 32 men's World Championships (7 of them were A-pool tournaments), one OWG and eight Olympic Qualification tournaments (table 2, figure 3). The A-pool tournament was the highest (top) level of tournaments.

During the eight ice hockey seasons (from 1 July 2006 to 30 June 2014), all ice hockey injuries were analysed from 39 female World Championships and OWGs for *Study II* (table 2). From the 69 male junior ice hockey tournaments, all ice hockey injuries were analysed during the nine ice hockey seasons (from 1 July 2006 to 30 June 2015) for *Study III* (table 2, figure 3).

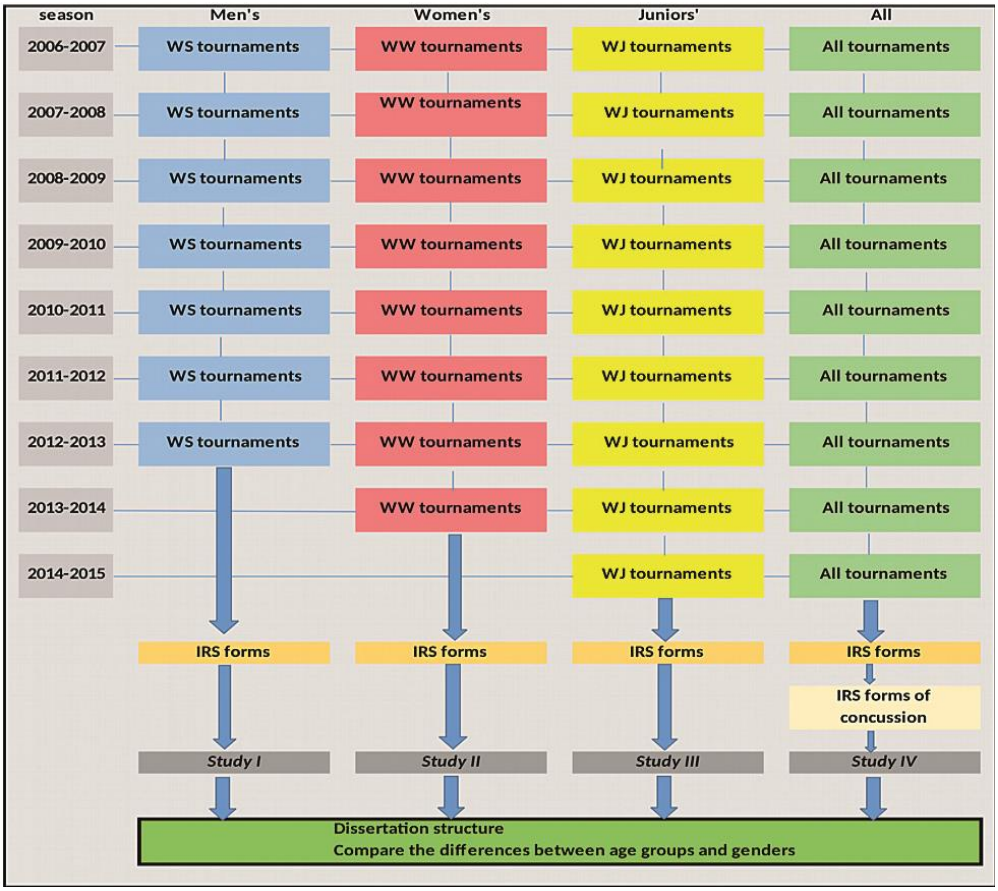


FIGURE 3. The flow of injuries

For *Study IV,* all concussions during the nine ice hockey seasons between 2006 and 2015 (from 1 July 2006 to 30 June 2015) were analysed from the 169 ice hockey tournaments. Forty-four of them were World Senior Championships (WS) (ten of them were A-pool tournaments), two Olympic Winter Games (OWG), and eight Olympic Qualification tournaments. Seventy tournaments were World Junior Under-18 and Under-20 Championships (WJ U18; WJ U20) (19 of them were A-pool tournaments). Forty-three tournaments were women's World Championships (WW) (14 of them were A-pool tournaments), and two OWGs. Fifteen of the Women's World Championships were Women's Under-18 tournaments (WW U18) (table 3, figure 3). A total of 3293 games were played in the 169 tournaments by 1212 teams comprising 142244 athletic game exposures.

	Tournaments	Groups	Number of tournaments
WC	World Men Championships (WC)		7
	Olympic Winter Games (OWG)(2010)		1
	Olympic Qualification Tournaments		8
	World Men Championships Division I (WC Div I)	Gr A	7
		Gr B	7
	World Men Championships Division II (WC Div II)	Gr A	2
		Gr B	7
	World Men Championships Division III (WC Div III)		2
	Total		41
WWC	World Women Championships (WWC)		6
	Olympic Winter Games (OWG)(2010, 2014)		2
	Olympic Qualification Tournaments		3
	World Women Championship Division I (WWC Div I)	No groups	2
		Gr A	3
		Gr B	1
	World Women Championships Division II (WWC Div II)	No groups	2
		Gr A	1
		Gr B	2
	World Women Championships Division III (WWC Div III)		1
	World Women Championships Division IV (WWC Div IV)		2
	Total		25
WWC U18	World Women Championships U18 (WWC U18)		8
	World Women Championships U18 Division I (WWC U18 Div I)	No groups	4
		Gr A	1
	WWC U18 Div I QT		1
	Total		14

	Tournaments	Groups	Number of tournaments
WC U20	World Juniors U20 Championship (WC U20)		9
	World Juniors U20 Championship Division I (WC U20 Div I)	Gr A	9
		Gr B	5
	World Juniors U20 Championships Division II (WC U20 Div II)	Gr A	6
		Gr B	4
	World Juniors U20 Championships Division III (WC U20 Div III)	No groups	3
	Total		36
WC U18	World Juniors U18 Championship (WC U18)		9
	World Juniors U18 Championship Division I (WC U18 Div I)	Gr A	7
		Gr B	7
	World Juniors U18 Championships Division II (WC U18 Div II)	Gr A	5
		Gr B	3
	World Juniors U18 Championships Division II (WC U18 Div II)	No groups	1
		Gr A	1
	Total		33

TABLE 2. Investigated tournaments in the World Men's Championships (WC), World Juniors' Under-20 Championships (WJ U20), World Juniors' Under-18 Championships (WJ U18), Women's Championship (WWC) and the World Women's Under-18 Championship (WWC U18).

	Tournaments	Groups	Number of tournaments
WS	World Men Championships (WS)		10
	Olympic Winter Games (OWG)(2010,2014)		2
	Olympic Qualification Tournaments		8
	World Men Championships Division I (WS Div I)	Gr A	9
		Gr B	9
	World Men Championships Division II (WS Div II)	Gr A	4
		Gr B	8
	World Men Championships Division III (WS Div III)		4
	Total		54
WC U20	World Juniors U20 Championship (WC U20)		10
	World Juniors U20 Championship Division I (WC U20 Div I)	Gr A	9
		Gr B	5
	World Juniors U20 Championships Division II (WC U20 Div II)	Gr A	6
		Gr B	4
	World Juniors U20 Championships Division III (WC U20 Div III)	No groups	3
	Total		37
WC U18	World Juniors U18 Championship (WC U18)		9
	World Juniors U18 Championship Division I (WC U18 Div I)	Gr A	7
		Gr B	7
	World Juniors U18 Championships Division II (WC U18 Div II)	Gr A	5
		Gr B	3
	World Juniors U18 Championships Division II (WC U18 Div II)	No groups	1
		Gr A	1
	Total		33
WWC	World Women Championships (WWC)		7
	Olympic Winter Games (OWG)(2010, 2014)		2
	Olympic Qualification Tournaments		3
	World Women Championship Division I (WWC Div I)	No groups	2
		Gr A	4
		Gr B	2
	World Women Championships Division II (WWC Div II)	No groups	2
		Gr A	2
		Gr B	3
	World Women Championships Division III (WWC Div III)		1
	World Women Championships Division IV (WWC Div IV)		2
	Total		30
WWC U18	World Women Championships U18 (WWC U18)		9
	World Women Championships U18 Division I (WWC U18 Div I)	No groups	4
		Gr A	1
	WWC U18 Div I QT		1
	Total		15

TABLE 3. Investigated tournaments for *Study IV* in the World Men's Championships (WS), World Juniors' Under-20 Championships (WJ U20), World Juniors' Under-18 Championships (WJ U18), Women's Championship (WWC) and the World Women's Under-18 Championship (WWC U18).

4.2.2 Definition of an injury

In *Studies I-IV*, the definition of an injury was made in accordance with the accepted international ice hockey norms (Stuart & Smith 2000). The definition of an injury was the combination of time-loss injuries and injuries that required medical attention including lacerations, all dental injuries, concussions and fractures. Minor injuries that allowed the athlete to continue playing and did not require medical attention were not included. An injury was reported when one of the following criteria was observed:

- any injury sustained in a practice or a game that prevented the player from returning to the same practice or game;
- any injury sustained in a practice or a game that caused the player to miss a subsequent practice or game;
- a laceration that required medical attention;
- all dental injuries;
- all concussions;
- all fractures.

A concussion was a clinical diagnosis made by a team physician. At the Team Medical Personnel Meeting before every tournament physicians were advised to follow the recommendations provided by the Consensus Statement on Concussion in Sport and were given the Sport Concussion Assessment Tool (SCAT) to use as a tool in making the clinical diagnosis (Aubry et al 2002, McCrory et al 2005, McCrory et al 2009, McCrory et al 2013a).

Concussions caused by illegal contacts were defined as checking to head (CTH), checking from behind (CFB), sticks, fighting and body contact (BC) in female games. All other concussions were caused by legal contact.

4.2.3 Population at risk

The population-at-risk or player exposure to injury was determined by an estimation of the collective playing time. The number of player-games was based on 20-22 players competing for each team in a game, depending on the specific level and year of a given tournament. Only

the participating athletes were included in the denominator when calculating the incidence of injury. All the players of the team participating in a game, had an impact on the game, and were at risk for injury during every moment of the game.

4.2.4 Data collection

Before each tournament, a team medical personnel meeting (TMPM) was organised by the IIHF Medical Supervisor (MS). The TMPM gave the Medical Supervisor the ability to review the definition of each injury, the game injury report form (GIR) and the injury report system (IRS, figure 5) form to the individual team physicians. The GIR form was used to verify the number of injuries that satisfied the definition (figure 4). The individual team physician followed all the players on their team and submitted the GIR form to the Medical Supervisor after each game. The team physician was also required to complete a detailed injury report (IRS form) for every injury. The IRS form was returned to the Medical Supervisor during the tournament as soon as all the sufficient information had been obtained and the final diagnosis was confirmed. Each championship the IIHF Medical Supervisor was assigned and was responsible for the data collection. The IRS form was filled out only once for each injury. It included detailed information on the game period, ice location, mechanism, anatomical site, severity and specific injury diagnosis. Time-loss was used as a proxy to determine the injury severity. The severity was graded into four groups by the team physician according to the IRS form (figure 5). The anonymous forms were returned to the IIHF Medical Committee for insertion into a computer-based injury report system for ice hockey injuries (Medhockey, Medisport Ltd, Finland) (figure 6).

IIHF Daily Injury Report Form

IIHF Championship: _____

National Association: _____

Date: _____ / _____ / _____ (dd/mm/yy)

Using this form, please report if there were any injuries sustained by any player on your team during the above-mentioned day during this IIHF Championship. We would ask that you also report if there were no injuries sustained by players on your team during this day of this IIHF Championship. If an injury was sustained during this day then an IIHF Injury Report Form must be completed and submitted to the IIHF Medical Supervisor or, in his absence, to the IIHF Directorate Chairman providing the details of the injury sustained.

The definition of an injury used by the IIHF for reporting purposes is as follows:

1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player does not return to the play for the remainder of the game following an injury
3. All concussions
4. All dental injuries
5. Any laceration which requires medical attention
6. All fractures

Please check (✓) the appropriate box below. Please provide the number of injuries sustained if you check article 'A'.

Injury Report	(✓)
A. During this day there were _____ injuries sustained by our team. (number)	
B. During this day there were no injuries sustained by our team	

Team Physician/Medical Representative: _____ (print name)

Signature: _____

Date: _____

FAIR PLAY AND RESPECT

November 2010

FIGURE 4. The IIHF game injury report form.

Injury Report System/IRS

(only one injury/form)

Injury Definition

The definition of an injury in the IIHF Injury Reporting System is as follows
1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player doesn't return to the play for the remainder of the game following an injury
3. All concussions
4. Any dental injury
5. Any laceration which requires medical attention
6. All fractures

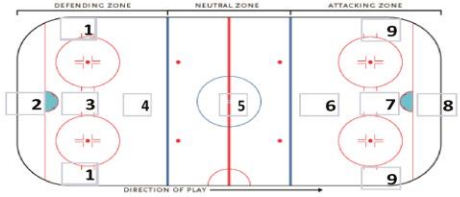
Country: _____ **IIHF Championship:** _____ **Date of injury:** D _____ M _____ Y _____

Zone of Injury A

1. No contact with boards
2. Contact with boards

Zone of Injury B

Mark the area on the ice surface where the injury occured.
Note that Home and Visitor ends are marked to identify offensive and defensive activity



Game / Period
1. warm up
2. 1st
3. 2nd
4. 3rd
5. Ot
playing time: _____

off-ice / on-ice

Practice
off-ice / on-ice

Situation

Even Strength	5/5	Penalty Killing	4/5
	4/4		3/5
	3/3		3/4
Power Play	5/4	Goalie	
	5/3	1. Yes	
	4/3	2. No	

Source of Diagnosis
1. Medical Doctor 2. Physiotherapist 3. Other _____

Side / Body part: fill out a separate form for each injury

1. N/A 2. Left 3. Right 4. Both

1. Head	10. Shoulder	19. Chest	28. Genitals
2. Face	11. Scapula	20. Abdomen	29. Hip
3. Neck	12. Upper arm	21. Kidneys	30. Thigh
4. Throat	13. Elbow	22. Upper Back	31. Knee
5. Jaw/Chin	14. Forearm	23. Lower Back	32. Leg
6. Teeth/Mouth	15. Wrist	24. Coccyx	33. Ankle
7. Eye	16. Hand	25. Buttocks	34. Foot
8. Ear	17. Thumb	26. Pelvis	35. Toes
9. Clavicle	18. Fingers	27. Groin	36. Other: _____

Dental: Mouthguard? 1. Yes 2. No
Custom made? 1. Yes 2. No

Knee: Circle the appropriate structure involved:
1. ACL 2. PCL 3. MCL 4. LCL 5. Meniscus 6. PF*
Grade: 1. _____ 2. _____ 3. _____

Shoulder: Circle the appropriate structure involved:
1. AC* 2. SC* 3. Glenohumeral
Grade: 1. _____ 2. _____ 3. _____

Player information:
1. Age _____
2. Height (cm) _____
3. Weight (kg) _____

Position:
1. Centre
2. Wing
3. Defence
4. Goalie

Nature of injury:
1. Acute 2. Recurrent:
a. this season
b. last season

Dx/assessment:
1. Contusion
2. Sprain (Ligament)
3. Strain (Muscle-Tendon)
4. Laceration
5. Dislocation/Subluxation
6. Fracture
7. Neurotrauma/Concussion
8. Other _____

Time Lost:
The amount of time player is expected to be out of play
1. Return same day
2. Less than 1 week
3. 1 to 3 weeks
4. More than 3 weeks

Cause of injury:
1. Type of Check
a. Body Check
b. Check from Behind
c. Check to the Head
2. Stick Contact
3. Puck Contact
4. Unintended Collision
5. Fighting
6. Non-Contact
7. Skate
8. Other: _____

Was a penalty Called on the Play?
1. Yes 2. No
1. 2 min.
2. 2+2 min
3. 2+10 min
4. 5+20 min
5. Other: _____

Diagnosis:
ICD-code **DG:** _____

Equipment:
1. Full Face mask
a. shield _____
b. cage _____
2. Visor _____
3. None _____

PF= Patellofemoral, Kneecap **AC= Acromioclavicular Joint** **SC= Sternoclavicular Joint**

FIGURE 5. The IIHF individual injury report form.

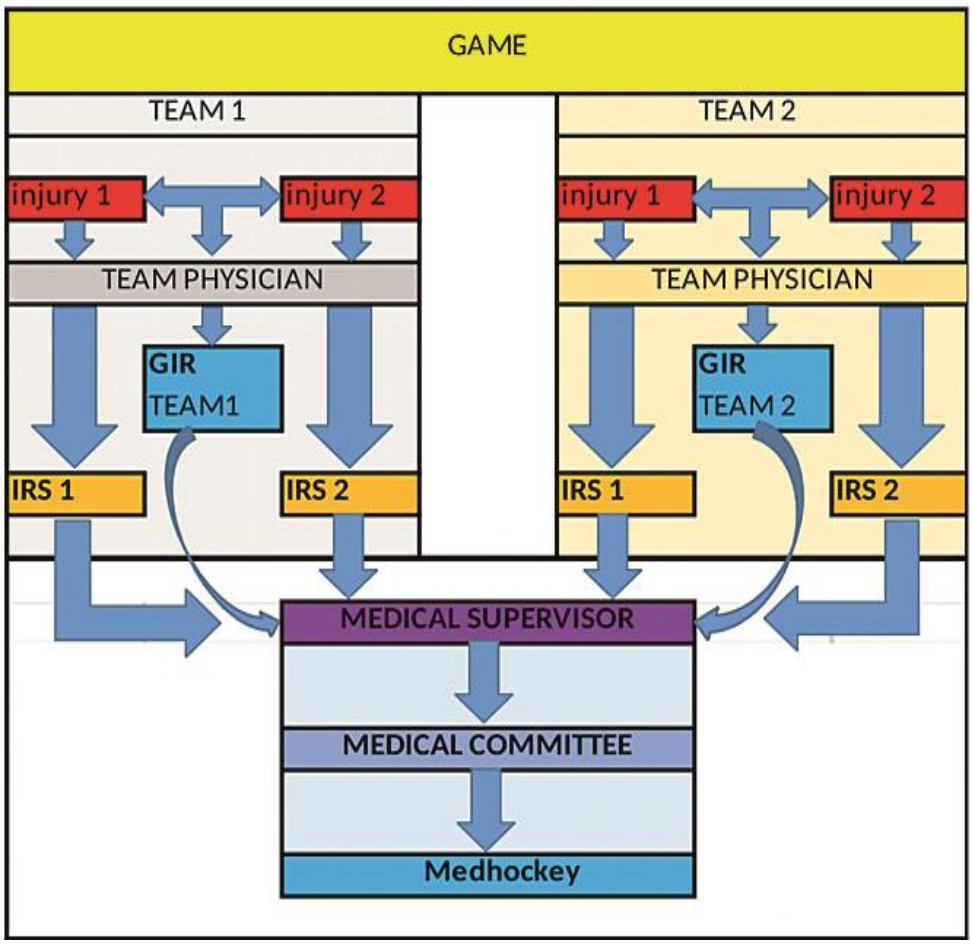


FIGURE 6. Data collection system for *Studies I-IV* (GIR = game injury report form, IRS = injury report form)

4.2.5 Incidence of injury

Injury rate (IR) was expressed as the number of injuries per 1000 ice hockey player-games and/or per 1000 player-game hours. These two different injury rate definitions were used to allow better comparison with other ice hockey leagues and other sports (rugby, football, basketball). Injuries that occurred during practice were excluded because there were very few documented practice injuries. Therefore, the given injury rates in this dissertation refer to game injuries only.

The player-game injury rate was an average risk of injury for one individual player per 1000 games (# injuries / # players (two teams) / # games x 1000 = injuries per 1000 player-games). These results are mostly comparable to the results per 1000 athlete -exposures in games. The injury rate for 1000 player-game hours was based on a 60-minute active game with five players and a goalie per team on the ice at the same time (# injuries / # players on ice same time (two teams) / # games x 1000 = number of injuries per 1000 player-game hours). These results are comparable to the results from the European leagues and other studies from the European sports.

4.2.6 Statistical analyses

As noted above, the given injury rates refer to game injuries only (practice injuries excluded). In *Study I*, results from A-pool (top level) tournaments were reported separately. The subgroup 'flexible boards and glass' was collected from the tournaments where comparable boards with the NHL were used. The more flexible boards and glass were developed to improve player safety (Poutiainen et al 2014). To determine the association between the arena characteristics and occurrence of injuries, Poisson and Logistic regressions were used. Logistic regression was used when the number of analysed injuries in each game was zero or one. In other statistical analyses, Poisson regression was applied to allow for several injuries per game. In these analyses, weighting with standardised active playing time was employed. Generalised Estimating Equations (GEE) were used to determine the association between the concussion and player position in A-pool tournaments.

In *Study II* the injury results are presented as total numbers, percentages and rates (injuries per 1000 player-games and per 1000 player-game hours). Risk ratios and 95% confidence intervals for player position-wise concussion were calculated by comparing concussions in one position to concussions in all other positions. Time-loss was used as a proxy for the severity of an injury.

The outcomes from A-pool tournaments are reported separately in *Study III*, because they represent the top-level international championships in each age group. The injury results are presented as

total numbers, percentages and rates (injuries per 1000 player-games and per 1000 player-game hours).

In *Study IV* the outcomes from A-pool (top/highest level in each age group and gender) tournaments are reported separately, because the tournaments represent the highest level of international championships in each age group. The injury results are presented as total numbers, percentages and rates (injuries per 1000 player-games and per 1000 player-game hours). Risk ratios (RRs) and 95% confidence intervals (Cl) for concussion were calculated by comparing traditional boards and glass to flexible boards and glass (Poutiainen et al 2014). RRs were also used to compare differences between the genders. Odds ratios (ORs) and 95% CI were calculated to determine the association between player's positions, groups, causes, the arena characteristics and concussions. ORs were calculated for the senior women's World Championships and World Women Under-18 tournaments separately.

4.2.7 Reliability and validity of the injury registry system

The IIHF has used the above-described injury report system since 1998. Thus, the questionnaires were thoroughly tested prior the start of the current study period. An injury was precisely defined, and before each tournament, the injury definition was explained to the team physicians by the IIHF Medical Supervisor during the team medical personnel meeting. Game injury report (GIR) and individual injury report (IRS) forms were also checked and discussed during each meeting.

The IIHF Medical Supervisor collected all the forms after each game to ensure 100% data collection from each reported injury. Personal contact with the team physician after each game gave the ability for the Medical Supervisor to diminish selection bias and guarantee proper completion of each IRS form. The seven- to nine-year study period increased the number of outcomes and thus improved the reliability and validity of the study.

The IIHF Injury Reporting System was in use before this PhD candidate started the project, but he took part in the development of the GIR form and the second edition of the IRS form before the current data collection period. The PhD candidate has been developing the Medhockey software, together with Medisport Ltd. (Finland) and the

testing of the program was carried out during the 2005-2006 season before actual deployment. The Medical Supervisors of the tournaments was also educated by the PhD candidate regarding injury definition and data collection. During the entire thesis process, he has been the key person in data management, data cleaning and data analysis.

5 RESULTS

5.1 Injuries in men's international ice hockey

We registered, with permission from the IIHF, all ice hockey injuries from 32 men's World Championships, one Olympic Winter Games and eight Olympic qualification tournaments during seven ice hockey seasons from 2006 to 2013. A total of 844 games were played in the 41 tournaments by 303 teams (6666 players). A-pool (top) level competitions consisted of 436 games in the 8 tournaments played by 124 teams (2728 players).

5.1.1 Incidence of injuries

In total, 528 injuries in 511 incidents were reported in 844 games. The injury rate per 1000 player-games was 14.2 for all men's World Championships (WC) and 16.3 per 1000 player-games for men's WC A-pool tournaments and the Olympic Winter Games (OWG). The annual injury rate ranged between 12.2 (2011) and 17.5 (2008) in men's WC and from 10.3 (2013) to 20.6 (2008) in men's A-pool tournaments and OWGs. The injury rate per 1000 player-game hours was 52.1 for all men's World Championships and 59.6 for men's WC A-pool tournaments (figure 7).

5.1.2 Head and face injuries

The head and face were the most frequently injured body parts (39.8%; IR 5.7) (figure 8). The face was the most common location. Facial injuries comprised 72.4% of the head injuries in all men's World Championships, and the injury rate was 4.1 per 1000 player-games. Seventy-four percent of facial injuries were lacerations, and 59.3% of them were caused by a stick. The injury rate for dental injuries was 0.5

(9.5% of the head injuries) and for eye injuries 0.1 (1.4%) per 1000 player-games.

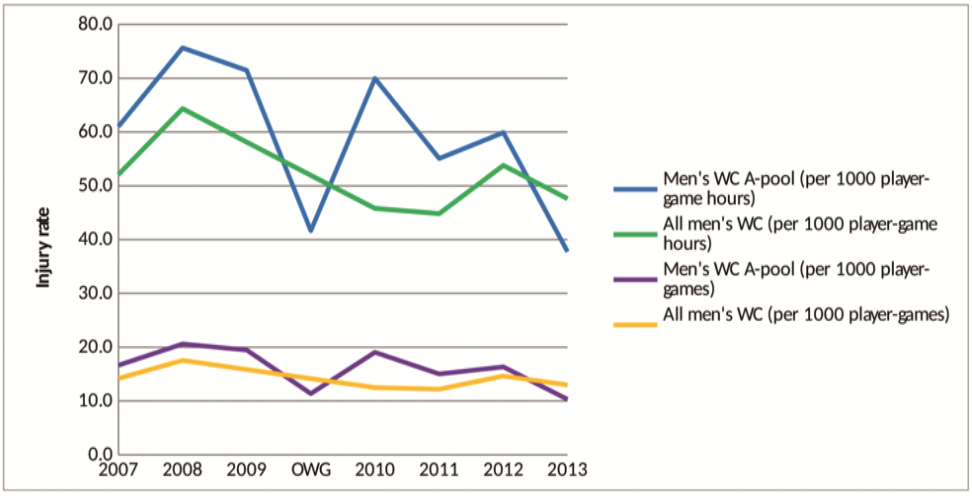


FIGURE 7. Annual ice hockey injury rates for all men's World Championship and men's World Championship A-pool tournaments.

FIGURE 8. Injury rate by anatomic region per 1000 player-games in men's ice hockey World Championship tournaments.

5.1.3 Lower-body injuries

Lower-body injuries consist of 30.7% of all injuries. The knee was the most common lower-body injury site: 46.9% of the lower-body injuries affected the knee. The injury rate was 2.0 per 1000 player-games for knee injuries. Medial collateral ligament (MCL) sprain was the most common knee injury (56.6% of the knee injuries). Most of the MCL injuries (51.2 %) were mild, Grade I sprains. Anterior cruciate ligament (ACL) disruption covered 10.5% of all knee injuries. Ankle and thigh injuries were the second and third common lower-body injuries (figure 8).

5.1.4 Upper-body injuries

Injuries involved the upper-body in 21.8% of game injuries. The most common location was the shoulder (49.6%). The injury rate was 1.5 per 1000 player-games for shoulder injuries. Acromioclavicular joint sprain (50.9%) and glenohumeral joint injury (40.4%) were the most frequent diagnoses. The fingers (14.2%), wrist (10.8%) and hand (10.8%) injuries were in the second, third and fourth positions, respectively (figure 8).

5.1.5 Injury types by diagnosis

The vast majority of injuries (92.8%) were acute in nature. Lacerations were the most common type of injury (26.1%). Sprains (21.8%) and contusions (15.0%) made up the next largest groups. Fourteen percent of injuries were fractures. Neurotrauma was diagnosed in 9.9% (Figure 9).

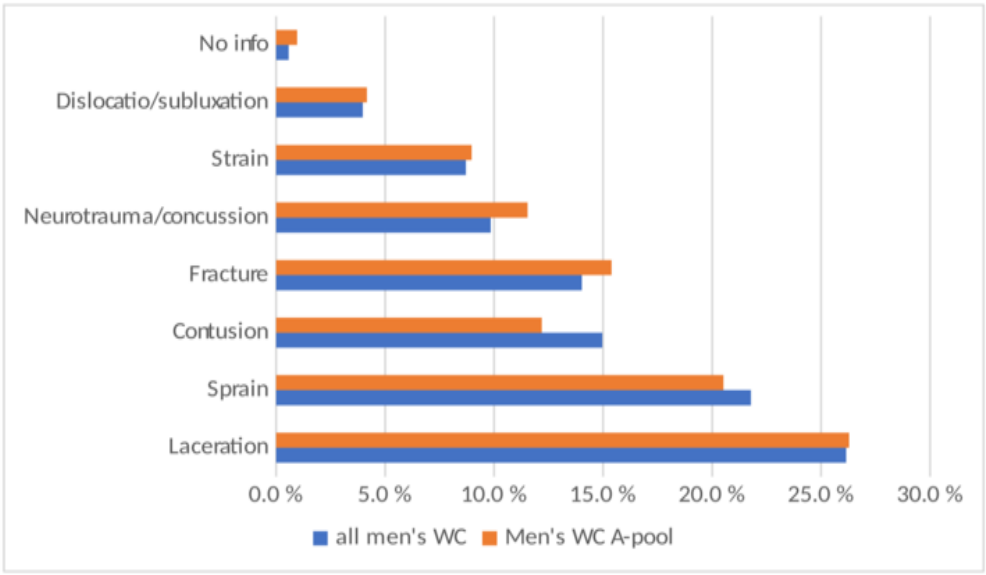


FIGURE 9. Injury distribution by diagnosis in the men's World Championship games.

5.1.6 Concussions

The injury rate of concussions was 1.4 per 1000 player-games in all men's World Championships and 1.9 in men's A-pool tournaments. Checks to the head were the most common cause for concussions (51.9%). In one-third of concussions, a penalty was called. For those players diagnosed with a concussion, 11.5% returned to play in the same game (men's WC A-pool = 5.6%). The centre had the highest percentage for concussion 25.0% (30.6% in men's WC A-pool). The majority of concussions occurred during the first period (42.3%; 47.2% in men's WC A-pool).

5.1.7 Contact with the boards

Most injuries occurred away from the boards (68.5%). This trend was apparent in all championships and was similar over the seven-year study period. A shoulder injury was the most common injury type that

occurred with board contact (27.3%). On the other hand, sixty-three percent of all shoulder injuries occurred with board contact. The majority of concussions occurred without board contact (55.8%).

5.1.7.1 Flexible boards and glass

There was a 29% lower risk of injury in the arenas where flexible boards and glass were used compared to arenas with traditional boards and glass [IRR 0.71, (95% CI 0.56 to 0.91)]. The A-pool WC tournaments that were played in arenas with flexible boards and glass had a shoulder injury rate of 0.9/1000 player-games as compared to 2.2/1000 player-games when traditional boards and glass were in place [IRR 0.36, (95% CI 0.15 to 0.90)] (figure 10). In addition to these significant findings, there were fewer concussions when flexible boards and glass were used instead of traditional boards and glass [OR 0.43, (95% CI 0.18 to 1.01)]. Also, there was a trend for a decrease in all other types of injuries in arenas with flexible boards and glass compared to arenas with traditional boards and glass [IRR 0.82, (95% CI 0.61 to 1.09)].

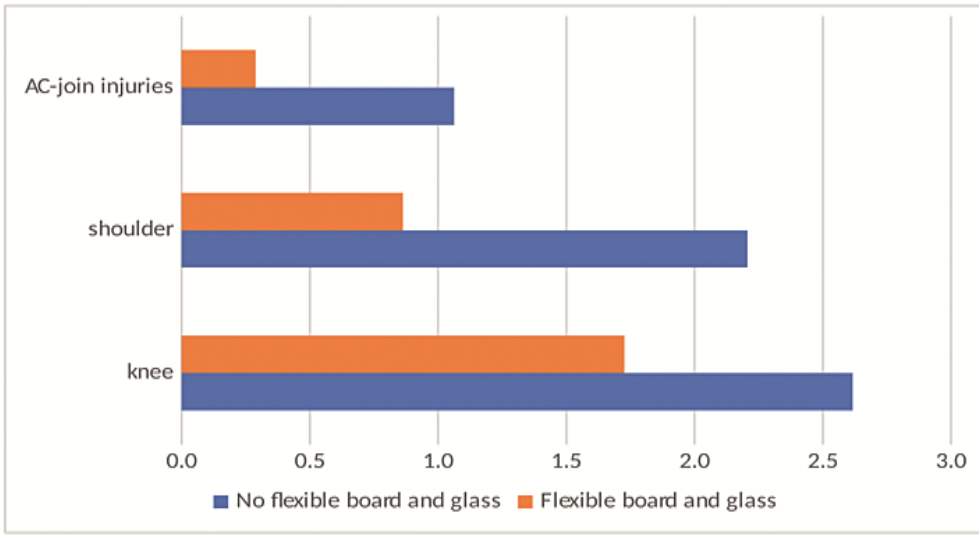


FIGURE 10. Injury rate at the shoulder, acromioclavicular and knee per 1000 player-games in men's World Championship A-pool tournaments. Flexible versus non-flexible boards and glass.

5.1.8 Causes of injury, penalties, injury severity

The three most common causes of the injuries were body checking (27.2%), hockey stick (21.1%) and puck (12.3%) contact. Seventy-seven percent of stick injuries involved the head and face. Penalties were assessed in 25.9% of stick injuries. Forty percent of checking to the head and nearly half of hitting from behind injuries resulted in a penalty called. In 14.5% of the injured players a recovery time was more than three weeks. The majority of injured players (53.8%) returned to play within one week.

5.1.9 Player position

Injuries were equally distributed according to player position. The goalkeeper was the least injured in all the positions (3.5%) despite the fact that the goalkeeper is on the ice for the entire game. The proportion of concussions sustained by the centre was about twice that of the defense and wing in the men's A-pool tournaments [OR 2.01, (95% CI 0.87-4.66)].

5.2 Injuries in women's international ice hockey

5.2.1 Incidence of injury

One hundred and sixty-eight injuries were reported in 637 games. For all female tournaments (WWC U18, WWC and OWG), the injury rate per 1000 player-games was 6.4. The annual injury rate ranged between 4.5 (2014) and 11.2 (2010) per 1000 player-games. The injury rate was higher for World Women's Under-18 Championship tournaments (IR 7.5/1000 player-games) than in World Women's Championships (IR 5.7 per 1000 player-games). The annual injury rate ranged between 4.2 (2012) and 11.2 (2013) per 1000 player-games in WWC U18 and from 3.6 (2011) to 11.3 (2010) in WWC tournaments (figure 11). The injury rate per 1000 player-game hours was 22.0 for all female tournaments, 25.6 for World Women's Under-18 Championship tournaments, 19.7

for World Women's Championship tournaments and 29.8 for Olympic Winter Games.

5.2.2 Head and face injuries

Injuries involved the head and face in 20.8% of game injuries (IR 1.3; WWC U18 IR 1.9; WWC IR 1.0). A concussion was the most common head injury (74.3%; IR 1.0 per 1000 player-games). Lacerations were in 8.6% and dental injury in 5.7% (IR 0.1) of head and facial injuries. There were no eye injuries. Seventeen percent of the head and face injuries were facial injuries with an injury rate of 0.2/1000 player-games in all female tournaments (WWC U18 21.1%; IR 0.4; WWC 13.3 %; IR 0.1) (figure 12).

5.2.3 Lower-body injuries

The lower-body was the most commonly-injured body area (42.9%; IR 2.7 per 1000 player-games). The knee was the most frequent site of lower-body injury (48.6%; IR 1.3). The two most common knee injuries were medial collateral ligament (MCL) sprain (37.1%) and knee contusion (28.6%), respectively. Disruption of the anterior cruciate ligament (ACL) was found in 11.4% of all knee injuries. Ankle (27.8%; IR 0.8) and thigh injuries (8.3%; IR 0.2) were the second and third most common lower-body injuries (figure 12).

5.2.4 Upper-body injuries

The upper-body injuries consist of 22.0% of all injuries (IR 1.4 per 1000 player games). The shoulder was the most common location for an upper-body injury (32.4%), and the injury rate for it was 0.5 per 1000 player-games. Acromioclavicular (AC) joint sprain was the most frequent diagnosis, comprising one half of all shoulder injuries. Wrist (18.9%) and elbow (18.9%) injuries were the second and third most common upper-body injuries.

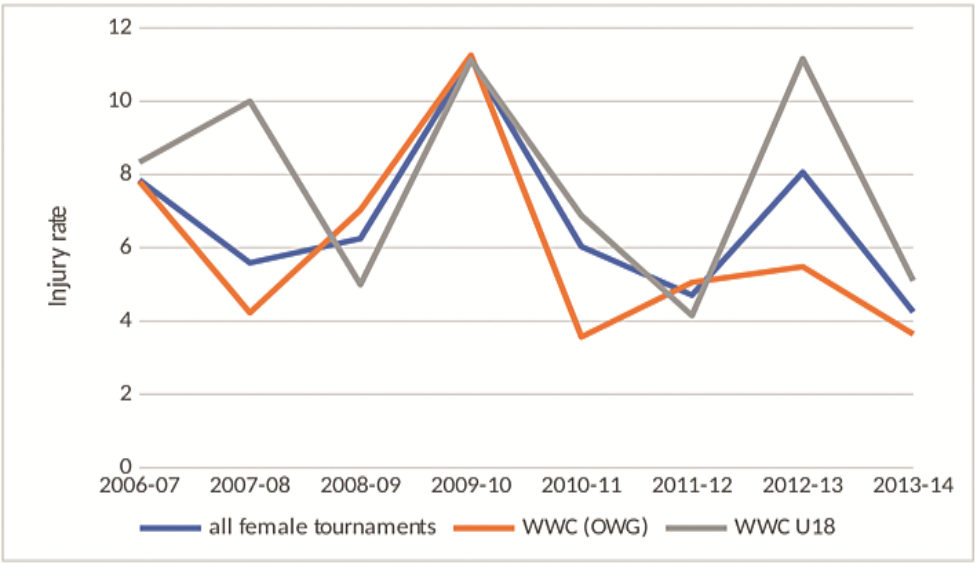


FIGURE 11. Annual ice hockey injury rates per 1000 player-games for all female tournaments, WWC and WWC U18 (OWG, Olympic Winter Games; WWC, World Women's Championship; WWC U18, World Women's Under-18 Championship).

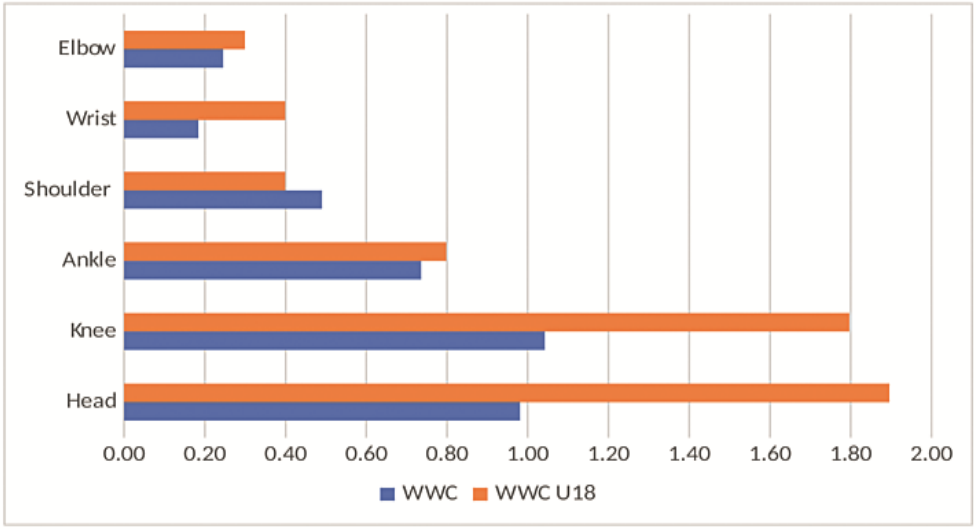


FIGURE 12. Injury rate by anatomic region per 1000 player-games in the World Women's Championship and World Women's Under-18 Championship.

5.2.5 Injury types by diagnosis

The vast majority of injuries (80.8%) were acute in nature. Most of the injuries were contusions (28.0%), followed by sprains (20.8%). The proportion for concussions was 15.5%. Twelve percent of injuries were strains, and five percent of them were lacerations (figure 13).

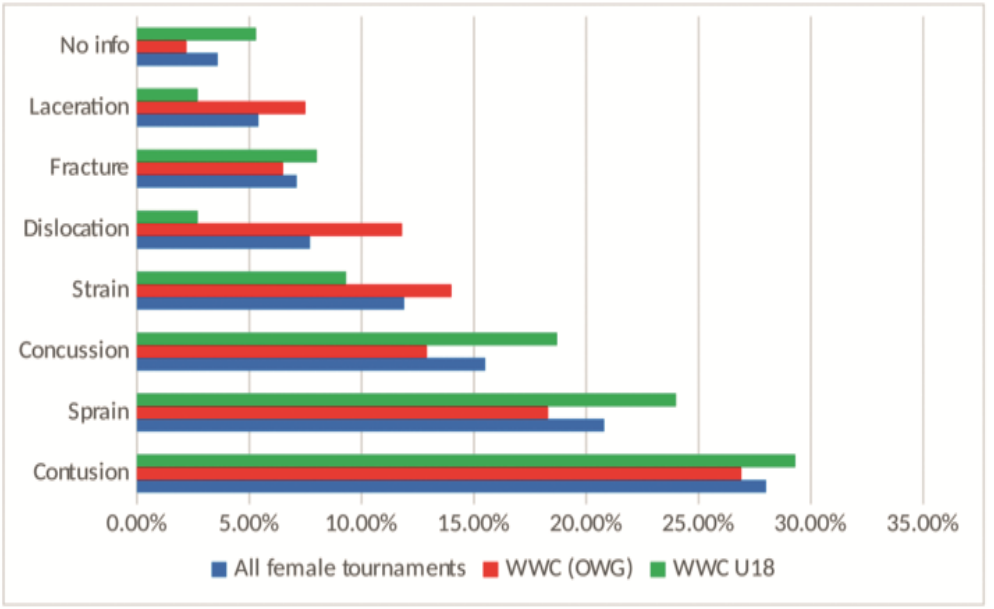


FIGURE 13. Injury distribution by diagnosis in all female tournaments, WWC and WWC U18 (OWG, Olympic Winter Games; WWC, World Women's Championship; WWC U18, World Women's Under-18 Championship).

5.2.6 Concussions

The concussion injury rate (IR) was 1.0 per 1000 player-games in all female tournaments. The concussion rate was two times higher (IR 1.4) in the World Women's Under-18 Championship tournaments than that of the World Women's Championship tournaments (IR 0.7). Unintended collisions (34.6%) and body checks (30.8%) were the two most common causes for concussions. A penalty was called in only one-fourth of the events when a concussion was caused by a body check. For those players diagnosed with a concussion, 11.5% returned

to play in the same game. The centre position had the highest risk for concussion (IR 1.6/1000 player-games), followed by the defense position (IR 0.5) and wing (IR 0.4). The risk ratio for a concussion at the centre position versus all other positions was 4.29 (95% CI 1.99 to 9.24). Most concussions occurred during the second (30.8%) and third (34.6%) periods. The majority of concussions occurred without board contact (65.4%).

5.2.7 Causes of injury, penalties and injury severity

Unintended collision (26.3%) was the most common cause of injury in women's ice hockey, followed by body checking (24.6%), and puck contact (12.0%), respectively. Injuries caused by a stick were mostly lower-body injuries (70.0%). Penalties were assessed in 24.4% of body check injuries, 40.0% in checking to the head and 50.0% in checking from behind injuries.

Almost ten percent of the players who were injured did not return for at least three weeks. Most of the severe injuries were wrist and hand fractures and knee sprains. However, the majority of injured players returned to play within one week (58.1%).

5.2.8 Player position, period and zone

There were no significant differences between player positions concerning injuries other than concussion. The second and third period had the highest percentages of injured players (35.3%; 37.1%) during the game. There were only a few injuries sustained during the warm up (2.3%) and overtime (1.7%). Players sustained injuries in the home zone (39.5%), visitor zone (31.7%) and neutral zone (19.8%).

5.3 Injuries in juniors' international ice hockey

5.3.1 Incidence of injury

Six hundred and thirty-three injuries were reported in 1326 games. The injury rate per 1000 player-games was 11.0 for all World Junior Championships. The annual injury rate ranged between 7.7 (2008) and 14.4 (2009). For the WJ U20 tournaments, 361 injuries were reported in 695 games comprising 29992 athletic game exposures. The injury rate was 12.0 per 1000 player-games, and the annual injury rate ranged from 7.0 (2008) to 15.8 (2009) (figure 14). For the WJ U18 tournaments, 272 injuries were reported in 631 games comprising 27334 athletic game exposures. The injury rate was 9.9 per 1000 player-games, and the annual injury rate ranged from 6.7 (2013) to 15.0 (2011) (figure 14). The injury rate per 1000 player-game hours was 39.8 for all WJ tournaments, 43.3 for WJ U20 tournaments and 35.9 for WJ U18 tournaments. Over the 9-year study period, there was a trend towards an increase in upper-body injuries and a decrease in lower-body injuries.

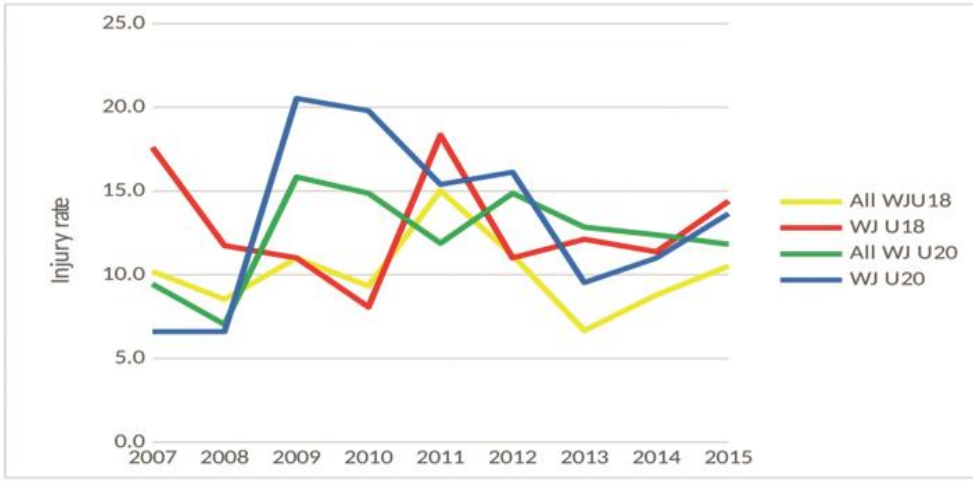


FIGURE 14. Annual ice hockey injury rates per 1000 player-games in all World Junior Under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior Under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).

5.3.2 Head and face injuries

The head and face were the most frequently injured body part in WJ U20 tournaments (48%; IR 5.8/1000 player-games; 20.6/1000 player-game hours) (figure 15). Facial injuries comprised 76% of the head and face injuries in all WJ U20 Championships with an injury rate of 4.4 per 1000 player-games. Eighty percent of the facial injuries were lacerations (IR 3.6), 41% were caused by a stick and a penalty was called less than 20% of the time. The dental injury rate was 0.7 (11% of the head injuries). No eye injuries were reported.

In WJ U18 tournaments, a concussion was the most common head and face injury (46%; IR 1.2 per 1000 player-games; 4.2 per 1000 player-game hours). Lacerations consist of forty-four percent of all injuries (IR 1.1), while 7% were dental injuries (IR 0.2). In WJ U18 tournaments, nearly half of the head and facial injuries involved the face with an injury rate of 1.2 per 1000 player-games. In WJ U18 A-pool (top level) tournaments, a laceration was the most common head and face injury (52%; IR 2.1). The proportion of concussions was 36% and IR 1.5 per 1000 player-games.

5.3.3 Upper-body injuries

Over the 9-year study period there was a trend towards an increase in upper-body injuries. Twenty-nine percent of injuries were upper-body injuries (IR 3.2 per 1000 player-games). The shoulder was the most common location for an upper-body injury in WJ U18 and WJ U20 tournaments (58%). The injury rate for shoulder injuries was 1.8 per 1000 player-games (6.7 per 1000 player-game hours) (figure 15). Acromioclavicular (AC) joint sprain (59%) was the most frequent diagnosis. In WJ U18 tournaments, the shoulder injury rate was 2.0 and in WJ U18 A-pool tournaments 2.4 per 1000 player-game hours. Finger and wrist injuries were the second and third most common upper-body injuries, respectively.

5.3.4 Lower-body injuries

The lower-body was involved in 24% of game injuries (IR 2.6 per 1000 player-games). The knee was the most frequent site of lower-body injury in World Junior tournaments (33%). The injury rate for the knee was 0.9 per 1000 player-games (3.1 per 1000 player-game hours) (figure 15). The most common knee injury was a medial collateral ligament (MCL) sprain (40%). Anterior cruciate ligament (ACL) rupture occurred in 6% of all knee injuries. Two-thirds of knee injuries resulted from unintended or intended collisions. Ankle and thigh injuries were the second and third most common lower-body injuries.

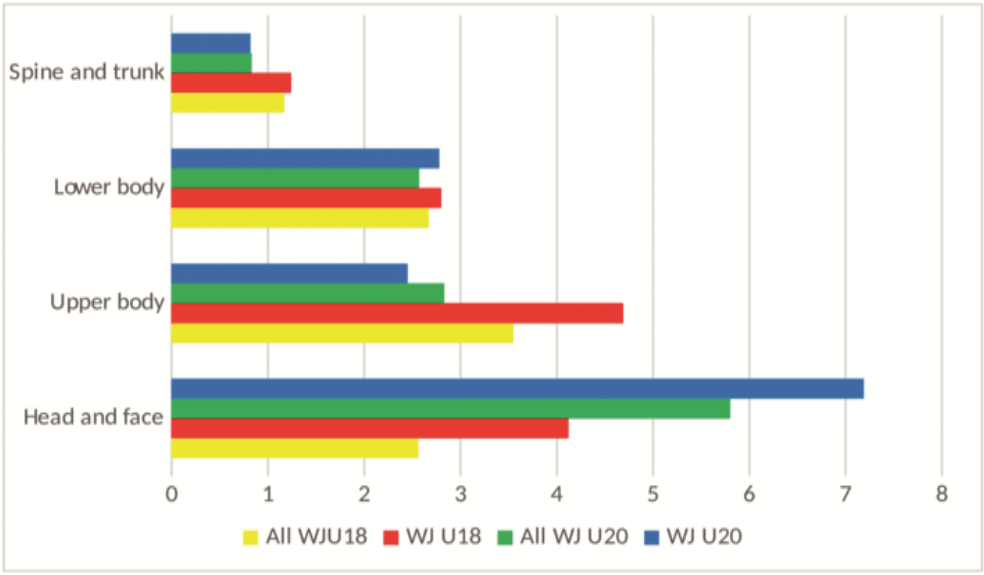


FIGURE 15. Injury rate by anatomical region per 1000 player-games in all World Junior Under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior Under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).

5.3.5 Injury types by diagnosis

Ninety percent of injuries were acute in nature. The most common diagnosis of injury was laceration (24%), followed by a contusion (22%), sprain (18%), concussion (10%) and fracture (10%) (figure 16). In

the U18 category, a sprain was the most common diagnosis of injury, while in the U20 age group a laceration was the most common injury type.

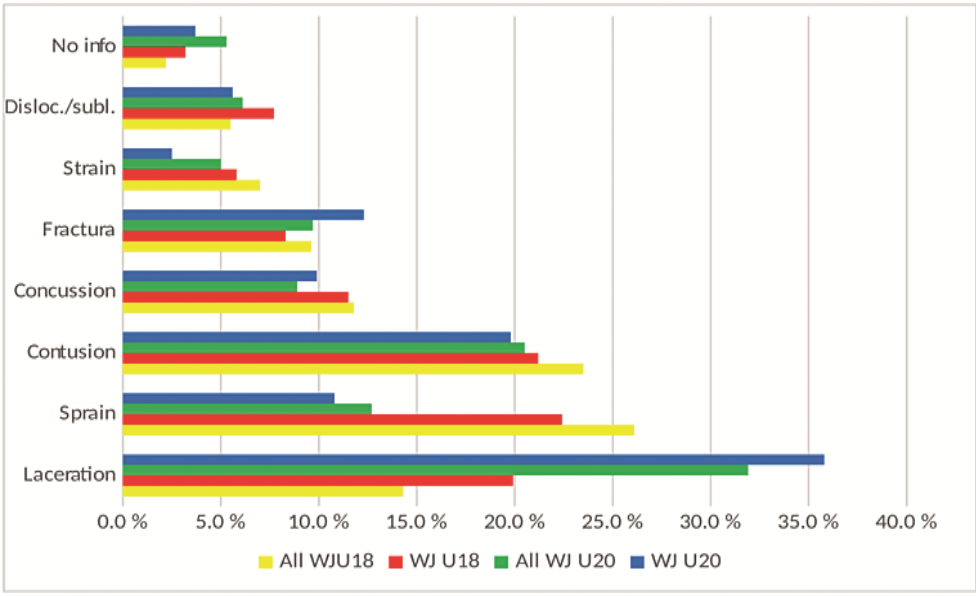


FIGURE 16. Injury rate by diagnosis per 1000 player-games in all World Junior Under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior Under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).

5.3.6 Concussions

The concussion injury rate was 1.1 per 1000 player-games (4.0 per 1000 player-game hours) in all WJ tournaments, 1.2 in WJ U18 tournaments and 1.0 in WJ U20 tournaments. Checking to head was the most common cause (48%) for concussion, followed by body checks (23%). Two-thirds of concussions were caused by illegal hits. A penalty was called in half of the events when checking to the head or checking from behind caused a concussion. For those players diagnosed with a concussion, six percent returned to play on the day of injury. The wing position (IR 0.5 per 1000 player-game hours) had the highest risk of concussion, followed by the defense position (IR 0.4) and centre (IR 0.1). Most concussions occurred during the third (38%) period.

5.3.7 Contact with the boards

Most injuries occurred away from the boards. In WJ U18 tournaments, 36% (IR 3.6; in A-pool (top level) IR 4.4) of injuries occurred with board contact. Twenty-four percent of the injuries occurred with board contact in WJ U20 tournaments (IR 2.9) (figure 17). Shoulder (30%) and head (18%) injuries were the two most common injuries that occurred in contact with the boards. Fifty-four percent of shoulder injuries were caused by board contact (59% in WJ U18). More than half of the concussions occurred without board contact.

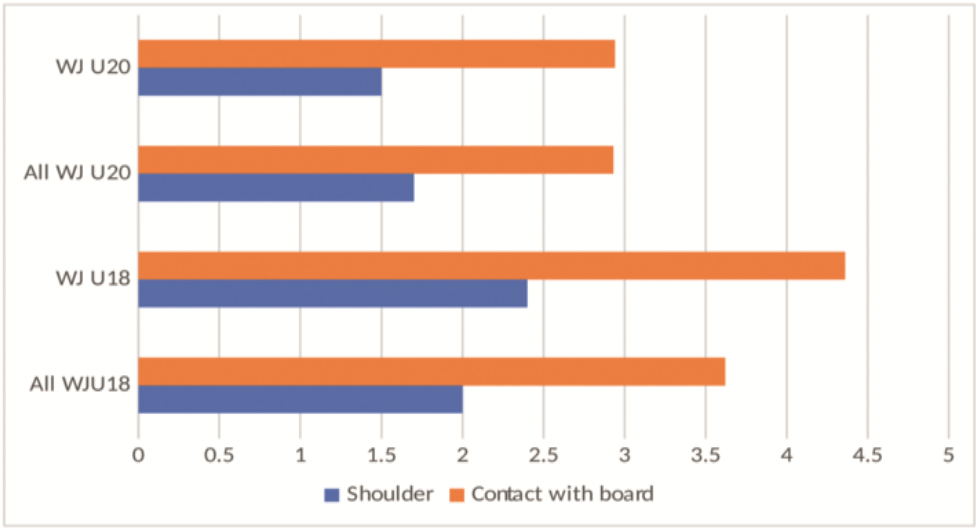


FIGURE 17. Injury rates for shoulder injuries and injuries occurred with board contact in all World Junior Under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior Under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).

5.3.8 Causes of injury, penalties and injury severity

Body checking was the most common cause of injury (32%), followed by stick (13%), and puck contact (13%). Half of the finger, hand and wrist injuries were caused by a puck or stick. In WJ U18 tournaments, body checking caused 39% of all injuries, while the stick caused only 3% of them. However, the stick caused one-fifth of the injuries in WJ

U20 tournaments. Seventy-eight percent of them occurred to the head and facial area. Penalties were assessed in 35% of the cases when checking to the head caused the injury while this figure was 46% when checking was from behind.

Based on an estimate of time recovery, ten percent of injured players did not return for at least three weeks. Most of the severe injuries were fractures (38%) and sprains (27%). The majority of injured players returned to play within one week.

5.3.9 Player position, period and zone

Injuries were distributed according to player position as follows: wing 44% (two wings per team), centre 17% (one centre per team), and defense 32% (two defenses per team). The goalkeeper was the least injured of all positions (3%). Half of the injuries occurred in the wing position in the WJ U18 tournaments. The second and third period had the highest percentages of injured players (34%, respectively) during the game. Players sustained injuries in the home zone (37%), visitor zone (38%) and neutral zone (17%).

5.4 Concussions in international ice hockey

5.4.1 Incidence of injury

One hundred sixty concussions were reported in 3293 games. Concussions accounted for ten percent of all injuries in the championships. The average IR for concussion per 1000 player-games was 1.1 for all the IIHF World Championships. The annual injury rate ranged from 0.7 (2007) to 1.6 (2012). The results of the different groups can be found in table 4.

	number	games	IR per 1000 player-games	IR per 1000 player-hours
All WC	160	3293	1,1	4,0
WS	65	1199	1,2	4,5
WS A-pool	46	650	1,6	5,9
WJ U20	34	725	1,1	3,9
WJ U20 A-pool	18	308	1,3	4,9
WJ U18	32	631	1,2	4,2
WJ U18 A-pool	18	276	1,5	5,4
all WW	29	738	0,9	3,9
WW A-pool	6	185	0,8	2,7
WW U18	15	265	1,4	4,7

TABLE 4. Injury rate for concussion per 1000 player-games and per 1000 player-hours in all World Championships (WC) at all skill levels of men (WS), women (WW), juniors under-20 years (WJ U20), WJ U20 A-pool, juniors under-18 years (WJ U18), WJ U18 A-pool, all WW, WW A-pool and WW U18 tournaments (A-pool = highest/top level in each age group and gender).

5.4.2 Annual injury rate for concussions

The time trend of concussions and annual IRs are shown in figure 18. The highest concussion rate was in the men's World Championships A-pool (top level) tournaments and OWGs. In the men's tournaments, the injury rate for concussions decreased, especially in WS A-pool tournaments. Since 2012, the annual concussion rate in the men's tournament has been lower than that of the WJ tournaments. The annual concussion rate slowly increased in WJ U18 and WJ U20 tournaments (figure 18). In the WW tournaments, no clear time trend was observed.

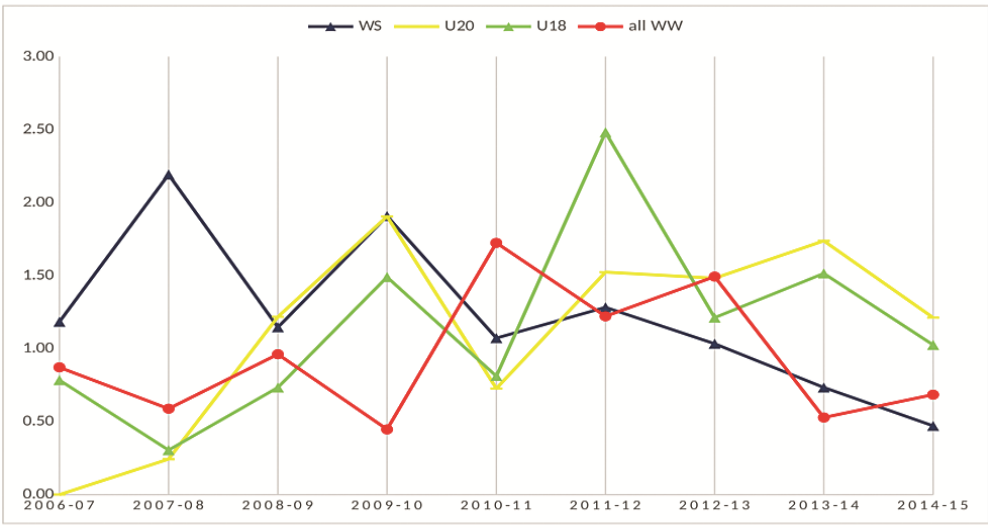


FIGURE 18. Annual injury rates per 1000 player-games for concussions in the World Senior, World Junior Under-20 and Under-18 and Women's World Championships tournaments.

5.4.3 Contact with the boards

The majority of concussions occurred without board contact (56%; IR 0.6). This trend was apparent in all championships and was similar over the 9-season study period, with the exception of the seasons 2007-2009. In the WJ U20 A-pool (top level) tournaments, 72% (IR 1.0) and in the WW U18 tournaments, 67% (IR 0.9) of concussions occurred away from the boards. The highest injury rate for a concussion (when a concussion occurred with board contact) was in the WS A-pool (IR 0.7) and WJ U18 (IR 0.7) A-pool tournaments.

5.4.3.1 Flexible boards and glass

The men's A-pool (top level) WC tournaments, in which flexible boards and glass were used, showed an overall concussion injury rate of 1.0 per 1000 player-games, as compared to 2.0 per 1000 player-games when traditional boards and glass were in place [for the latter RR 2.07, (95% CI 1.06 to 4.04)]. When concussions occurred with board contact,

the injury rate was 0.2 per 1000 player games when flexible boards and glass were in place, compared to the IR 1.1 when traditional boards and glass were used [for the latter RR 6.44, (95% CI 1.50 to 27.61)]. If the concussion occurred without board contact, no differences were seen in the concussion rates: traditional boards and glass (IR 0.9) vs. flexible boards and glass (IR 0.8) (figure 19).

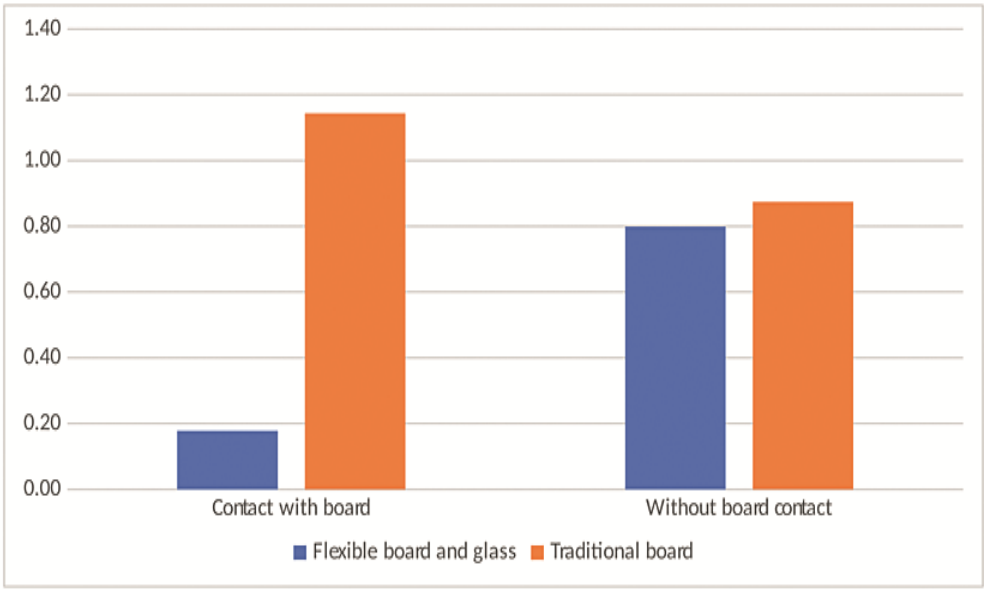


FIGURE 19. Injury rate for concussion per 1000 player-games when traditional or flexible boards and glass were used and when concussions occurred with or without board contact.

5.4.4 Causes of concussions and penalties

Contact with another player (89%) was the most common situation leading to a concussion. Checking to head caused 42% of concussions, followed by a body check (23%), checking from behind (13%), and unintended collision (13%). Ninety percent of the concussions that were caused by checking from behind occurred with board contact. The highest concussion rate caused by checking to the head was in WJ U18 (56%) and WJ U20 A-pool (top level) (61%) tournaments (IR 0.8, respectively). Concussions were caused mainly by unintended

collision (34%; IR 0.3) and body checking (31%; IR 0.3) in the WW tournaments. Fighting caused 3% of the concussions in all the tournaments and 7% in the WS A-pool tournaments (figure 20).

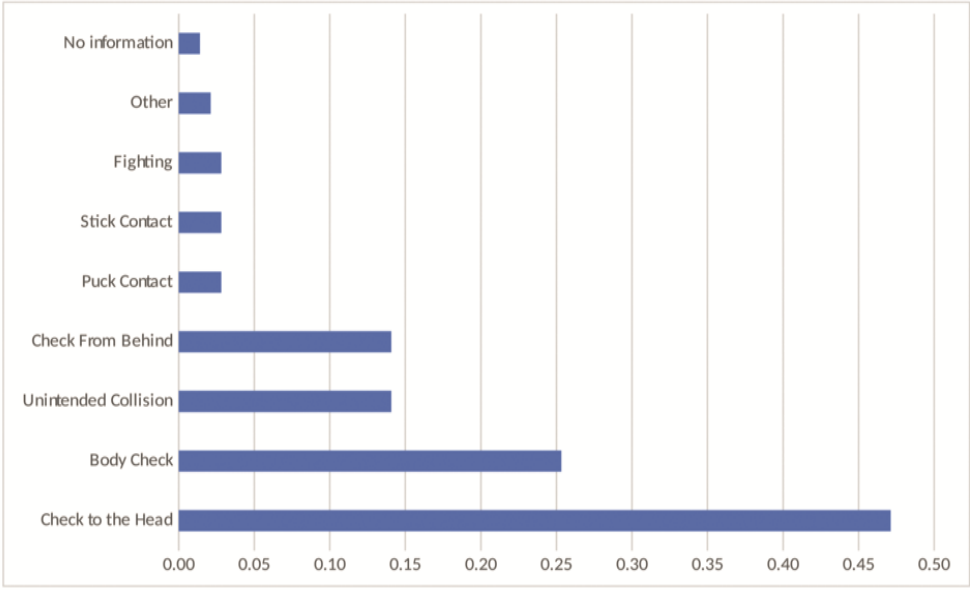


FIGURE 20. Injury rates per 1000 player-games for causes of all concussions.

Two-thirds of the concussions were caused by illegal hits. The trend of annual injury rate for concussions caused by illegal contacts was slowly decreasing in all tournaments. The trend of the annual concussion rate caused by legal hits was slowly increasing. However, in the WS tournaments, the trend of the annual injury rate for concussions caused by illegal hits was significantly decreasing. The trend for legally-caused concussions remained stable (figure 21). In the WJ tournaments the trends of the annual concussion rate caused by illegal or legal contacts were increasing (figure 22).

Penalties were assessed in one-third of the concussions. In half of the concussions caused by checking from behind and in forty percent of concussions caused by checking to head, a penalty was called.

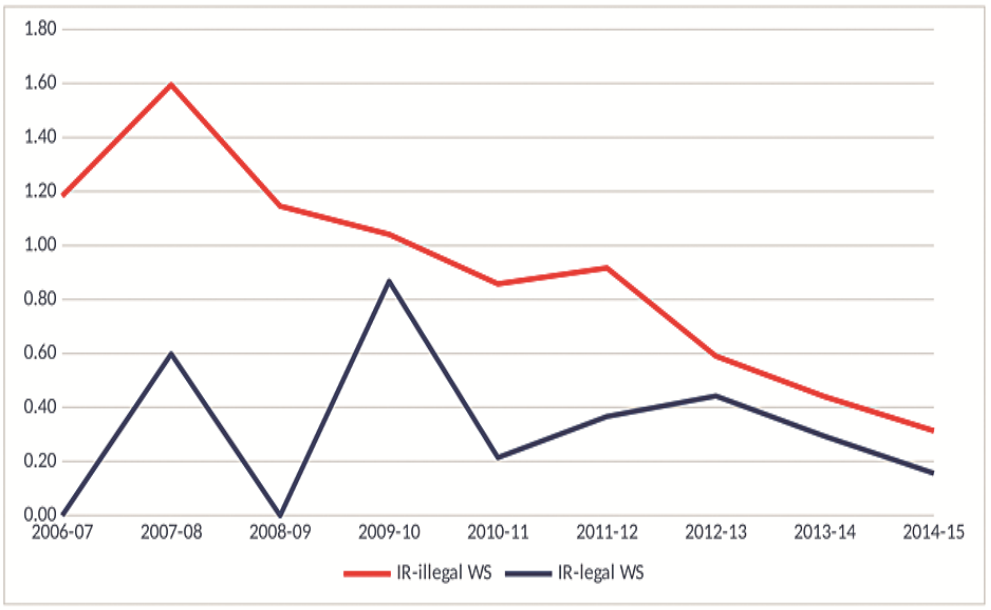


FIGURE 21. Annual injury rate per 1000 player-games for concussions in the World Senior Championships tournaments caused by legal or illegal hits.

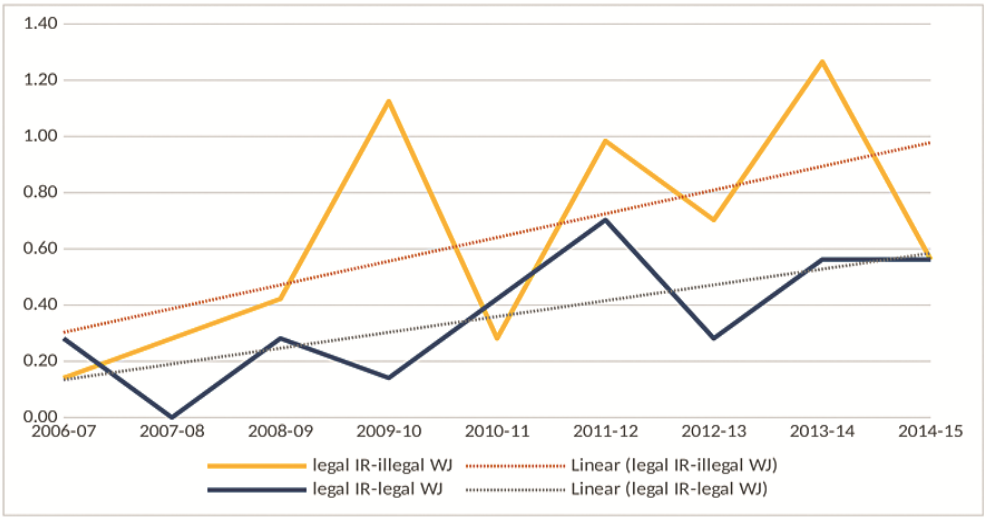


FIGURE 22. Annual injury rate per 1000 player-games for concussions in the WJ tournaments (World Junior Under-20 and Under-18 Championships) caused by legal or illegal hits.

5.4.5 Injury Severity

Nine percent of the players who were diagnosed with a concussion returned to play in the same game. In the WS tournaments, 14% of the concussed players returned on the day of the injury before the Zurich Consensus Statement 2012 was published (no return to play on the day of a concussion) (McCrory et al. 2013a). Following the Zurich Consensus publication, none of the concussed players in the men's World Championship tournaments returned to the same game. However, in all female and World Junior tournaments, the percentage of players who returned on the day of the injury was similar before and after the 2012 Zurich Consensus Statement.

5.4.6 Player position, period and zone

Concussions were distributed according to player position: wing 37% (two wings per team), centre 23% (one centre per team), and defense 38% (two defenses per team). The goalkeeper was the least injured of all positions (1%). Two-thirds of concussions occurred among forwards and one-third among defense in the men's A-pool (top level) tournaments. The highest concussion rate for the centre was in the men's A-pool tournaments (IR 0.4) and in the female tournaments (45%; IR 0.4). Compared to the other positions, the wing (53%; IR 0.6; two wings per team) had the highest risk for concussion in the WJ U18 tournaments.

The percentages of periods for concussed players were 33%, 31%, and 31% during the games. Only a few concussions occurred during the warm up or overtime. Forty-three percent of the concussions occurred during the first period in the men's A-pool games, and the third period had the lowest injury rate for concussions. In the WJ U18 and WW tournaments, the lowest injury rate was during the first period and the highest during the third period.

The proportion of concussions in the visitor's zone was 37%, followed by the home zone 36% and the neutral zone 23%). In the WJ U20 A-pool tournaments, 28% of concussions occurred in the neutral zone.

5.4.7 Risk factors for concussion

The concussion rate for men was higher than that for women, but the results were statistically insignificant [RR 1.29, (95% CI 0.87 to 1.91)]. Results related to the player's position, the cause of concussion and the arena characteristics are summarised in table 5.

Variables	Category	WS		WS A		WJ U20		WJ U18		WW*		WW U18	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Position	Defence	1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Wing	0.96	(0.56 to 1.66)	1.27	(0.65 to 2.50)	0.59	(0.28 to 1.24)	**2.47**	**(1.03 to 5.94)**	0.50	(0.12 to 1.98)	1.00	(0.20 to 4.94)
	Centre	1.07	(0.56 to 2.04)	1.59	(0.75 to 3.39)	0.53	(0.20 to 1.42)	1.14	(0.33 to 3.88)	1.66	(0.51 to 5.44)	**5.44**	**(1.45 to 20.41)**
	Goalie	**0.04**	**(0.00 to 0.61)**	0.06	(0.00 to 1.05)	**0.05**	**(0.00 to 0.87)**	0.28	(0.03 to 2.30)	0.15	(0.01 to 2.69)	0.66	(0.07 to 6.35)
Group		1.16	(0.78 to 1.75)	**1.55**	**(1.01 to 2.38)**	1 (referent)		1.09	(0.68 to 1.74)	0.62	(0.34 to 1.14)	1.22	(0.68 to 2.20)
Cause	Others	1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	CTH	**6.53**	**(4.03 to 10.58)**	**5.04**	**(2.82 to 9.02)**	**9.08**	**(4.63 to 17.79)**	**5.55**	**(2.77 to 11.09)**	1.27	(0.28 to 5.73)	0.54	(0.07 to 4.09)
	CFB	1.28	(0.65 to 2.49)	1.26	(0.57 to 2.80)	0.68	(0.22 to 2.03)	1.62	(0.67 to 3.92)	0.58	(0.08 to 4.48)	0.24	(0.01 to 4.00)
	BC	1.59	(0.85 to 2.97)	1.96	(0.98 to 3.93)	**2.94**	**(1.41 to 6.13)**	1.30	(0.50 to 3.36)	2.11	(0.58 to 7.63)	**5.35**	**(1.87 to 15.29)**
Board	Flexible			1 (referent)									
	Traditional			**2.17**	**(1.11 to 4.25)**								
Concussion with	Flexible			1 (referent)									
board contact	Traditional			**6.73**	**(1.57 to 28.85)**								

*WW and WW U18 results are calculated separately

Check to the head (CTH), Checking from behind (CFB), and body checking (BC).

statistically significant results are indicated in bold

TABLE 5. Association between player's positions, groups, causes, the arena characteristics and concussions.

5.5 Differences between men's, women's, and juniors' injury profile

5.5.1 Incidence of injury

The highest injury rate was in men's games (IR 14.2; in WS A-pool (top level) 16.3) and the lowest in women's games (IR 6.4). In male junior games the IR was lower than in men's games but higher than in women's games (WJ U18 IR 9.9; WJ U20 IR 12.0). In WW U18 tournaments, the injury rate was 7.5, which was higher than that of WWC tournaments (IR 5.7) (figure 23). Regardless of gender or age group the injury rate was higher in A-pool tournaments as compared to the lower divisions.

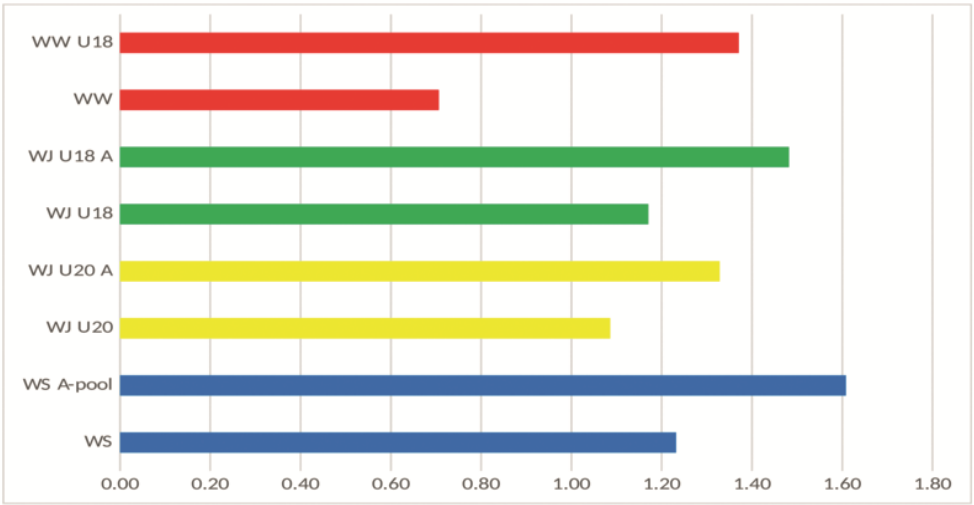


FIGURE 23. Injury rates by different age groups and gender per 1000 player-games (A-pool is the highest/top level tournament in each age group and gender).

5.5.2 Injuries by anatomical region

In WS and WJ U20 tournaments, the head and face were the most commonly injured body parts. The injury rate for the head and face

was significantly higher in WS and WJ U20 tournaments as compared to the other groups. In WJ U18 tournaments, the upper-body had the highest IR, which was higher than that of WS tournaments. The lower-body was the most injured body part in women's games. The injury rate for spinal and trunk injuries was at the same level in different groups (figure 24).

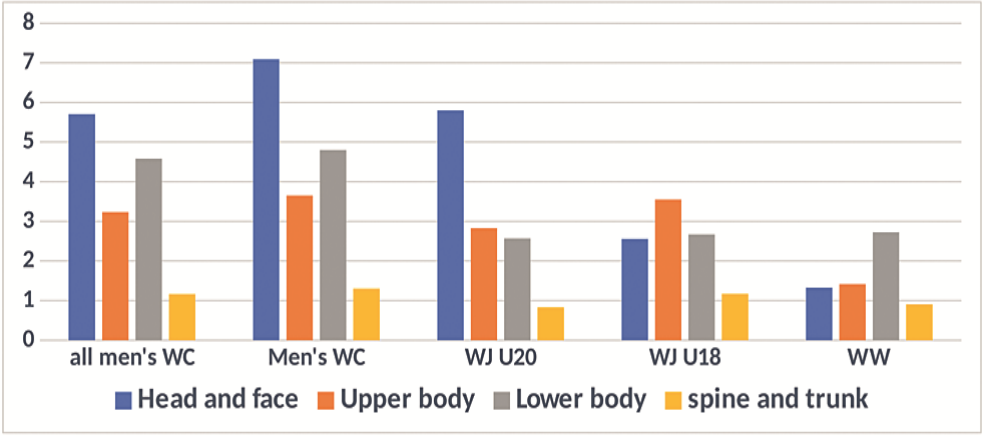


FIGURE 24. Injury rate by anatomic region by different age groups and gender per 1000 player-games.

5.5.2.1 Head and face injuries

In WJ U20 tournaments, the injury rate for the head and face was highest (IR 5.8), especially in WJ U20 A-pool (top level) tournaments (IR 7.2). Most of them were facial injuries (WJ U20 IR 4.4; WJ U20 A-pool IR 5.6). Regardless of the mandatory use of full-face protection in WJ U18 tournaments, the IR for head and face injuries was in WJ U18 A-pool 4.1 (figure 25). However, IR for facial injuries (IR 2.2) was significantly lower than that of WJ U20 tournaments. In WW U18 tournaments, IR for head and face injuries was significantly higher (IR 1.9) compared to the results in WWC (IR 1.0). The injury rate for facial injuries was lowest (IR 0.2) in all WWC tournaments (figure 26).

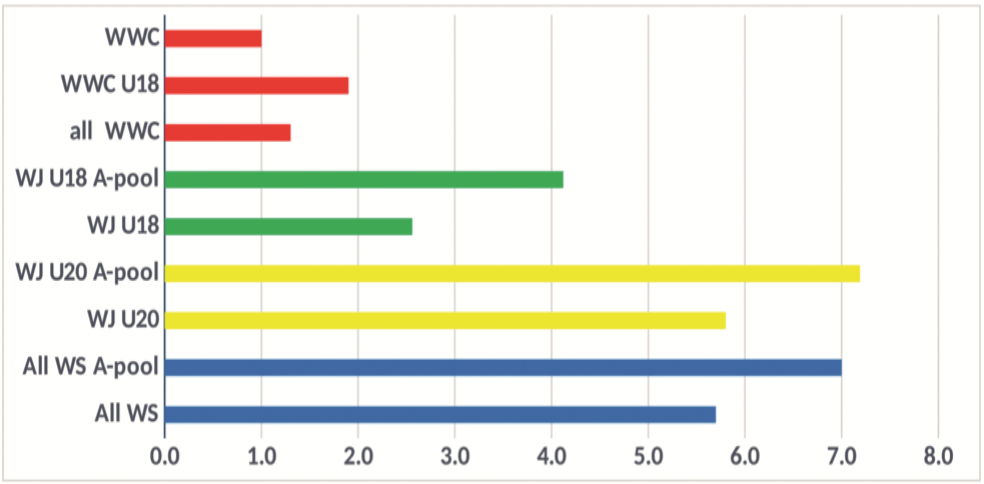


FIGURE 25. Injury rate for head and face injuries by different age groups and gender per 1000 player-games (A-pool is the highest/top level tournament in each age group and gender).

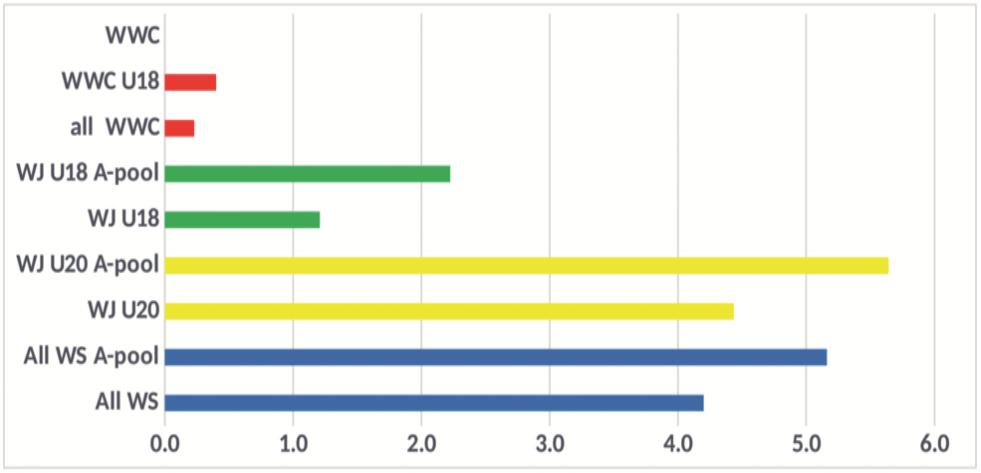


FIGURE 26. Injury rate for facial injuries by different age groups and gender per 1000 player-games (A-pool is the highest/top level tournament in each age group and gender).

5.5.2.2 Lower-body injuries

The highest injury rate for lower-body injuries was in WS tournaments (IR 4.6). In all WWC tournaments, lower-body injuries were the most common injured body area. However, the IR for lower-body injuries was similar to that of WJ tournaments. The injury rate for knee injuries was 0.8 in WJ U18 tournaments, 0.9 in WJ U20 tournaments and 2.0 in WS tournaments (in WS A-pool (top level) IR 2.3). Respectively, in WW U18, the knee injury risk was close to the level of men (IR 1.8). In WWC tournaments, the IR for knee injuries was similar to the juniors (IR 1.0) (figure 27). Eleven percent of knee injuries were ACL injuries in men's games and 6% in WJ games. Injury rate for ACL injuries was 0.22/1000 player-games in WS tournaments and 0.05/1000 player-games in WJ tournaments. The injury rates for ankle injuries were highest in all WWC (IR 0.8).

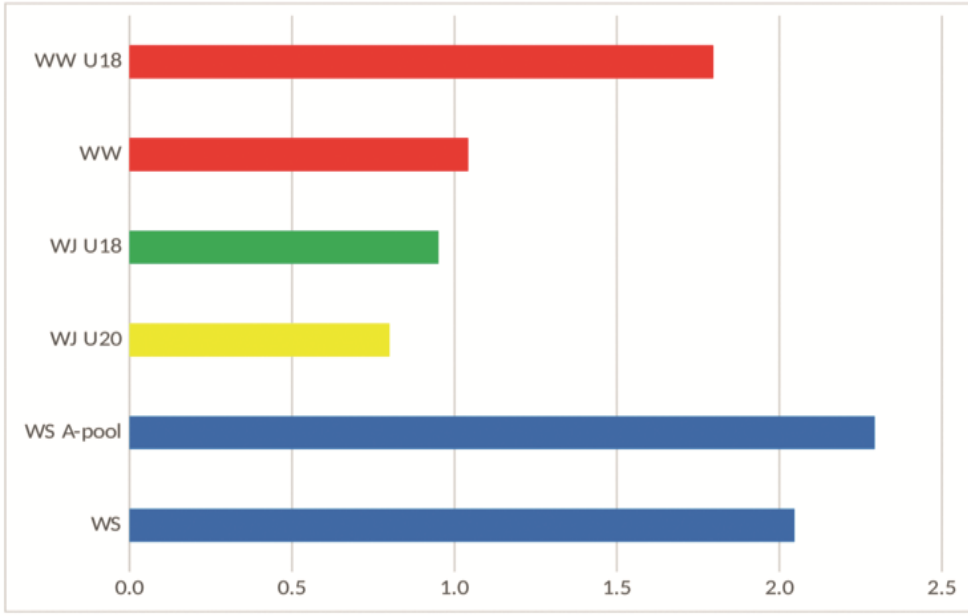


FIGURE 27. Injury rate for knee injuries by different age groups and gender per 1000 player-games.

5.5.2.3 Upper-body injuries

The injury rate for upper-body injuries were highest in WJ U18 tournaments (IR 3.55). More than half of them were shoulder injuries (IR 2.0; in WJ U18 A-pool (top level) 2.4). In men's and WJ U20 tournaments, the injury rate for shoulder injuries was similar. Shoulder injuries were not as common in all WWC tournaments (figure 28). In all groups, AC-joint sprain was the most frequent diagnosis of shoulder injuries (WS 51%; WJ 59%; WWC 50%).

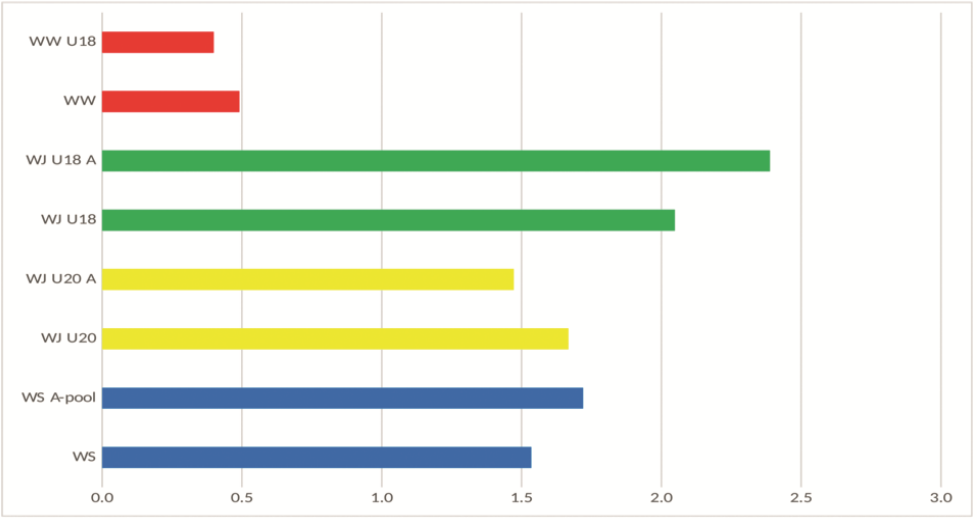


FIGURE 28. Injury rate for shoulder injuries by different age groups and gender per 1000 player-games.

5.5.3 Injury types by diagnosis

In WS and WJ U20 tournaments lacerations were the most common diagnosis (WS 26%, IR 3.7; WJ U20 32%, IR 3.8), while in WJ U18, sprains (26%; IR 2.6) and in all WWC tournaments, contusions (28%; IR 1.8) were the most frequent diagnosis. Lacerations occurred in 14% (IR 1.4) of WJ U18 and in 5% (IR 0.3) of all WWC tournaments. The percentage for fractures was lowest in all WWC (7%; IR 0.5) and highest in WS (14%; IR 2.0). Ten percent of injuries were fractures in WJ tournaments (IR 1.1).

5.5.4 Concussions

Ten percent of injuries were concussions. The average injury rate (IR) for concussions was 1.1 per 1000 ice hockey player-games for all IIHF WC tournaments. The IR was the highest in the men's WC A-pool (top level) tournaments and OWG (IR 1.6). However, the annual IR for concussion in the men's tournaments has been lower than that of the World Junior tournaments since 2012. The risk of concussion was a little bit higher in WJ U18 tournaments than that of WJ U20. In WW U18, the concussion rate (IR 1.4) was twice as high as in WWC and higher than that of WS (figure 29). In the men's tournaments, the trend of concussions caused by illegal hits decreased over the study period, while in WJ games, the trend for the annual risk of concussions caused by illegal hits increased. After the 2012 Zurich Consensus Statement, none of the concussed players in the men's WC returned to play on the day of the injury.

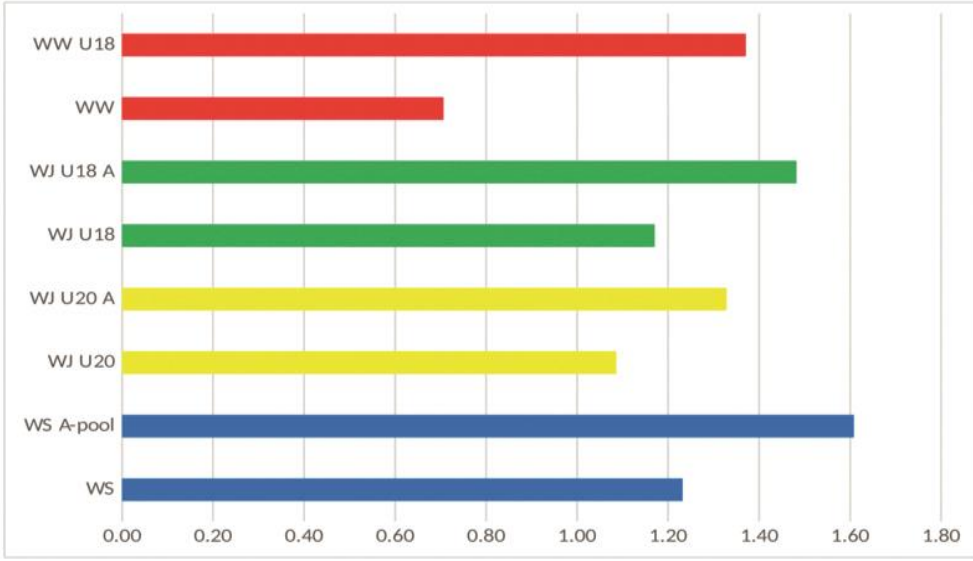


FIGURE 29. Injury rate for concussion by different age groups and gender per 1000 player-games (A-pool is the highest/top level tournament in each age group and gender).

5.5.5 Contact with the boards

The majority of injuries occurred away from the boards in all groups. The shoulder was the most common body part injured regarding contact with boards in male tournaments, and the head and the face were the most common in female games. More than half of the shoulder injuries occurred with board contact in male games (IR 0.97 WS; IR 0.78 WJ U20; IR 1.19 WJ U18). In female games, only one-third of the shoulder injuries occurred with board contact (IR 0.15 per 1000 player games). The majority of concussions occurred without board contact.

5.5.5.1 Flexible boards and glass

There was a 29% lower risk of an injury in the arenas where flexible boards and glass were used compared to arenas with traditional boards and glass [IRR 0.71, (95% CI 0.56-0.91)]. In the WS A-pool (top level) tournaments where flexible boards and glass were used the injury rate for shoulder injuries was 0.9 per 1,000 player-games compared to the IR 2.2 per 1,000 player-games when traditional boards and glass were in place [IRR 0.36, (95% CI 0.15-0.90)] (figure 30).

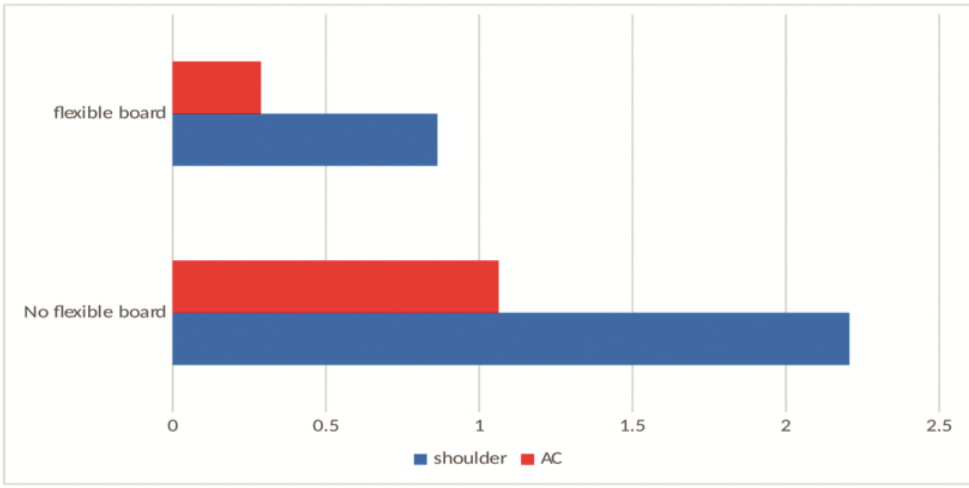


FIGURE 30. The effect of flexible boards and glass on shoulder injuries (IR per 1000 player-games). AC =Acromioclavicular join.

The men's A-pool (top level) WC tournaments that were played in arenas with flexible boards and glass had an overall concussion IR of 1.0 per 1000 player-games, as compared to 2.0 per 1000 player-games when traditional boards and glass were in place [for the latter RR 2.07, (95% CI 1.06 to 4.04)]. When concussions occurred with board contact the IR was 0.2 per 1000 player games when flexible boards and glass were used, compared to the IR 1.1 when traditional boards and glass were used [for the latter RR 6.44, (95% CI 1.50 to 27.61)]. There were no differences between the IRs of concussions when the concussion occurred without board contact: traditional boards and glass (IR 0.9) vs. flexible boards and glass (IR 0.8) (figure 31).

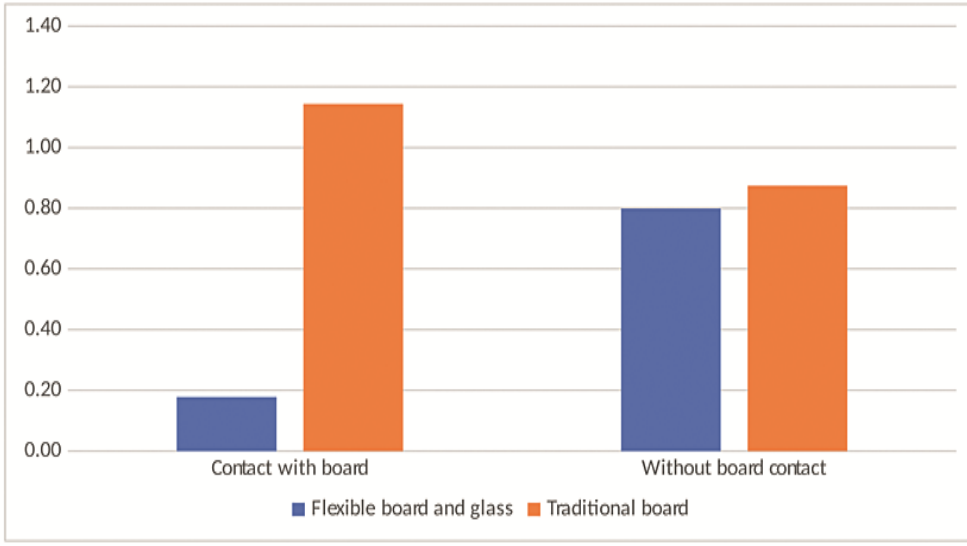


FIGURE 31. The effect of flexible boards and glass on concussions (IR per 1000 player-games).

5.5.6 Causes of injury

The most common cause of injury during games was a body check for male athletes and an unintended collision for female athletes. The stick caused 24 % of injuries in WS tournaments (IR 3.0), 20 % in WJ U20 tournaments (IR 2.4), 3% (IR 0.3) WJ U18 tournaments and 6% of

injuries (IR 0.4) in all WWC tournaments. The percentage of injuries caused by the puck was similar in the different groups.

5.5.7 Injury severity

The majority of players who were injured returned to play within one week. The estimated recovery time was more than three weeks in 10 % of injuries in WJ (IR 1,1) and in all WWC tournaments (IR 0.6). However, in men's games 15% of the injured players did not return for at least in three weeks (IR 2.1).

5.5.8 Player position, period and zone

Injuries were equally distributed according to player position in men's tournaments. In WJ tournaments, the most injured position was the wing 44% (2 wings per team) (WJ U18, 50%; WJ U20, 40%). The centre had the biggest risk in female games. In all groups, the goalkeeper was the least injured position. In WJ U20 tournaments, the defenseman had highest risk of concussion compared to the other positions [RR 2.3 (95% CI 1.2 to 4.5)] and in WJ U18 tournaments, the concussion rate for the wing was nearly three times at greater risk compared to other positions [RR 2.9 (95% CI 1.4 to 6.0)]. In the women's tournaments, the proportion of concussions sustained by the centre was about four times higher than that of other positions [RR 4.1 (95% CI 2.0 to 8.4)] (figure 32).

The risk of injury was highest in the second and third period in WJ and in all WWC tournaments, while in the men's games, the second period had the highest percentage of injured players. Most of the injuries occurred in the home zone.

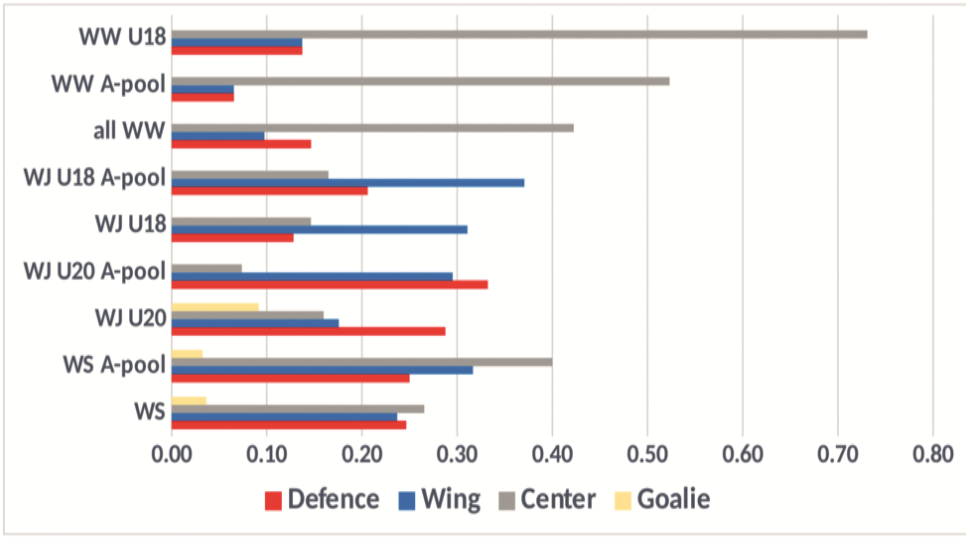


FIGURE 32. Risk of concussion by playing position in different age groups and genders (IR per 1000 players-game) (A-pool is the highest/top level tournament in each age group and gender).

6 DISCUSSION

6.1 Definition of injury

Differences in injury definition and the at-risk population assessment need to be taken into consideration when comparing the results of this dissertation to the existing literature. Some of the earlier studies included only time-loss injuries and others included a combination of time-loss and medical attention required. Diagnoses have usually been made by team medical staff: physician or athletic trainer/physiotherapist.

If only time-loss injuries were included, it left out for example most of the lacerations. Lacerations are very common in ice hockey. If all injuries are collected, minor injuries, like contusions, reflect the injury profile, which in fact may not affect the player's game ability. A clear and strict definition of an injury is needed to equalise methods of data collection. In ice hockey, widely-recommended definition of an injury is a combination of time-loss injuries and injuries requiring medical attention, which leave out minor injuries, but collect all injuries that required future investigation like concussions, dental injuries, and fractures supplemented with lacerations.

6.2 Population at risk

In most of the North American studies, the population at risk has been defined as the total number of players who take part in practices or games, including players who are on the bench (Flik et al. 2005, Agel et al. 2007a and 2007 b, Agel & Harvey 2010). Sometimes only one goalie was included (Benson et al. 2011). The number was used in the denominator when calculating the incidence and the results were presented as per 1000 athletic -exposures. Warm up, penalties and

overtime were excluded (Flik et al. 2005, Agel et al. 2007a and 2007b, Agel & Harvey 2010).

When athletic exposures were used, the results were more comparable between practices and games and describe the average risk of players in a game or a practice. In the same way, two goalies shall be used when counting the population at risk. All the players of the team participating in a game, had an impact on the game and were at risk for injury during every moment of the game. When all the players are used in the denominator, the players' bench belongs to the playing field. Players' benches are used for recovery after each very intensive shift on the ice. In comparison to other sports, for example, soccer, players have a possibility to recover during a match by walking between running intervals. In ice hockey, the player-game is comparable with athletic -exposure in a game, because the active playing time is usually 60 minutes. Because the number of practices is much higher compared to the games, the overall injury rate describes the injury rate of practices more than that of games. However, the distributions of injuries are more likely to reflect the distributions of game injuries.

In studies from European ice hockey leagues, only the players who are on ice were at risk of injury. Usually one goalie, two defensemen and three forwards were in denominator when calculating the incidence, and the results were reported as per 1000 player-hours or per 1000 player-game hours. An average playing time was used (Lorentzon et al. 1988, Mölsä et al. 1997). This definition of at-risk population takes out the players who are recovering on the bench and ready to return to the ice. Mentally, they are all the time part of the game; they receive continuous advice from coaches; they are intensely following the progress of the game, and at the same time, they try to recover physically. However, in that time they are not in contact with the opposing players and thus have a lower risk of injury. When individual playing time is used, the results are close to the results per 1000 player-game hours. An individual playing time gives an opportunity to compare the risk of injury between players in a team relative to the individual playing time.

Both ways give the possibility to compare results in ice hockey, but it is still difficult to compare the results between the different sports.

Perhaps in future studies, the results shall be given in both ways. A consensus statement for injury definition and data collection specific for ice hockey is needed to increase the comparability of the findings.

6.3 Injuries in men's ice hockey

This observational study followed 41 men's ice hockey World Championship tournaments over a seven-year period to determine the incidence, type, mechanism and severity of injuries. During the study period, 6666 players sustained 528 injuries in 844 games.

6.3.1 Incidence of injury

In the present study, the incidence of injury in the men's World Championships was 14.2 per 1000 player-games (IR 52.1 per 1000 player-game hours) and in the men's WC A-pool (top level) tournaments and Olympic Winter Games, 16.4 per 1000 player-games (IR 59.6 per 1000 player-game hours).

The incidence of injury was reported to be in North American collegiate ice hockey from 13.8 to 18.7 per 1000 athletic-exposures (McKnight et al. 1992, Flik et al. 2005, Agel et al. 2007a, Agel & Harvey 2010). McKay et al. (2014) reported in the prospective study of six NHL seasons, the average injury rate to be 15.6 per 1000 athletic -exposures. In Finland and Sweden, the injury rate for ice hockey injuries has been from 66 to 78.4 per 1000 player-game hours in National League level and 36 per 1000 player-game hours in the Division I league (Lorenzon et al. 1988, Mölsä et al. 1997). In another study, Mölsä et al. (2000) reported that the injury rate increased significantly from 54 per 1000 player-game hours in the 1970s to 83 per 1000 player-game hours in the 1990s. These findings are comparable and support the results reported in earlier studies. The injury rate from the 1990s has not changed compared to the results of the 2010s.

6.3.2 Type of injury

Contusions and lacerations, especially facial lacerations have been the most common diagnosis of injury. The number of the facial lacerations has been decreasing because of the increased use of facial protection (half-visor or full-face protection) (Stuart et al. 2002). However, the rate of contusions, sprains and strains were reported to increase significantly with each decade (Mölsä et al. 2000). In North American collegiate studies, concussions were one of the most common diagnosis followed by shoulder and knee ligament injuries (Flik et al. 2005, Agel and Harvey 2010). McKay et al. (2014) reported in NHL study that the most commonly injured body regions were the head (16.8%), thigh (14.0%) and knee (13.0%).

The proportion of head injuries were higher in the present study compared to what McKay et al. (2014) reported in the NHL study. Lacerations were the most common diagnosis, followed by sprains and contusions in the present study. Fourteen percent of injuries were fractures and ten percent were neurotraumas. The knee was the most common lower-body injury (46.9%). The proportion for knee injuries was 14.4% of all injuries. The injury rate for knee injuries was comparable with the results at the NHL (McKay et al 2014) and collegiate level (Agel et al. 2007a). Half of them were medial collateral (MCL) sprains, and a half of the latter were Grade I injuries. Anterior cruciate ligament (ACL) disruption covered 10.5% of all knee injuries. The shoulder was the most common upper-body injury (49.6%). Half of them were acromioclavicular (AC) joint injuries.

6.3.3 Causes and period

Body checking, unintended contact with other player or contact with the boards and glass were the main causes of an injury. Most facial lacerations were caused by a stick (Lorentzon et al. 1988, Mölsä et al. 1997, McKay et al. 2014). The present study supports these findings.

In the studies from 1980s and 1990s, there were fever injuries in first period, while most of them occurred during the third period (Lorentzon et al. 1988, Mölsä et al. 1997). McKay et al. (2014) reported that injuries were significantly more frequent in the first period (48.1%)

than the second (25.4%) or third (24.4%) periods. In the present study, the highest percentage of injury occurred during second period, but the differences were not statistically significant. Differences between the studies may be explained by differences in players' physiological performance and that players were more energetic at the beginning of the game. A greater number of players on a team gives coaches the possibility to use four shifts. In this option, players have more recovery time between shifts and can play intensively when they are on the ice. The same effect can be seen using longer breaks during periods.

6.4 Injuries in women's ice hockey

This observational study followed 39 women's Ice Hockey World Championship tournaments over an 8-year period to determine the incidence, type, mechanism and severity of injuries. During the study period, 5344 players sustained 168 injuries in 637 games.

6.4.1 Incidence of injury

In the women's National Collegiate Athletic Association (NCAA), ice hockey game injury rates were reported to be from 12.1 to 12.6 per 1000 athlete –exposures (AEs). The athlete –exposure was determined by the number of athletes participating in a game or practice, regardless of the duration or type of exposure (Agel et al. 2007b, Agel & Harvey 2010). Schick and Meeuwisse (2003) reported that the injury rate for female ice hockey was 10.43 per 1000 athlete -exposures (AEs) for game injuries. In women's ice hockey, the risk of injury was greater with increasing age and at the more elite levels of play (Keightley et al. 2013).

In the present study, the injury rate was lower than reported earlier at the collegiate level, which may be due to tougher competition of individual playing time in North America than Europe. The injury rate was higher in the World Women's Under-18 Championship tournaments than that of the World Women's Championships. The higher injury rate for WWC U18 may reflect the fact that the physical

readiness of girls is deficient; they do not have enough strength and awareness to avoid collisions, and they are physically not as capable to withstand collisions. However, the injury rate was highest in the Olympic Winter Games.

6.4.2 Injured anatomic region and type of injury

Most injuries in women's ice hockey were lower-body injuries. Sprain/strain was main type of injury. Concussions were the most common diagnosis, followed by the hip/groin and ankle injuries in collegiate ice hockey (Schick & Meeuwisse 2003, Agel et al. 2007b, Agel and Harvey 2010). The concussion rate for game injuries was as high as 2.72 per 1000 athletic-exposures (Agel et al. 2007b).

In the present study, contusions were the most common type of injury followed by ligament sprains. The lower-body was injured most frequently (42.9% of game injuries). In all female tournaments, three-fourths of the head and facial injuries were concussions. Concussions were the most common diagnosis in female ice hockey, followed by knee and ankle sprains.

6.4.3 Causes of injury

Body checking and unintentional collision with an opponent were the common mechanisms of injury in female ice hockey (Agel & Harvey 2010). Ninety-six percent of injuries were related to contact mechanisms (Schick & Meeuwisse 2003). In the present study, unintended collision (26.3%) was the most common cause of injury in women's ice hockey, followed by body checking (24.6 %) and puck contact (12.0%), respectively. Injuries caused by a stick were mostly lower-body injuries (70.0%). The results of the present study support the earlier studies from women's ice hockey.

6.5 Injuries in juniors' ice hockey

This prospective, observational study followed 69 male junior ice hockey World Championship tournaments over a 9-year period to determine the incidence, type, mechanism, and severity of injuries. During the study period, 633 injuries were reported in 10518 players competing in 1326 games.

6.5.1 Incidence of injury

In North American collegiate-level ice hockey incidence of injury was reported to be from 13.8 to 18.7 per 1000 athletic -exposures. Stuart and Smith (1995) reported an injury rate of 96.1 per 1000 player-game hours in elite Junior A ice hockey in North America. The injury rate for lacerations was 32.4 per 1000 player-game hours. The anatomical region most often injured was the face (IR 38 per 1000 player-game hours). Over the study period, facial protection was not mandatory for players aged 18 and older. The lack of any facial protection has been attributed to the high risk of facial trauma, especially lacerations. (Stuart and Smith 1995). At the high school level, the injury rate was lower compared to the Junior A level: IR 34.4 per 1000 player-game hours (Smith et al. 1997). However, there were differences in the definition of injury. Most studies included both time-loss injuries and injuries requiring medical attention (McKnight et al. 1992, Smith et al. 1997, Pinto et al. 1999, Flik et al. 2005, Agel et al. 2007a, Agel & Harvey 2010, Matic et al. 2015).

In the present study, the total injury rate was lower than that of North American studies. In WC U18 tournaments the injury rate was lower than that of WC U20 tournaments, which support the findings of earlier studies where the injury rate was lower at the high school level compared to the Junior-A level. Differences in the style of play, officiating and ice surface size between North America and Europe may help explain the lower injury rate in the juniors' World Championships.

6.5.2 Injured anatomical region and type of injury

In the present study, anatomical regions of injury were different in Under-20 category compared to the Under-18 age group. The head and face were injured most frequently (48% of game injuries) in WJ U20 tournaments followed by the upper-body and lower-body, respectively. The majority of head and face injuries involved the face (76%). The upper-body was the most commonly injured anatomical region (36% of game injuries) in WJ U18 tournaments the lower-body being the second and the head and face were the third most commonly injured anatomical region.

Players competing at the minor hockey, high school, and junior levels of competition sustained most of their injuries to the upper extremity, head and face and lower extremity, respectively (Benson & Meeuwisse 2005). In junior hockey, the three most commonly reported types of injuries were sprains/strains, contusions and lacerations. Similarly, the most frequent types of injuries in high school hockey were contusions, sprains/strains, lacerations and concussions (Benson & Meeuwisse 2005). The present study supports these findings; contusions, sprains/strains and lacerations were the three most common types of injuries. The order for the type of injuries varies from one study to another. Agel and colleagues (2007a) reported that more than one-third of all game injuries were to the upper extremity (34%) in NCAA ice hockey. The lower extremity (34%) and head and neck injuries (15%) accounted for the majority of other game injuries. Full-facial protection has been a requirement in the NCAA for all ice hockey players since 1978. Concussions were the most common diagnosis followed by the shoulder and knee (Agel et al. 2007a).

6.5.2.1 Facial injuries

The incidence of injury was 158.9 per 1000 player-game hours in players wearing no facial protection, 73.5 per 1000 player-game hours in players wearing partial facial protection (half shield) and 23.2 per 1000 player-game hours in players wearing full-facial protection (full cage or shield) (Stuart et al. 2002). Facial protection showed a

statistically significant reduction in the number and type of facial injuries.

In the present study three-fourths of head and face injuries in WJ U20 were facial injuries and 80% of the facial injuries were lacerations. In WJ U18 tournaments a laceration was diagnosed only in 14% of all injuries, most likely due to the fact that full-facial protection is mandatory in the under-18 category. The use of a half visor instead of full-face protection in the under-20 category increases the risk of injury (LaPrade et al. 1995, Benson et al. 1999, Benson et al. 2002, Stuart et al. 2002, Meeuwisse 2002, Asplund et al. 2009). For this reason, mandatory use of full-facial protection for under-20 players seem justified.

6.5.3 Causes of injury, position and period

In the present study, injuries were caused by body checking (32%), stick (13%) and puck contact (13%). In WJ U18 tournaments, body checking caused 39% of all injuries, while the stick accounted for only 3%. In WJ U20 tournaments, the stick caused 20% of the injuries, and the majority of them were to the head and faciale area (78%). The wing had the highest risk for injury, especially in the under-18 age group.

More than half of the injuries were caused by collision with another player or the boards and glass followed by stick and puck contact. Wings and defensemen had the highest injury rates for injury and the position of goalie had the fewest injuries compared to the other positions (Benson et Meeuwisse 2005).

Flik et al. (2005) reported that the risk of injury was 36.5% in the first and second period and 27% in last period. Only time-loss injuries were included in the definition. The present study supports these results.

6.6 Concussions in ice hockey

This prospective, observational study in 2006-2015 followed 169 ice hockey World Championship tournaments and Olympic Winter Games over 9 ice hockey seasons to determine the incidence and circumstances of concussions in international ice hockey. Concussions

accounted for 10% of all injuries in the championships, including 160 concussions in 26130 players competing in 3293 games.

6.6.1 Incidence of injury

Concussions are a known problem at all levels of the game and have been reported to account for 2-14% of all ice hockey injuries and 15-30% of all hockey head injuries (Izraelski 2014). At the North American collegiate level, concussion incidence rates have varied between studies, ranging from as low as 7.9% to as high as 18.6% overall (McKnight et al. 1992, Flik et al. 2005, Agel et al. 2007a, Hootman et al. 2007). In women's games, the proportion of concussions from all injuries was from 15.2% to 21.6% (Schick & Meeuwisse 2003, Agel et al. 2007b, Zuckerman et al. 2015). In the current study, the overall percentage of concussions was 10%. In women's games, the proportion of concussions was highest (15%) and lowest in WC U20 tournaments (9%). These results support earlier studies.

At the collegiate level, the overall concussion rate has varied from 0.22 to 0.79 per 1000 athletic exposures. The injury rates for concussions in games were from 1.47 to 2.41 per 1000 athletic exposures (McKnight et al. 1992, Flik et al. 2005, Agel et al. 2007a, Hootman et al. 2007, Agel & Harvey 2010, Clay et al. 2013, Zuckerman et al. 2015). Wennberg and Tator (2008) reported the mean incidence for concussions over the ten seasons in NHL 1.45 per 1000 athlete -exposures. Benson and colleagues (2011) reported the incidence of concussions in the NHL at 1.8 per 1000 athlete -exposures. In women's ice hockey, the overall injury rate for concussions varied between studies from 0.75 to 0.91 per 1000 athlete -exposures. The game injury rate for concussions was higher than that of men's games (from 2.01 to 2.72 per 1000 athlete -exposures). In high school ice hockey, the concussion rate was from 1.2 to 1.5 per 1000 athlete -exposures for games (Schick & Meeuwisse 2003, Agel et al. 2007b, Hootman et al. 2007, Agel & Harvey 2010, Brainard et al. 2012, Zuckerman et al. 2015,).

In the current investigation, the overall concussion rate was 1.1. In men's tournaments, the injury rate for concussions was the highest (IR 1.2) and it was the lowest in all WW tournaments (IR 0.9). In the North American studies (Dick 2009, Marar et al. 2012, Covassin et al. 2016),

the women's concussion rate has been reported to be higher compared to the men's concussion rate. In the present study, the injury rates were always the highest in A-pool (top level) tournaments, compared to other divisions in each age group. The highest concussion rate was in men's A-pool tournaments (IR 1.6), which is comparable with that reported in the NHL (Benson et al. 2011). In WC U18 A-pool tournaments, IR for concussions was 1.5, and in WWC U18 tournaments, IR for concussions was 1.4, which was two times higher than the injury rate for concussions in WWC tournaments (IR 0,7). Results from the World Junior tournaments were comparable with findings from high school ice hockey (Marar et al. 2012, Clay et al. 2013, Matic et al. 2015, Pfister et al. 2016). In the men's and women's category at the collegiate level, ice hockey injury rates for concussions were higher than that of WS and WWC tournaments (Flik et al. 2005, Agel et al. 2007a, Zuckerman et al. 2015).

6.6.2 Annual injury rate for concussions and illegal hits

Pauelsen and colleagues (2016) have shown an increase in the concussion rate over a 29-season period, a shift in the injury pattern toward relatively more concussions and an increased concussion severity. In the present study, the concussion rate increased in World junior tournaments and decreased in men's tournaments. The annual risk of concussion in WS tournaments since 2012 has been lower than that of WJ tournaments. The research interval was longer in the Swedish study compared to the present study. However, in the Swedish study, the number of concussions per 1000 games increased from season 2000 to 2001 and was significantly higher than that of the NHL studies (Benson et al. 2011, Hutchinson et al. 2015a, Pauelsen et al. 2016).

The concussion rate resulting from illegal hits decreased in WS tournaments but has slowly increased in other tournaments. More attention is needed in particular to decrease the risk of concussion caused by illegal hits in WJ tournaments. Further studies are needed to clarify the possible effect of improved rule enforcement, disciplinary panel suspensions, player education and the attitude on reducing the risk of concussions.

6.6.3 Flexible boards and glass

The men's A-pool (top level) WC tournaments that were played in arenas with traditional boards and glass had a two-times higher overall concussion injury rate compared to arenas where flexible boards and glass were in place. When concussions occurred with board contact, the risk of concussion was more than six times higher if traditional boards and glass had been used compared with flexible boards and glass.

More than half of the concussions occurred away from the boards. In the WJ U20 A-pool tournaments (IR 1.0) and in WW U18 tournaments, two-thirds (IR 0.9) of concussions occurred without board contact. The highest injury rate for concussions that occurred with board contact was in the WS A-pool (IR 0.7) and WJ U18 (IR 0.7) A-pool tournaments.

This dissertation study showed that the risk of concussion is lower in arenas where flexible boards and glass are in use. The purpose of flexible boards and glass is to improve impact energy absorption (resorption), resulting in lower peak forces and greater stopping distances (Poutiainen et al. 2014).

Installation of flexible boards and glass is highly recommended to decrease the risk of concussions and shoulder injuries in all future tournaments in all levels and age groups.

6.6.4 Return to the game on the day of injury

None of the concussed players since 2012 returned to the same game in the WS tournaments. This is in line with the 4th Consensus Statement on Concussion in Sport (2013) (McCrory et al. 2013a). Conversely, the policy of returning to competition on the day of injury has not changed in the other tournaments. More thorough education on concussion management and effective injury prevention measures are especially needed for the World Junior and World Women tournaments.

6.6.5 Period, position and gender

Hutchison et al. (2015) reported in a systematic video analysis of the National Hockey League (NHL) Part I and Part II that the majority of concussions occurred in the first period (47%). Concussions were distributed relatively equal in the second (27.9%) and third (25.1%) periods (Hutchinson et al. 2015a). During the first period, the players are maximally energised and able to apply more force with greater acceleration to contacts. Our finding from WS A-pool (top level) tournaments supports this result. But this finding does not support the risk analysis in our WJ U18 and women's tournaments in which the risk for concussion was lowest in the first period and highest in the third period. Players are expected to be more tired in the third period. Also, there may be an increase in game intensity in the third period because of its importance in determining the outcome of the game.

Sixty-five percent of the concussions in the NHL were sustained by forwards, 32% by defensemen and 3% by goalies. The proportion of concussions sustained by a centre was about twice that of defensemen and wingers (Benson et al. 2011). In Swedish ice hockey, 47% of the concussions occurred to wings, 34% to defensemen, 11% to centre and 8% to the goalie (Pauelsen et al. 2016).

The present results from WS A-pool (top level) tournaments supports the NHL findings by Benson et al. (2011) and Hutchison et al. (2015a). The centre had a statistically significant higher risk for concussion in the World Women Under-18 tournaments compared with the other positions. In the WW U18 tournaments, most concussions were caused by body checking or unintended collision. These results may reflect the fact that girls may not have enough strength and skill to avoid collisions and are physically not as capable to withstand collisions.

6.7 Comparison between age groups and genders

This comparative study analysed the differences by age groups and sex in international ice hockey. Highest injury rate was in WS tournaments (IR 14.2) and lowest in WWC tournaments (IR 5.7). The injury rate was

always highest in A-pool (top level) tournaments in each age and gender group. The head and face were the most commonly injured body parts in WS and WJ U20. In WJ U18, upper-body was the most commonly injured body part and has the highest IR 3.55 compared to the other groups. The injury rate for knee injuries in WJ were similar to that of WWC tournaments, but it was two times higher in WS and WW U18 tournaments. Flexible boards and glass significantly decreased the risk of shoulder injuries and concussions. Ten percent of injuries were concussions.

6.7.1 Incidence of injury

In the male ice hockey, the injury rate increased along with the level of ice hockey. In WJ U18 tournaments, the injury rate is lowest while it is highest in men's World Championships. Accordingly, the injury rate is highest in A-pool (top level) tournaments within each age group. In female hockey, the highest injury rate was in WWC U18 tournaments, which may indicate that players try hard, but their readiness to withstand intense games is not so good. In these young ladies, most injuries were caused by unintended collisions and unintended body checking.

The injury rates in WS tournaments were similar to the results of earlier studies done in the USA and Canada (McKnight et al. 1992, Flik et al. 2005, Agel et al. 2007a, Agel & Harvey 2010). The risk of injury for junior and female players competing in IIHF tournaments was lower than reported for North American players (Stuart & Smith 1995, Pinto et al. 1999, Schick & Meeuwisse 2003, Agel et al. 2007b, Agel & Harvey 2010). It is possible that differences in the style of play, officiating, and ice surface size between North America and Europe explain the lower injury rate in the WJ and in all WWC games.

6.7.2 Head and face injuries

The risk for head and face injuries were significantly higher in WS and WJ U20 tournaments compared to the other groups. Most of the facial injuries were facial lacerations. Most of them were caused by the stick.

Due to the fact that full-facial protection is mandatory at all levels of female ice hockey, a laceration was diagnosed only in 5.4% of all injuries (IR 0.3).

There is good evidence that full-facial protection reduces the number and risk of overall head and facial injuries in ice hockey, compared with partial facial protection and no facial protection (Asplund et al. 2009). Also in this dissertation study, full-facial protection offered a significantly higher level of protection against facial injuries and lacerations than half-facial protection. In addition, full and partial facial protections do not increase the risk of neck injuries or concussions and concussed players with full-facial protection returned to practice or games sooner than players with partial facial protection.

Thus, compulsory use of full-face protection is a great opportunity to reduce the risk of injury especially in the WJ U20 category, which possesses the highest injury rate for facial injuries.

6.7.3 Highest rate for knee injuries in the WS

The rate for knee injuries was 2.0 per 1000 player-games in WS tournaments and was the highest in WS A-pool (top level) (IR 2.3). This result was similar to the NHL (McKay et al. 2014) and collegiate ice hockey (Agel et al. 2007a). However, the rate for knee injuries was 0.9 in WJ tournaments. Respectively, the risk of ACL injury was significantly higher in WS tournaments (IR 0.22/1000 player-games), as compared to WJ tournaments (IR 0.05/1000 player-games). Further studies are needed to explain the differences in knee injuries between the age groups in male games.

In the WW U18 category the rate for knee injuries was two times higher than that of WWC tournaments. Poor knee control is especially common among female athletes and highlights the need for neuromuscular training to enhance knee control in order to decrease the risk of future injuries (Malinzak et al. 2001, Chappell et al. 2002, Ford et al. 2003, Kernozek et al. 2005, Leppänen et al. 2014, Leppänen et al. 2016, Leppänen et al. 2017)

6.7.4 How to reduce the risk of shoulder injury

The rate for shoulder injuries was lowest in all WWC tournaments where body checking was not allowed. A lot of injuries occurred in women's games because of unintended collisions. Two-thirds of shoulder injuries in women's tournaments occurred in open ice (without board contact). The body-checking rule in female games is likely to reflect the lower rate of shoulder injuries in women's tournaments. This rule thus has a firm injury prevention basis.

In male games, close to two thirds of shoulder injuries occurred in contact with the board. The risk for male shoulder injuries was highest in the WJ U18 group as compared to the older groups. Muscular strength may partly explain the difference, since it is lowest in the Under-18 category. Future studies are needed to determine the effect of power training on the risk of shoulder injury.

This study showed that flexible boards and glass decreases the risk of shoulder injuries. Therefore, installation of flexible boards and glass is highly recommended to decrease the risk of shoulder injuries (and concussions) in all future tournaments.

6.7.5 Player position as a risk of injury

Injuries were equally distributed according to player position in men's tournaments. In WJ tournaments, the most dangerous position was wing, 44% (2 wings per team) (WJ U18, 50%; WJ U20, 40%). The centre had the highest risk in female games. In all groups, the goalkeeper had the lowest injury risk.

In WJ U20 tournaments the defenseman had the highest risk of concussion compared to the other positions, and in WJ U18 tournaments, the concussion rate for the wing was nearly three times higher compared to the other positions. In the women's tournaments, the proportion of concussions sustained by the centre player was about four times higher than that of other positions. This definitely needs future studies and thus a reliable explanation.

The high risk of injury for the wing in WJ U18 players may reflect the fact that many of the injuries occur with board contact, and therefore flexible boards and glass are needed for these games.

Increased muscle strength and power via conditioning training could also decrease the risk of injury in WJ U18 wing players. In female games, unintended collisions are the most common cause for injury, and therefore female ice hockey should pay more attention to neuromuscular body control and fluent game reading.

6.8 Strengths and limitations of the study

6.8.1 Strengths

A strength of these studies was the large number of players who were followed at the highest level of international competition. The research period varied from seven to nine years between the studies. The IIHF Injury Report System has been in use since 1998, but the study period started from 2006, when Medhockey software was starting to be used. Thus, the teams and their medical staff were familiar with the Injury Report System before the research intervals.

A strength was also that before each tournament, a team medical personnel meeting was organised by the IIHF Medical Supervisor, allowing for review of the definition of each injury, game injury report form (GIR), and the Injury Report System form (IRS) with the individual team physicians. The number of injury events was determined with an accepted injury definition that incorporated a specific diagnosis, standardised nomenclature, a reliable data collection instrument, and time lost from play. Detailed information was collected with the two validated questionnaires (Stuart & Smith 2000).

A third strength was that the Medical Supervisors collected study forms after each game, thus ascertaining excellent coverage of all injuries. They followed all the games during a tournament and inquired about possible injuries as well as players who were missing from the team roster. Because the team physicians diagnosed all the injuries, the data collection was as reliable and accurate as possible.

6.8.2 Limitations

A limitation of the study was that injuries were analysed in tournament games only, and thus practice or training injuries were not included. Although the injury diagnoses were made by the team physicians, the diagnostic procedure depended on the experience of the physician, and thus the study had a chance for detection bias. A more consistent injury diagnosis would have required an examination of every injured athlete at each tournament by a single experienced physician.

Lack of control for the clustering effect by a team and/or team physicians was also a limitation of the study. However, to minimised the cluster effect by a team or team physician, a pre-tournament meeting was organised for the team medical staff. The Medical Supervisor followed all the games and met with team physicians after each game at least to reduce the selection bias and measurement bias.

Efforts to control the clustering effect by Medical Supervisors were reduced by regular education. In the men's World Championship A-pool tournaments and the Olympic Winter Games, only a small number of the IIHF Medical Committee members were in a position of Medical Supervisors. If a player concealed his/her injury from the team medical staff, an injury distribution bias could occur. Because of an anonymous injury registry, a limitation was also the inability to control for lack of independence if players were included across multiple tournaments and years of play. This could occur especially in men's and women's World Senior tournaments.

A limitation was also that injury incidence rates were estimated by collective playing time, since individual on-ice exposure could not be measured. In addition, each game was assumed to be played for 60 minutes. Penalties, overtime or time-loss injuries during a game were not taken into consideration. However, to determine the association between the arena characteristics and the occurrence of injuries weighting with a standardized, active playing time was used. The severity of the injury was based on an estimate of the time to return to play.

The studies of the dissertation were also affected by recall bias when the player and the physician subjectively reported the cause and zone of injury and whether or not a penalty was called. A more accurate

description of the injury mechanisms would require a detailed review of the multi-angle game videos.

Finally, in *Study IV*, a concussion was a clinical diagnosis made by a team physician. At the Team Medical Personnel Meeting, physicians were advised to follow the recommendations provided by the Consensus Statement on Concussion in Sport and were given the Sport Concussion Assessment Tool (SCAT) for making the clinical diagnosis (McCrory et al. 2005, McCrory et al. 2009, McCrory et al. 2013a). A more consistent and detailed injury diagnosis would have required the examination of every injured athlete at each tournament by a single physician experienced in concussion diagnosis.

7 MAIN FINDINGS AND CONCLUSIONS

1. The risk of injury was highest in men's ice hockey tournaments. Injury incidence varied from 12.2 to 17.5 per 1000 player-games and from 44.7 to 64.2 per 1000 player-game hours.

2. Head and face (especially facial) injuries were most common in men's and male junior U20 tournaments, where full-facial protection was not mandatory. Therefore, compulsory use of full-face protection can be seen as a great opportunity to reduce the risk of injury especially in the WJ U20 category, where there was the highest injury rate for facial injuries.

3. Risk of knee injury was two times higher in men's tournaments compared with male juniors' and women's tournaments but similar to the risk in female U18 tournaments. Further studies are needed to explain the differences of knee injuries between the age and gender groups. In women, poor knee control is prevalent and thus may highlight the need for neuromuscular training.

4. The shoulder injury rate was highest in male U18 Championships and men's tournaments. Flexible boards and glass significantly decreased shoulder injuries and concussions that occurred with board contact. Installation of flexible boards and glass is thus highly recommended to decrease the risk of concussions and shoulder injuries in all future tournaments.

5. During the study years, the men's A-pool (top level) ice hockey tournaments showed a decrease in the general annual concussion rate that was similar to the decrease in concussions caused by illegal hits. This observation should inspire the ice hockey community to clarify the possible effect of improved rule enforcement, disciplinary panel suspensions, and player

education and attitudes on the reduction of the risk of concussions.

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REFERENCES

Agel, J., Dompier, T. P., Dick, R. & Marshall, S. W. 2007a. 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 42 (2), 241-248.

Agel, J., Dick, R., Nelson, B., Marshall, S. W. & Dompier, T. P. 2007b. Descriptive epidemiology of collegiate women's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 2000-2001 through 2003-2004. Journal of Athletic Training 42 (2), 249-254.

Agel, J. & Harvey, E. J. 2010. A 7-year review of men's and women's ice hockey injuries in the NCAA. Canadian Journal of Surgery 53 (5), 319-323.

Andersen, C. A., Clarsen, B., Johansen, T. V. & Engebretsen, L. 2013. High prevalence of overuse injury among iron-distance triathletes. British Journal of Sports Medicine 47 (13), 857-861.

Asplund, C., Bettcher, S. & Borchers, J. 2009. Facial protection and head injuries in ice hockey: a systematic review. British Journal of Sports Medicine 43 (13), 993-999.

Aubry, M., Cantu, R., Drovak, J., Graf-Baumann, T., Johnston, K., Kelly, J., Lovell, M., McCrory, P., Meeuwisse, W. & Schamasch, P.; Concussion in Sport Group. 2002. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. British Journal of Sports Medicine 36 (1), 6-10.

Barkhoudarian, G., Hovda, D. A. & Giza, C. C. 2016. The Molecular Pathophysiology of Concussive Brain Injury - an Update. Physical Medicine and Rehabilitation Clinics of North America 27 (2), 373-393.

Benson, B. W. & Meeuwisse, W. H. 2005. Ice hockey injuries. Medicine and Sport Science 49, 86-119.

Benson, B. W., Meeuwisse, W. H., Rizos, J., Kang, J. & Burke, C. J. 2011. A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. Canadian Medical Association Journal 183 (8), 905-911.

Benson, B. W., Mohtadi, N. G., Rose, M. S. & Meeuwisse, W. H. 1999. Head and neck injuries among ice hockey players wearing full face shields vs half face shields. Journal of the American Medical Association 282 (24), 2328-2332.

Benson, B. W., Rose, M. S. & Meeuwisse, W. H. 2002. The impact of face shield use on concussions in ice hockey: a multivariate analysis. British Journal of Sports Medicine 36 (1), 27-32.

Brainard, L. L., Beckwith, J. G., Chu, J. J., Crisco, J. J., McAllister, T. W., Duhaime, A. C., Maerlender, A. C. & Greenwald, R. M. 2012. Gender differences in head impacts sustained by collegiate ice hockey players. Medicine and science in sports and exercise 44 (2), 297-304.

Brooks, J. H. & Fuller, C. W. 2006. The influence of methodological issues on the results and conclusions from epidemiological studies of sports injuries: illustrative examples. Sports Medicine 36 (6), 459-472.

Chappell, J. D., Yu, B., Kirkendall, D. T. & Garrett, W. E. 2002. A comparison of knee kinetics between male and female recreational athletes in stop-jump tasks. The American Journal of Sports Medicine 30 (2), 261-267.

Clarsen, B., Krosshaug, T. & Bahr, R. 2010. Overuse injuries in professional road cyclists. The American Journal of Sports Medicine 38 (12), 2494-2501.

Clay, M. B., Glover, K. L. & Lowe, D. T. 2013. Epidemiology of concussion in sport: a literature review. Journal of Chiropractic Medicine 12 (4), 230-251.

Covassin, T., Moran, R. & Elbin, R. J. 2016. Sex Differences in Reported Concussion Injury Rates and Time Loss From Participation: An Update of the National Collegiate Athletic Association Injury Surveillance Program From 2004-2005 Through 2008-2009. Journal of Athletic Training 51 (3), 189-194.

Darrow, C. J., Collins, C. L., Yard, E. E. & Comstock, R. D. 2009. Epidemiology of severe injuries among United States high school athletes: 2005-2007. The American Journal of Sports Medicine 37 (9), 1798-1805.

Deitch, J. R., Starkey, C., Walters, S. L. & Moseley, J. B. 2006. Injury Risk in Professional Basketball Players: A Comparison of Women's National Basketball Association and National Basketball Association Athletes. The American Journal of Sports Medicine 34 (7), 1077-1083.

Delaney, J. S., Al-Kashmiri, A. & Correa, J. A. 2014. Mechanisms of injury for concussions in university football, ice hockey, and soccer. Clinical Journal of Sport Medicine 24 (3), 233-237.

Dick, R. W. 2009. Is there a gender difference in concussion incidence and outcomes? British Journal of Sports Medicine 43 Suppl 1, i46-50.

Drakos, M. C., Domb, B., Starkey, C., Callahan, L. & Allen, A. A. 2010. Injury in the National Basketball Association A 17-Year Overview. Sports Health: A Multidisciplinary Approach 2 (4), 284-290.

Echemendia., R.J., Meeuwisse, W., McCrory, P., Davis, G.A., Putukian, M., Leddy, J, Makdissi, M., Sullivan, S.J., Broglio, S.P., Raftery, M., Schneider, K., Kissick, J., McCrea, M., Dvorak, J., Sills, A.K., Aubry, M., Engebretsen, L., Loosemore, M., Fuller, G., Kutcher, J., Ellenbogen, R., Guskiewicz, K., Patricios, J. & Herring, S. 2017. The Sport Concussion Assessment Tool 5th Edition (SCAT5). British Journal of Sports Medicine 51 (11), 851-858.

Echlin, P. S., Tator, C. H., Cusimano, M. D., Cantu, R. C., Taunton, J. E., Upshur, R. E., Hall, C. R., Johnson, A. M., Forwell, L. A. & Skopelja, E. N. 2010. A prospective study of physician-observed concussions during junior ice hockey: implications for incidence rates. Neurosurgical Focus 29 (5), E4.

Emery, C. A., Hagel, B., Decloe, M., Carly, M. 2010. Risk factors for injury and severe injury in youth ice hockey: a systematic review of the literature. Injury Prevention 16 (2), 113-8.

Emery, C. A., Black, A. M., Kolstad, A., Martinez, G., Nettel-Aguirre, A., Engebretsen, L., Johnston, K., Kissick, J., Maddocks, D., Tator, C., Aubry, M., Dvorák, J., Nagahiro, S. & Schneider, K. 2017. What strategies can be used to effectively reduce the risk of concussion in sport? British Journal of Sports Medicine 2017 doi: 10.1136/bjsports-2016-097452. [Epub ahead of print].

Engebretsen, L., Bahr, R., Cook, J. L., Derman, W., Emery, C.A., Finch, C. F., Meeuwisse, W. H., Schwellnus M. & Steffen, K. 2014. The IOC Centres of Excellence bring prevention to sports medicine. British Journal of Sports Medicine 48 (17), 1270-1275.

Flik, K., Lyman, S. & Marx, R. G. 2005. American collegiate men's ice hockey: an analysis of injuries. The American Journal of Sports Medicine 33 (2), 183-187.

Ford, K. R., Myer, G. D. & Hewett, T. E. 2003. Valgus knee motion during landing in high school female and male basketball players. Medicine and science in sports and exercise 35 (10), 1745-1750

Frontera, W. R., Micheo, W. F., Aguirre, G., Rivera-Brown, A. & Pabon, A. 1997. Patterns of disease and utilization of health services during international sports competitions. Archivos de Medicina del Deporte 14, 479-484.

Frontera, W. R. 2003. Epidemiology of Sports Injuries: Implications for Rehabilitation. Rehabilitation of sports injuries: scientific basis. Volume X of the Encylopaedia of sports medicine an IOC Medical Committee publication in collaboration with the International Federation of Sports Medicine. Edited by Walter R. Frontera. 2003, 3-9.

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., Hägglund, M., McCrory, P. & Meeuwisse, W. H. 2006. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Scandinavian Journal of Medicine & Science in Sports 16 (2), 83-92.

Fuller, C. W., Molloy, M. G., Bagate, C., Bahr, R., Brooks, J. H. M., Donson, H., Kemp, S. P. T., McCrory, P., McIntosh, A. S., Meeuwisse, W. H., Quarrie, K. I., Raftery, M. & Wiley, P. 2007. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. British journal of sports medicine 41 (5), 328-331.

Giza, C. C. & Hovda, D. A. 2001. The Neurometabolic Cascade of Concussion. Journal of Athletic Training 36 (3), 228-235.

Giza, C. C. & Hovda, D. A. 2014. The new neurometabolic cascade of concussion. Neurosurgery. 75 Suppl 4, S24-33.

Hamilton, G.M., Meeuwisse, W. H., Emery, C. A., Steele, R. J. & Shrier, I. 2011. Past injury as a risk factor: an illustrative example where appearances are deceiving. American Journal of Epidemiology. 173 (8), 941-948.

Harmon, K. G., Drezner, J. A., Gammons, M., Guskiewicz, K. M., Halstead, M., Herring, S. A., Kutcher, J. S., Pana, A., Putukian, M. & Roberts, W. O. 2013. American Medical Society for Sports Medicine position statement: concussion in sport. British Journal of Sports Medicine 47 (1), 15-26.

Hootman, J. M., Dick, R. & Agel, J. 2007 Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. Journal of Athletic Training 42(2):311-9.

Hutchison, M. G., Comper, P., Meeuwisse, W. H. & Echemendia, R. J. 2015a. A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? British Journal of Sports Medicine 49 (8), 547-551.

Hutchison, M. G., Comper, P., Meeuwisse, W. H. & Echemendia, R. J. 2015b. A systematic video analysis of National Hockey League (NHL) concussions, part II: how concussions occur in the NHL. British Journal of Sports Medicine 49 (8), 552-555.

Hägglund, M., Waldén, M. & Ekstrand, J. 2006. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. British Journal of Sports Medicine 40 (9), 767-772.

Hägglund, M., Waldén, M., Til, L. & Pruna, R. 2010. The importance of epidemiological research in sports medicine. Apunts Medicina de l'Esport (45), 166, 57-59.

Izraelski, J. 2014. Concussions in the NHL: A narrative review of the literature. Journal of the Canadian Chiropractic Association 58 (4), 346-352.

Jacobsson, J., Timpka, T., Kowalski, J., Nilsson, S., Ekberg, J., Dahlström, Ö & Renström, P. A. 2013. Injury patterns in Swedish elite athletics: annual incidence, injury types and risk factors. British Journal of Sports Medicine 47(15):941-952.

Keightley, M., Reed, N., Green, S. & Taha, T. 2013. Age and competition level on injuries in female ice hockey. International Journal of Sports Medicine 34 (8), 756-759.

Kernozek, T. W., Torry, M. R., Van Hoof, H., Cowley, H. & Tanner, S. 2005. Gender differences in frontal and sagittal plane biomechanics during drop landings. Medicine and science in sports and exercise 37 (6), 1003-1012.

Kuzuhara, K., Shimamoto, H. & Mase, Y. 2009. Ice hockey injuries in a Japanese elite team: a 3-year prospective study. Journal of Athletic Training 44 (2), 208-214.

LaPrade, R. F., Burnett, Q. M., Zarzour, R. & Moss, R. 1995. The effect of the mandatory use of face masks on facial lacerations and head and neck injuries in ice hockey. A prospective study. American Journal of Sports Medicine 23 (6), 773-775.

LaPrade, R. F., Surowiec, R. K., Sochanska, A. N., Hentkowski, B. S., Martin, B. M., Engebretsen, L. & Wijdicks, C. A. 2014. Epidemiology, identification, treatment and return to play of musculoskeletal-based ice hockey injuries. British Journal of Sports Medicine 48 (1), 4-10.

Leppänen, M., Aaltonen, S., Parkkari, J., Heinonen, A. & Kujala, U. M. 2014 Interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. Sports Medicine 44, 473-486.

Leppänen, M., Pasanen, K., Kulmala, J.-P., Kujala, U. M., Krosshaug, T., Kannus, P., Perttunen, J., Vasankari, T. & Parkkari, J. 2016. Knee control and jump-landing technique in young basketball and floorball players. International Journal of Sports Medicine 37: 334–338.

Leppänen, M., Pasanen, K., Kujala, U. M., Vasankari, T., Kannus, P., Äyrämö, S., Krosshaug, T., Bahr, R., Avela, J., Perttunen, J. & Parkkari, J. 2017. Stiff Landings Are Associated with Increased ACL Injury Risk in Young Female Basketball and Floorball Players. American Journal of Sports Medicine 45 (2), 386-393.

Lian, Ø B., Engebretsen, L. & Bahr, R. 2005. Prevalence of Jumper's Knee Among Elite Athletes From Different Sports A Cross-sectional Study. The American Journal of Sports Medicine 33 (4), 561-567.

Lorentzon, R., Werden, H. & Pietilä, T. 1988. Incidence, nature, and causes of ice hockey injuries: a three year prospective study of a Swedish elite ice hockey team. American Journal of Sports Medicine 16 (4), 392-396.

MacCormick, L., Best, T. M., Flanigan, D. C. 2014. Are There Differences in Ice Hockey Injuries Between Sexes?: A Systematic Review. Orthopaedic Journal of Sports Medicine 2 (1), 2325967113518181.

Macera, C. A., Pate, R. R., Powell, K. E., Jackson, K. L., Kendrick, J. S. & Craven, T. E. 1989. Predicting lower-extremity injuries among habitual runners. Archives of Internal Medicine 149 (11), 2565-2568.

Malinzak, R. A., Colby, S. M., Kirkendall, D. T., Yu, B. & Garrett, W. E. 2001. A comparison of knee joint motion patterns between men and women in selected athletic tasks. Clinical Biomechanics 16 (5), 438-445.

Marar, M., McIlvain, N. M., Fields, S. K. & Comstock, R. D. 2012. Epidemiology of concussions among United States high school athletes in 20 sports. American Journal of Sports Medicine 40 (4), 747-755.

Matic, G. T., Sommerfeldt, M. F., Best, T. M., Collins, C. L., Comstock, R. D. & Flanigan, D. C. 2015. Ice hockey injuries among United States high school athletes from 2008/2009-2012/2013. Physician and sportsmedicine 43 (2), 119-125.

McBain, K., Shrier, I., Shultz, R., Meeuwisse, W. H., Klugl, M., Garza, D. & Matheson, G. O. 2012. Prevention of sports injury I: a systematic review of applied biomechanics and physiology outcomes research. British Journal of Sports Medicine 46 (3), 169-173.

McCrory, P., Johnston, K., Meeuwisse, W., Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., Kelly, J., Lovell, M. & Schamasch, P. 2005. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. British Journal of Sports Medicine 39 (4), 196-204.

McCrory, P., Meeuwisse, W., Johnston, K., Dvorak, J., Aubry, M., Molloy, M. & Cantu, R. 2009. Consensus Statement on Concussion in Sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. British Journal of Sports Medicine 43 Suppl 1:i76-90.

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, B., Dvorák, J., Echemendia, R. J., Engebretsen, L., Johnston, K., Kutcher, J. S., Raftery, M., Sills, A., Benson, B. W., Davis, G. A., Ellenbogen, R. G., Guskiewicz, K., Herring, S. A., Iverson, G. L., Jordan, B. D., Kissick, J., McCrea, M., McIntosh, A. S., Maddocks, D., Makdissi, M., Purcell, L., Putukian, M., Schneider, K., Tator, C. H. & Turner, M. 2013a. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. British Journal of Sports Medicine 47 (5), 250-258.

McCrory, P., Meeuwisse, W. H., Kutcher, J. S., Jordan, B. D. & Gardner, A. 2013b. What is the evidence for chronic concussion-related changes in retired athletes: behavioural, pathological and clinical outcomes? British Journal of Sports Medicine 47 (5), 327-330.

McCrory, P., Meeuwisse, W., Dvorak, J., Aubry, M., Bailes, J., Broglio, S., Cantu, R.C., Cassidy, D., Echemendia, R.J., Castellani, R.J., Davis, G.A., Ellenbogen, R., Emery, C., Engebretsen, L., Feddermann-Demont, N., Giza, C.C., Guskiewicz, K.M., Herring, S., Iverson, G.L., Johnston, K.M., Kissick, J., Kutcher, J., Leddy, J.J., Maddocks, D., Makdissi, M., Manley, G.T., McCrea, M., Meehan, W.P., Nagahiro, S., Patricios, J., Putukian, M., Schneider, K.J., Sills, A., Tator, C.H., Turner, M. & Vos, P.E. 2017. British Journal of Sports Medicine 51 (11), 838-847.

McKay, C. D., Tufts, R. J., Shaffer, B. & Meeuwisse, W. H. 2014. The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. British Journal of Sports Medicine 48 (1), 57-62.

McKnight, C. M., Ferrara, M. S. & Czerwinska, J. M. 1992. Intercollegiate ice hockey injuries: a three-year analysis. Journal of Athletic Training 27 (4), 338-343.

Meeuwisse, W. H. 1994. Assessing Causation in Sport Injury: A Multifactorial Model. Clinical Journal of Sport Medicine 4 (3), 166-170.

Meeuwisse, W. H. 2002. Full facial protection reduces injuries in elite young hockey players. Clinical Journal of Sport Medicine 12 (6), 406.

Mountjoy, M., Junge, A., Alonso, J. M., Clarsen, B., Pluim, B. M., Shrier, I., van den Hoogenband, C., Marks, S., Gerrard, D., Heyns, P., Kaneoka, K., Dijkstra, H. P. & Khan, K. M. 2016. Consensus statement on the methodology of injury and illness surveillance in FINA (aquatic sports). British Journal of Sports Medicine 50 (10), 590-596.

Myklebust, G., Hasslan, L., Bahr, R. & Steffen, K. 2011. High prevalence of shoulder pain among elite Norwegian female handball players. Scandinavian Journal of Medicine & Science in Sports 23 (3), 288-294.

Mölsä, J., Airaksinen, O., Näsman, O. & Torstila, I. 1997. Ice hockey injuries in Finland. A prospective epidemiologic study. American Journal of Sports Medicine 25(4):495-9.

Mölsä, J., Kujala, U., Näsman, O., Lehtipuu, T. P. & Airaksinen, O. 2000. Injury profile in ice hockey from the 1970s through the 1990s in Finland. American Journal of Sports Medicine 28 (3), 322-327.

Noble, J. M. & Hesdorffer, D. C. 2013. Sport-related concussions: a review of epidemiology, challenges in diagnosis, and potential risk factors. Neuropsychology Review 23 (4), 273-284.

Pasanen, K., Parkkari, J., Kannus, P., Rossi, L., Palvanen, M., Natri, A. & Järvinen, M. 2008. Injury risk in female floorball: a prospective one-season follow-up. Scandinavian Journal of Medicine & Science in Sports 18 (1), 49-54.

Pauelsen, M., Nyberg, G., Tegner, C. & Tegner, Y. 2016. Concussion in Ice Hockey—A Cohort Study Across 29 Seasons. Clinical Journal of Sport Medicine 50 (5), 298-304.

Pfister, T., Pfister, K., Hagel, B., Ghali, W. A. & Ronksley, P. E. 2016. The incidence of concussion in youth sports: a systematic review and meta-analysis. British Journal of Sports Medicine 50(5):292-297.

Pinto, M., Kuhn, J. E., Greenfield, M. L. & Hawkins, R. J. 1999. Prospective analysis of ice hockey injuries at the Junior A level over the course of one season. Clinical Journal of Sport Medicine 9 (2), 70-74.

Pluim, B. M., Fuller, C. W., Batt, M. E., Chase, L., Hainline, B., Miller, S., Montalvan, B., Renstrom, P., Stroia, K. A., Weber, K. & Wood, T. O. 2009. Consensus statement on epidemiological studies of medical conditions in tennis. British Journal of Sports Medicine 43 (12), 893-897.

Poutiainen, P., Peltonen, J., Isolehto, J. & Avela, J. 2014. Comparison of impact characteristics of four different ice hockey arena dasher boards. European Journal of Sport Science 14 (1), 11-18.

Ristolainen, L., Heinonen, A., Turunen, H., Mannström, H., Waller, B., Kettunen, J. A. & Kujala, U. M. 2010. Type of sport is related to injury profile: A study on cross country skiers, swimmers, long-distance runners and soccer players. A retrospective 12-month study. Scandinavian Journal of Medicine and Science in Sports 20 (3), 384-393.

Rishiraj, N., Lloyd-Smith, R., Lorenz, T., Niven, B. & Michel, M. 2009. University men's ice hockey: rates and risk of injuries over 6-years. Journal of Sports Medicine and Physical Fitness 49 (2), 159-166.

Ruhe, A., Gänsslen, A. & Klein, W. 2014. The incidence of concussion in professional and collegiate ice hockey: are we making progress? A systematic review of the literature. British Journal of Sports Medicine 48 (2), 102-106.

Schick, D. M. & Meeuwisse, W. H. 2003. Injury Rates and Profiles in Female Ice Hockey Players. American Journal of Sports Medicine 31 (1), 47-52.

Schneider, K. J., Leddy, J. J., Guskiewicz, K. M., Seifert, T., McCrea, M., Silverberg, N. D., Feddermann-Demont, N., Iverson, G. L., Hayden, A., Makdissi, M. 2017. Rest and treatment/rehabilitation following sport-related concussion: a systematic review. British Journal of Sports Medicine. doi: 10.1136/bjsports-2016-097475. [Epub ahead of print].

Smith, A. M., Stuart, M. J., Wiese-Bjornstal, D. M. & Gunnon, C. 1997. Predictors of injury in ice hockey players. A multivariate, multidisciplinary approach. American Journal of Sports Medicine 25 (4), 500-507.

Snellman, K., Parkkari, J., Kannus, P., Leppälä, J., Vuori, I. & Järvinen, M. 2001. Sports injuries in floorball: a prospective one-year follow-up study. International Journal of Sports Medicine 22 (07), 531-536.

Starkey, C. 2000. Injuries and illnesses in the National Basketball Association: a 10-year perspective. Journal of Athletic Training 35 (2), 161.

Stuart, M. J. & Smith, A. 1995. Injuries in Junior A ice hockey. A three-year prospective study. American Journal of Sports Medicine 23 (4), 458-461.

Stuart, M.J. & Smith A.M. 2000. "Principles of Ice Hockey Injury Research," Safety in Ice Hockey: Third Volume, ASTM STP 1341, A.B. Ashare, Ed., American Society for Testing and Materials, West Conshohocken, PA, 2000, 19-31.

Stuart, M. J., Smith, A. M., Malo-Ortiguera, S. A., Fischer, T. L. & Larson, D. R. 2002. A comparison of facial protection and the incidence of head, neck, and facial injuries in Junior A hockey players. A function of individual playing time. American Journal of Sports Medicine 30 (1), 39-44.

Tegner, Y. & Lorentzon, R. 1996. Concussion among Swedish elite ice hockey players. British Journal of Sports Medicine 30 (3), 251-255.

Timpka, T., Alonso, J. M., Jacobsson, J., Junge, A., Branco, P., Clarsen, B., Kowalski, J., Mountjoy, M., Nilsson, S., Pluim, B., Renstrom, P., Ronsen, O., Steffen, K. & Edouard, P. 2014. Injury and illness definitions and data collection procedures for use in epidemiological studies in Athletics (track and field): consensus statement. British journal of sports medicine 48 (7), 483-490.

Tranaeus, U., Götesson, E. & Werner, S. 2016. Injury Profile in Swedish Elite Floorball A Prospective Cohort Study of 12 Teams. Sports Health: A Multidisciplinary Approach, 1941738116628472.

van Mechelen, W., Hlobil, H. & Kemper, H. C. 1992. Incidence, severity, aetiology and prevention of sports injuries. Sports medicine 14 (2), 82-99.

Visnes, H. & Bahr, R. 2013. Training volume and body composition as risk factors for developing jumper's knee among young elite volleyball players. Scandinavian Journal of Medicine & Science in Sports 23 (5), 607-613.

Walter, S. D. & Hart, L. E. 1990. Application of epidemiological methodology to sports and exercise science research. Exercise and Sport Sciences Reviews 18:417-448.

Weir, A., Brukner, P., Delahunt, E., Ekstrand, J., Griffin, D., Khan, K. M., Lovell, G., Meyers, W. C., Muschaweck, U. & Orchard, J. 2015. Doha agreement meeting on terminology and definitions in groin pain in athletes. British journal of sports medicine 49 (12), 768-774.

Wennberg, R. 2004. Collision frequency in elite hockey on North American versus international size rinks. Canadian Journal of Sciences 31 (3), 373-377.

Wennberg, R. 2005. Effect of ice surface size on collision rates and head impacts at the World Junior Hockey Championships, 2002 to 2004. Clinical Journal of Sport Medicine 15 (2), 67-72.

Wennberg, R. A. & Tator, C. H. 2008. Concussion incidence and time lost from play in the NHL during the past ten years. Canadian Journal of Neurological Sciences 35 (5), 647-651.

Wikström, J. & Andersson, C. 1997. A prospective study of injuries in licensed floorball players. Scandinavian Journal of Medicine & Science in Sports 7 (1), 38-42.

Wilcox, B. J., Machan, J. T., Beckwith, J. G., Greenwald, R. M., Burmeister, E. & Crisco, J.J. 2014. Head-impact mechanisms in men's and women's collegiate ice hockey. Journal of Athletic Training 49 (4), 514-520.

Yang, J., Tibbetts, A. S., Covassin, T., Cheng, G., Nayar, S. & Heiden, E. 2012. Epidemiology of overuse and acute injuries among competitive collegiate athletes. Journal of athletic training 47 (2), 198-204.

Zuckerman, S. L., Kerr, Z. Y., Yengo-Kahn, A., Wasserman, E., Covassin, T. & Solomon, G. S. 2015. Epidemiology of Sports-Related Concussion in NCAA Athletes from 2009-2010 to 2013-2014: Incidence, Recurrence, and Mechanisms. American Journal of Sports Medicine 43 (11), 2654-2662.

ATTACHMENT I. Injury patterns of ice hockey injuries in literature.

Research	level		Injury rate	Head and face	Upper body	Lower body	Spain ahd trunk	Contusion	Sprain	Strain	Fracture	Laceration	Concussion	Checking	Player contact	Puck	Stick	Period I	period II	period III
Mölsä et al (1997)	FHL		66 pgh	18 %				38.8%	39.7%		8.0%		4.8%	29.7 %	14.6%	7.9%	14.6%			
	I Division		36 pgh																	
Mölsä et al (2000)	FHL	1976-1979	54 pgh	28 %				41 %	30 %		15 %			19 %	8 %	18 %	29 %			
	FHL	1988-1989	55 pgh	20 %				46 %	42 %		7 %			38 %	15 %	12 %	21 %			
	FHL	1992-1993	83pgh	14 %				46 %	53 %		10 %			35 %	22 %	11 %	19 %			
													8.9%					24 %	36 %	40 %
Lorentzon et al (1988)	SHL		78.4 pgh	6.3%	24.2%	53.7%	15.8%	32.9%	15.8%	17.1%	13.2%		5.3%	32.9 %	25.0%	14.5%	11.8%	27 %	30 %	36 %
Agel et al (2007a)	NCAA		16.27 AE	15.4%	34.4%	34.3%	14.3%	13.2%	22.5%	13.4%	1.7%	1.1%	1.47 (9.0%)		47.7%	7.0%	6.4%	27.5%	35.5%	35.5%
Flik et al (2005)	College		13.8 AE	19 %	22 %	34 %	18 %						18.6%		32.8%	6.2%	1.2%	36.5%	36.5%	27.0%
McKnight et al (1992)	College		14.73AE	1.13AE	3.06AE	4.24AE	1.79AE	3.32AE	3.03AE	1.5AE	0.58AE	0.91AE	0.22AE		4.2AE	0.99AE	0.58AE			
Agel & Harvey (2010)	NCAA		18.69AE										0.72AE							
Kuzuhara et al (2009)	JPN		74.3 pgh	11.7pgh	23.0pgh	31.9pgh	3.9pgh	35.4 pgh	7.0 pgh	15.6pgh	1.9pgh	9.3pgh	1.6pgh		13.2pgh	15.6pgh	24.5pgh			
Smith et al 1997	High school		34.4pgh																	
Matic et al (2015)	High school		23.2AE	33.8%	20.6%								0.64AE	46 %						
Stuart et al (2002)	Junior A	no facial protection	158.9pgh										12.2pgh							
		visor	73.5pgh										8.2pgh							
		full face protection	23.2pgh										2.9pgh							
Stuart & Smith (1995)	Junior A		96.1 pgh	28 %	28 %	20 %	24 %													x
Pinto et al (1999)	Junior A		83pgh	24.2%	29.5%	22.8%	18.8%													
Rishiraj et al (2009)	Varsity		8.2AE	40 %	23 %	20 %	8 %	12 %	20 %	20 %	8 %	11 %	13 %							
Schick & Meeuwisse (2003)	men		22.40AE	14.3%	28.6%	37.3%	16.2%	6.8%	21.2%	12.5%	2.5%	0	10.6%		38.37%		12.79%	34.95 %	33.98%	31.07%
	women		10,43AE	16.7%	15.1%	46.9%	16.6%	1.5%	18.2%	18.1%	3.8%	0	15.1%		48.39%			6.9%	51.72%	41.38%
Agel et al (2007b)	women NCAA		12,6AE	25.4%	30.3%	31.8%	11.4%	4.4%	13.7%	11.1%	0	0	21.6% (2.72AE)		46.8%	3.0%	6.5%			
Agel & Harvey (2010)	women NCAA		12.10AE	21.8%	27.2%	31.5%	17.2%						0.82AE							

ATTACHMENT II. Injury rate for concussion in literature.

	level	gender	proportion	overall IR per 1000 Aes	IR for games: IR per 1000 Aes	IR for games: IR per 1000 player-game hours	IR for games: IR per 100 games	IR for games: IR per 1000 games
Tegner & Lorentzon(1996)	SHL	male	6.0%			6.5 pgh		
Lorentzon et al. (1988)	SHL	male	5.3%					
Mölsä et al (1997)	FHL	male	4.8%					
Mölsä et al (2000)	FHL	male	2.7%					
Pauelsen et al (2016)	SHL	male	10 %					77
Benson et al (2011)	NHL	male			1.8		5.8	
Hutchinson et al (2015a)	NHL	male					6.05	
Wennberg and Tator (2008)	NHL	male			1.45			
Agel et al (2007a)	NCAA	male	9.0%		1.47			
Agel & Harvey (2010)	NCAA	male		0.72				
		female		0.82				
Hootman et al (2007)	NCAA	male	7.9%	0.41				
		female	18.3%	0.91				
Zuckerman et al (2015)	NCAA	male			2.49			
		female			2.01			
Flik et al (2005)		male	18.6%	0.91	3.2		6.56	
McKnight et al (1992)	College	male		0.22				
Agel et al (2007b)	NCAA	female	21.6%	2.72				
Schick & Meeuwisse (2003)	CWUAA	male	10.6%	0.97				
		female	15.1%	1.18				
Marar et al (2012)	HS	male	22.2%		1.46			
Matic et al (2015)	HS	male		0.64				
Echlin et al (2010)	J				21.5			
		Facial protection						
Stuart et al (2002)	J	none				12.2		
		visor				8.2		
		full				2.9		
Benson et al (1999)	J	visor			1.59			
		full			1.53			

ATTACHMENT III. Ice hockey injuries by anatomic region in all men's World Championship games.

Anatomic region	2007 Number	2007 IR per 1000 player-games	2007 IR per 1000 player-game hours	2008 Number	2008 IR per 1000 player-games	2008 IR per 1000 player-game hours	2009 Number	2009 IR per 1000 player-games	2009 IR per 1000 player-game hours	2010 Number	2010 IR per 1000 player-games	2010 IR per 1000 player-game hours	2011 Number	2011 IR per 1000 player-games	2011 IR per 1000 player game hours	2012 Number	2012 IR per 1000 player-games	2012 IR per 1000 player game hours	2013 Number	2013 IR per 1000 player-games	2013 IR per 1000 player game hours	TOT Number	TOT IR per 1000 player-games	TOT IR per 1000 player-game hours
Face	16	3,8	13,9	26	5,2	19,0	25	4,8	17,5	17	2,9	10,8	13	2,8	10,2	17	3,1	11,4	15	2,2	8,1	129	3,5	12,7
Knee	13	3,1	11,3	12	2,4	8,8	6	1,1	4,2	9	1,6	5,7	6	1,3	4,7	16	2,9	10,8	14	2,1	7,6	76	2,0	7,5
Shoulder + Clavicle	6	1,4	5,2	5	1,0	3,7	15	2,9	10,5	7	1,2	4,5	11	2,4	8,6	6	1,1	4,0	9	1,3	4,9	59	1,6	5,8
Head	5	1,2	4,3	13	2,6	9,5	7	1,3	4,9	12	2,1	7,6	6	1,3	4,7	8	1,5	5,4	7	1,0	3,8	58	1,6	5,7
Fingers+ thumb+ hand	2	0,5	1,7	2	0,4	1,5	2	0,4	1,4	5	0,9	3,2	3	0,6	2,4	10	1,8	6,7	7	1,0	3,8	31	0,8	3,1
Ankle+leg	1	0,2	0,9	7	1,4	5,1	1	0,2	0,7	3	0,5	1,9	4	0,9	3,1	5	0,9	3,4	4	0,6	2,2	25	0,7	2,5
Groin+hip + pelvis	3	0,7	2,6	2	0,4	1,5	5	1,0	3,5	2	0,3	1,3	4	0,9	3,1	2	0,4	1,3	5	0,7	2,7	23	0,6	2,3
Teeth	1	0,2	0,9	5	1,0	3,7	2	0,4	1,4	8	1,4	5,1	0	0,0	0,0	1	0,2	0,7	3	0,4	1,6	20	0,5	2,0
Thigh	4	0,9	3,5	5	1,0	3,7	2	0,4	1,4	2	0,3	1,3				4	0,7	2,7	5	0,7	2,7	22	0,6	2,2
Chest+ throat	2	0,5	1,7	2	0,4	1,5	2	0,4	1,4	3	0,5	1,9	2	0,4	1,6	3	0,5	2,0	5	0,7	2,7	19	0,5	1,9
Foot+toes	1	0,2	0,9	4	0,8	2,9	4	0,8	2,8	1	0,2	0,6	1	0,2	0,8	2	0,4	1,3	3	0,4	1,6	16	0,4	1,6
Neck+ upper back+ lower back	3	0,7	2,6	1	0,2	0,7	4	0,8	2,8	1	0,2	0,6	2	0,4	1,6	2	0,4	1,3	3	0,4	1,6	16	0,4	1,6
Wrist	2	0,5	1,7	1	0,2	0,7	4	0,8	2,8	1	0,2	0,6	2	0,4	1,6	1	0,2	0,7	2	0,3	1,1	13	0,4	1,3
upperarm + forearm+ elbow	1	0,2	0,9	1	0,2	0,7	3	0,6	2,1							3	0,5	2,0	4	0,6	2,2	12	0,3	1,2
Abdomen + genitals+ kidneys				1	0,2	0,7				1	0,2	0,6	3	0,6	2,4				1	0,1	0,5	6	0,2	0,6
Eye				1	0,2	0,7	1	0,2	0,7				0	0,0	0,0				1	0,1	0,5	3	0,1	0,3
TOT	60	14,2	52,1	88	17,5	64,3	83	15,9	58,1	72	12,5	45,8	57	12,2	44,8	80	14,7	53,8	88	13,0	47,6	528	14,2	52,1

ATTACHMENT IV. Ice hockey injuries by anatomic region in all female World Championship games and OWG.

	WWC (OWG)			WWC U18			all female tournaments		
Ananatomic region	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours
Face	2	0,1	0,4	2	0,2	0,7	4	0,2	0,5
Knee	17	1,0	3,6	18	1,8	6,1	35	1,3	4,6
Shoulder + Clavicle	8	0,5	1,7	4	0,4	1,4	12	0,5	1,6
Head	14	0,9	3,0	15	1,5	5,1	29	1,1	3,8
Fingers+thumb+ hand	6	0,4	1,3	2	0,2	0,7	8	0,3	1,0
Ankle+leg	13	0,8	2,8	8	0,8	2,7	21	0,8	2,7
Groin+hip+pelvis	6	0,4	1,3	3	0,3	1,0	9	0,3	1,2
Teeth	0	0,0	0,0	2	0,2	0,7	2	0,1	0,3
Thigh	5	0,3	1,1	1	0,1	0,3	6	0,2	0,8
Chest+throat	3	0,2	0,6	2	0,2	0,7	5	0,2	0,7
Foot+toes	2	0,1	0,4	1	0,1	0,3	3	0,1	0,4
Neck+upper back+lower back	8	0,5	1,7	7	0,7	2,4	15	0,6	2,0
Wrist	3	0,2	0,6	4	0,4	1,4	7	0,3	0,9
upperarm+ forearm+elbow	5	0,3	1,1	5	0,5	1,7	10	0,4	1,3
Abdomen+genitals+ kidneys	1	0,1	0,2	1	0,1	0,3	2	0,1	0,3
Eye	0	0,0	0,0	0	0,0	0,0	0	0,0	0,0
TOT	93	5,7	19,7	75	7,5	25,6	168	6,4	22,0

IR, injury rate; OWG, OWG, Olympic Winter Games; WWC, World Women's Championship; WWC U18, World Women's under-18 Championship.

ATTACHMENT V. Ice hockey injuries by anatomic region in all Junior Under-20 World Championship games.

	2007		2008		2009		2010		2011		2012		2013		2014		2015		TOT		
Ananatomic region	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	Number	IR per 1000 player-games	IR per 1000 playing-hours
Face+ear	15	4,5	11	2,6	13	3,9	14	5,2	20	4,7	13	4,8	9	4,4	7	1,5	12	3,6	114	3,8	13,7
Knee	5	1,5	1	0,2	5	1,5	3	1,1	3	0,7	3	1,1		0,0	4	0,9	0	0,0	24	0,8	2,9
Shoulder + Clavicle	5	1,5	5	1,2	3	0,9	5	1,9	6	1,4	4	1,5	2	1,0	12	2,6	8	2,4	50	1,7	6,0
Head		0,0	2	0,5	5	1,5	5	1,9	3	0,7	4	1,5	4	2,0	12	2,6	6	1,8	41	1,4	4,9
Fingers+ thumb+ hand	2	0,6		0,0		0,0	2	0,7	4	0,9	4	1,5	4	2,0	2	0,4	1	0,3	19	0,6	2,3
Ankle+leg		0,0	1	0,2	8	2,4	2	0,7	3	0,7	2	0,7	3	1,5	2	0,4	2	0,6	23	0,8	2,8
Groin+hip+ pelvis	0	0,0	1	0,2	1	0,3	1	0,4		0,0	0	0,0		0,0	1	0,2	2	0,6	6	0,2	0,7
Teeth	1	0,3	1	0,2	8	2,4		0,0	1	0,2	1	0,4	1	0,5	4	0,9	2	0,6	19	0,6	2,3
Thigh		0,0	2	0,5	1	0,3	2	0,7	2	0,5	3	1,1	1	0,5	3	0,6	1	0,3	15	0,5	1,8
Chest+ throat+ scapula		0,0	1	0,2	2	0,6		0,0	1	0,2		0,0	1	0,5	3	0,6		0,0	8	0,3	1,0
Foot+toes	1	0,3	1	0,2	1	0,3	3	1,1	2	0,5	3	1,1		0,0		0,0		0,0	11	0,4	1,3
Neck+upper back+lower back	2	0,6	2	0,5	1	0,3	1	0,4	2	0,5		0,0		0,0	3	0,6	1	0,3	12	0,4	1,4
Wrist		0,0		0,0	3	0,9		0,0		0,0	1	0,4		0,0	1	0,2		0,0	5	0,2	0,6
upperarm+ forearm+ elbow		0,0	1	0,2	1	0,3		0,0	2	0,5	1	0,4	1	0,5	3	0,6	2	0,6	11	0,4	1,3
Abdomen+ genitals+ kidneys		0,0		0,0		0,0	1	0,4		0,0		0,0		0,0		0,0	2	0,6	3	0,1	0,4
Eye		0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0	0	0,0	0,0
Total	31	9,3	29	6,8	52	15,6	39	14,5	49	11,5	39	14,5	26	12,8	57	12,2	39	11,8	361	12,0	43,3

ATTACHMENT VI. Ice hockey injuries by anatomic region in all Junior Under-18 World Championship games.

Ananatomic region	2007 Number	2007 IR per 1000 player-games	2008 Number	2008 IR per 1000 player-games	2009 Number	2009 IR per 1000 player-games	2010 Number	2010 IR per 1000 player-games	2011 Number	2011 IR per 1000 player-games	2012 Number	2012 IR per 1000 player-games	2013 Number	2013 IR per 1000 player-games	2014 Number	2014 IR per 1000 player-games	2015 Number	2015 IR per 1000 player-games	TOT Number	TOT IR per 1000 player-games	TOT IR per 1000 playing-hours
Face+ear	5	1,2	4	1,2	1	0,7	2	0,7	4	1,6	3	0,9	3	0,9	2	0,6	4	1,0	28	1,0	3,7
Knee	7	1,7	5	1,5	1	0,7	2	0,7	3	1,2	4	1,2	2	0,6		0,0	2	0,5	26	1,0	3,4
Shoulder + Clavicle	3	0,7	5	1,5	3	2,2	2	0,7	13	5,3	4	1,2	4	1,2	11	3,3	11	2,8	56	2,0	7,4
Head	4	1,0	1	0,3	2	1,5	4	1,5	3	1,2	9	2,7	5	1,5	5	1,5	4	1,0	37	1,4	4,9
Fingers+ thumb+ hand	5	1,2	2	0,6		0,0	2	0,7	4	1,6	1	0,3	3	0,9	1	0,3	4	1,0	22	0,8	2,9
Ankle+leg	2	0,5	3	0,9	2	1,5	2	0,7	1	0,4	4	1,2	1	0,3	4	1,2	2	0,5	21	0,8	2,8
Groin+hip+ pelvis	4	1,0	1	0,3	1	0,7	1	0,4	1	0,4		0,0		0,0		0,0		0,0	8	0,3	1,1
Teeth		0,0		0,0	1	0,7		0,0	1	0,4		0,0		0,0	1	0,3	2	0,5	5	0,2	0,7
Thigh	3	0,7	2	0,6	2	1,5	5	1,9	2	0,8	2	0,6		0,0		0,0	2	0,5	18	0,7	2,4
Chest	1	0,2	1	0,3		0,0		0,0	2	0,8		0,0		0,0		0,0	3	0,8	7	0,3	0,9
Foot+toes	1	0,2	1	0,3		0,0		0,0		0,0		0,0		0,0	1	0,3		0,0	3	0,1	0,4
Neck+lower back	3	0,7	2	0,6	1	0,7	1	0,4		0,0	7	2,1	3	0,9		0,0	3	0,8	20	0,7	2,6
Wrist	1	0,2		0,0	1	0,7	2	0,7	1	0,4	1	0,3		0,0	1	0,3	3	0,8	10	0,4	1,3
upperarm+ forearm+ elbow		0,0	1	0,3		0,0	2	0,7	2	0,8	1	0,3	1	0,3	2	0,6		0,0	9	0,3	1,2
Abdomen+ kidneys		0,0		0,0		0,0		0,0		0,0		0,0		0,0	1	0,3	1	0,3	2	0,1	0,3
Eye		0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0		0,0	0	0,0	0,0
Total	39	9,7	28	8,4	15	11,0	25	9,3	37	15,0	36	10,8	22	6,7	29	8,8	41	10,4	272	9,9	35,9

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (Echemendia et al. 2017) (developed by the Concussion in Sport Group).

To download a clean version of the SCAT tools please visit the journal online (http://dx.doi.org/10.1136/bjsports-2017-097506SCAT5)

SCAT5©

SPORT CONCUSSION ASSESSMENT TOOL — 5TH EDITION

DEVELOPED BY THE CONCUSSION IN SPORT GROUP
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

FIFA

Patient details

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date of Injury: _____ Time: _____

WHAT IS THE SCAT5?

The SCAT5 is a standardized tool for evaluating concussions designed for use by physicians and licensed healthcare professionals[1]. The SCAT5 cannot be performed correctly in less than 10 minutes.

If you are not a physician or licensed healthcare professional, please use the Concussion Recognition Tool 5 (CRT5). The SCAT5 is to be used for evaluating athletes aged 13 years and older. For children aged 12 years or younger, please use the Child SCAT5.

Preseason SCAT5 baseline testing can be useful for interpreting post-injury test scores, but is not required for that purpose.Detailed instructions for use of the SCAT5 are provided on page 7. Please read through these instructions carefully before testing the athlete. Brief verbal instructions for each test are given in italics. The only equipment required for the tester is a watch or timer.

Recognise and Remove

A head impact by either a direct blow or indirect transmission of force can be associated with a serious and potentially fatal brain injury. If there are significant concerns, including any of the red flags listed in Box 1, then activation of emergency procedures and urgent transport to the nearest hospital should be arranged.

Key points

- Any athlete with suspected concussion should be REMOVED FROM PLAY, medically assessed and monitored for deterioration. No athlete diagnosed with concussion should be returned to play on the day of injury.
- If an athlete is suspected of having a concussion and medical personnel are not immediately available, the athlete should be referred to a medical facility for urgent assessment.
- Athletes with suspected concussion should not drink alcohol, use recreational drugs and should not drive a motor vehicle until cleared to do so by a medical professional.
- Concussion signs and symptoms evolve over time and it is important to consider repeat evaluation in the assessment of concussion.
- The diagnosis of a concussion is a clinical judgment, made by a medical professional. The SCAT5 should NOT be used by itself to make, or exclude, the diagnosis of concussion. An athlete may have a concussion even if their SCAT5 is "normal".

Remember:

- The basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Do not attempt to move the athlete (other than that required for airway management) unless trained to do so.
- Assessment for a spinal cord injury is a critical part of the initial on-field assessment.
- Do not remove a helmet or any other equipment unless trained to do so safely.

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (continues) (Echemendia et al. 2017) (developed by the Concussion in Sport Group).

1

IMMEDIATE OR ON-FIELD ASSESSMENT

The following elements should be assessed for all athletes who are suspected of having a concussion prior to proceeding to the neurocognitive assessment and ideally should be done on-field after the first first aid / emergency care priorities are completed.

If any of the "Red Flags" or observable signs are noted after a direct or indirect blow to the head, the athlete should be immediately and safely removed from participation and evaluated by a physician or licensed healthcare professional.

Consideration of transportation to a medical facility should be at the discretion of the physician or licensed healthcare professional.

The GCS is important as a standard measure for all patients and can be done serially if necessary in the event of deterioration in conscious state. The Maddocks questions and cervical spine exam are critical steps of the immediate assessment; however, these do not need to be done serially.

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

STEP 1: RED FLAGS

RED FLAGS:

- Neck pain or tenderness
- Double vision
- Weakness or tingling/ burning in arms or legs
- Severe or increasing headache
- Seizure or convulsion
- Loss of consciousness
- Deteriorating conscious state
- Vomiting
- Increasingly restless, agitated or combative

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

Lying motionless on the playing surface	Y	N
Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements	Y	N
Disorientation or confusion, or an inability to respond appropriately to questions	Y	N
Blank or vacant look	Y	N
Facial injury after head trauma	Y	N

STEP 3: MEMORY ASSESSMENT MADDOCKS QUESTIONS[2]

"I am going to ask you a few questions, please listen carefully and give your best effort. First, tell me what happened?"

Mark Y for correct answer / N for incorrect

What venue are we at today?	Y	N
Which half is it now?	Y	N
Who scored last in this match?	Y	N
What team did you play last week / game?	Y	N
Did your team win the last game?	Y	N

Note: Appropriate sport-specific questions may be substituted.

STEP 4: EXAMINATION GLASGOW COMA SCALE (GCS)[3]

Time of assessment			
Date of assessment			
Best eye response (E)			
No eye opening	1	1	1
Eye opening in response to pain	2	2	2
Eye opening to speech	3	3	3
Eyes opening spontaneously	4	4	4
Best verbal response (V)			
No verbal response	1	1	1
Incomprehensible sounds	2	2	2
Inappropriate words	3	3	3
Confused	4	4	4
Oriented	5	5	5
Best motor response (M)			
No motor response	1	1	1
Extension to pain	2	2	2
Abnormal flexion to pain	3	3	3
Flexion / Withdrawal to pain	4	4	4
Localizes to pain	5	5	5
Obeys commands	6	6	6
Glasgow Coma score (E + V + M)			

CERVICAL SPINE ASSESSMENT

Does the athlete report that their neck is pain free at rest?	Y	N
If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain free movement?	Y	N
Is the limb strength and sensation normal?	Y	N

In a patient who is not lucid or fully conscious, a cervical spine injury should be assumed until proven otherwise.

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

2

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (continues) (Echemendia et al. 2017) (developed by the Concussion in Sport Group).

OFFICE OR OFF-FIELD ASSESSMENT

Please note that the neurocognitive assessment should be done in a distraction-free environment with the athlete in a resting state.

STEP 1: ATHLETE BACKGROUND

Sport / team / school: _____

Date / time of injury: _____

Years of education completed: _____

Age: _____

Gender: M / F / Other

Dominant hand: left / neither / right

How many diagnosed concussions has the athlete had in the past?: _____

When was the most recent concussion?: _____

How long was the recovery (time to being cleared to play) from the most recent concussion?: _____ (days)

Has the athlete ever been:

Hospitalized for a head injury?	Yes	No
Diagnosed / treated for headache disorder or migraines?	Yes	No
Diagnosed with a learning disability / dyslexia?	Yes	No
Diagnosed with ADD / ADHD?	Yes	No
Diagnosed with depression, anxiety or other psychiatric disorder?	Yes	No

Current medications? If yes, please list:

_____

_____

_____

_____

_____

_____

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

2

STEP 2: SYMPTOM EVALUATION

The athlete should be given the symptom form and asked to read this instruction paragraph out loud then complete the symptom scale. For the baseline assessment, the athlete should rate his/her symptoms based on how he/she typically feels and for the post injury assessment the athlete should rate their symptoms at this point in time.

Please Check: ☐ **Baseline** ☐ **Post-Injury**

Please hand the form to the athlete

	none	mild		moderate		severe	
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6
Total number of symptoms:							of 22
Symptom severity score:							of 132
Do your symptoms get worse with physical activity?						Y	N
Do your symptoms get worse with mental activity?						Y	N
If 100% is feeling perfectly normal, what percent of normal do you feel?							

If not 100%, why?

_____

_____

_____

Please hand form back to examiner

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

3

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (continues) (Echemendia et al. 2017) (developed by the Concussion in Sport Group).

3

STEP 3: COGNITIVE SCREENING

Standardised Assessment of Concussion (SAC)[4]

ORIENTATION

What month is it?	0	1
What is the date today?	0	1
What is the day of the week?	0	1
What year is it?	0	1
What time is it right now? (within 1 hour)	0	1
Orientation score		of 5

IMMEDIATE MEMORY

The Immediate Memory component can be completed using the traditional 5-word per trial list or optionally using 10-words per trial to minimise any ceiling effect. All 3 trials must be administered irrespective of the number correct on the first trial. Administer at the rate of one word per second.

Please choose EITHER the 5 or 10 word list groups and circle the specific word list chosen for this test.

I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order. For Trials 2 & 3: I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before.

List	Alternate 5 word lists					Score (of 5) Trial 1	Trial 2	Trial 3
A	Finger	Penny	Blanket	Lemon	Insect			
B	Candle	Paper	Sugar	Sandwich	Wagon			
C	Baby	Monkey	Perfume	Sunset	Iron			
D	Elbow	Apple	Carpet	Saddle	Bubble			
E	Jacket	Arrow	Pepper	Cotton	Movie			
F	Dollar	Honey	Mirror	Saddle	Anchor			
					Immediate Memory Score			of 15
					Time that last trial was completed			

List	Alternate 10 word lists					Score (of 10) Trial 1	Trial 2	Trial 3
G	Finger Candle	Penny Paper	Blanket Sugar	Lemon Sandwich	Insect Wagon			
H	Baby Elbow	Monkey Apple	Perfume Carpet	Sunset Saddle	Iron Bubble			
I	Jacket Dollar	Arrow Honey	Pepper Mirror	Cotton Saddle	Movie Anchor			
					Immediate Memory Score			of 30
					Time that last trial was completed			

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

CONCENTRATION

DIGITS BACKWARDS

Please circle the Digit list chosen (A, B, C, D, E, F). Administer at the rate of one digit per second reading DOWN the selected column.

I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.

Concentration Number Lists (circle one)					
List A	List B	List C			
4-9-3	5-2-6	1-4-2	Y	N	0
6-2-9	4-1-5	6-5-8	Y	N	1
3-8-1-4	1-7-9-5	6-8-3-1	Y	N	0
3-2-7-9	4-9-6-8	3-4-8-1	Y	N	1
6-2-9-7-1	4-8-5-2-7	4-9-1-5-3	Y	N	0
1-5-2-8-6	6-1-8-4-3	6-8-2-5-1	Y	N	1
7-1-8-4-6-2	8-3-1-9-6-4	3-7-6-5-1-9	Y	N	0
5-3-9-1-4-8	7-2-4-8-5-6	9-2-6-5-1-4	Y	N	1
List D	List E	List F			
7-8-2	3-8-2	2-7-1	Y	N	0
9-2-6	5-1-8	4-7-9	Y	N	1
4-1-8-3	2-7-9-3	1-6-8-3	Y	N	0
9-7-2-3	2-1-6-9	3-9-2-4	Y	N	1
1-7-9-2-6	4-1-8-6-9	2-4-7-5-8	Y	N	0
4-1-7-5-2	9-4-1-7-5	8-3-9-6-4	Y	N	1
2-6-4-8-1-7	6-9-7-3-8-2	5-8-6-2-4-9	Y	N	0
8-4-1-9-3-5	4-2-7-9-3-8	3-1-7-8-2-6	Y	N	1
		Digits Score:			of 4

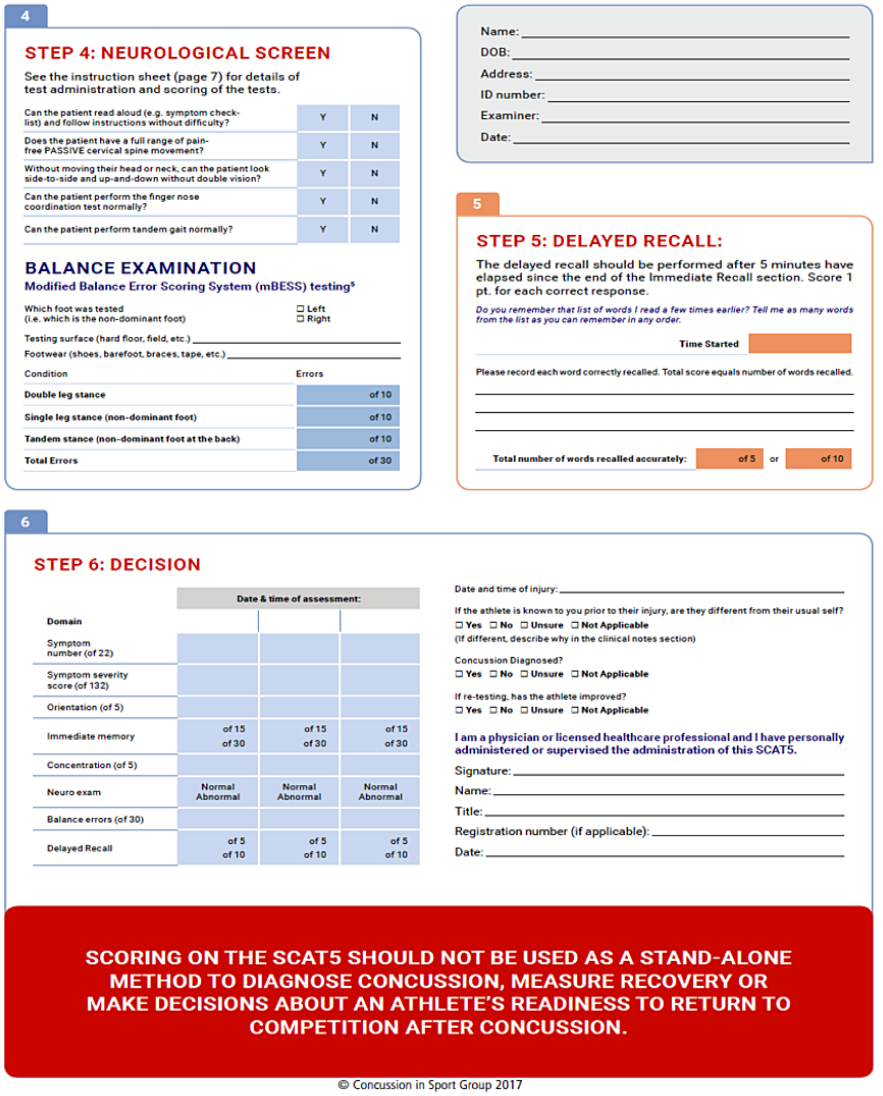
MONTHS IN REVERSE ORDER

Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November. Go ahead.

Dec - Nov - Oct - Sept - Aug - Jul - Jun - May - Apr - Mar - Feb - Jan	0 1
Months Score	of 1
Concentration Total Score (Digits + Months)	of 5

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (continues) (Echemendia et al. 2017) (developed by the Concussion in Sport Group).



4

STEP 4: NEUROLOGICAL SCREEN

See the instruction sheet (page 7) for details of test administration and scoring of the tests.

Can the patient read aloud (e.g. symptom check-list) and follow instructions without difficulty?	Y	N
Does the patient have a full range of pain-free PASSIVE cervical spine movement?	Y	N
Without moving their head or neck, can the patient look side-to-side and up-and-down without double vision?	Y	N
Can the patient perform the finger nose coordination test normally?	Y	N
Can the patient perform tandem gait normally?	Y	N

BALANCE EXAMINATION

Modified Balance Error Scoring System (mBESS) testing[5]

Which foot was tested (i.e. which is the non-dominant foot) ☐ Left ☐ Right

Testing surface (hard floor, field, etc.) _____

Footwear (shoes, barefoot, braces, tape, etc.) _____

Condition	Errors
Double leg stance	of 10
Single leg stance (non-dominant foot)	of 10
Tandem stance (non-dominant foot at the back)	of 10
Total Errors	of 30

Name: _____

DOB: _____

Address: _____

ID number: _____

Examiner: _____

Date: _____

5

STEP 5: DELAYED RECALL:

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section. Score 1 pt. for each correct response.

Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order.

Time Started

Please record each word correctly recalled. Total score equals number of words recalled.

_____

_____

_____

Total number of words recalled accurately: of 5 or of 10

6

STEP 6: DECISION

Domain	Date & time of assessment:		
Symptom number (of 22)			
Symptom severity score (of 132)			
Orientation (of 5)			
Immediate memory	of 15 of 30	of 15 of 30	of 15 of 30
Concentration (of 5)			
Neuro exam	Normal Abnormal	Normal Abnormal	Normal Abnormal
Balance errors (of 30)			
Delayed Recall	of 5 of 10	of 5 of 10	of 5 of 10

Date and time of injury: _____

If the athlete is known to you prior to their injury, are they different from their usual self?
☐ Yes ☐ No ☐ Unsure ☐ Not Applicable
(If different, describe why in the clinical notes section)

Concussion Diagnosed?
☐ Yes ☐ No ☐ Unsure ☐ Not Applicable

If re-testing, has the athlete improved?
☐ Yes ☐ No ☐ Unsure ☐ Not Applicable

I am a physician or licensed healthcare professional and I have personally administered or supervised the administration of this SCAT5.

Signature: _____

Name: _____

Title: _____

Registration number (if applicable): _____

Date: _____

SCORING ON THE SCAT5 SHOULD NOT BE USED AS A STAND-ALONE METHOD TO DIAGNOSE CONCUSSION, MEASURE RECOVERY OR MAKE DECISIONS ABOUT AN ATHLETE'S READINESS TO RETURN TO COMPETITION AFTER CONCUSSION.

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (continues) (Echemendia et al. 2017) (developed by the Concussion in Sport Group).

CLINICAL NOTES:

Name: _____
DOB: _____
Address: _____
ID number: _____
Examiner: _____
Date: _____

CONCUSSION INJURY ADVICE

(To be given to the person monitoring the concussed athlete)

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. Recovery time is variable across individuals and the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

If you notice any change in behaviour, vomiting, worsening headache, double vision or excessive drowsiness, please telephone your doctor or the nearest hospital emergency department immediately.

Other important points:

Initial rest: Limit physical activity to routine daily activities (avoid exercise, training, sports) and limit activities such as school, work, and screen time to a level that does not worsen symptoms.

1) Avoid alcohol

2) Avoid prescription or non-prescription drugs without medical supervision. Specifically:

   a) Avoid sleeping tablets

   b) Do not use aspirin, anti-inflammatory medication or stronger pain medications such as narcotics

3) Do not drive until cleared by a healthcare professional.

4) Return to play/sport requires clearance by a healthcare professional.

Clinic phone number: _____

Patient's name: _____

Date / time of injury: _____

Date / time of medical review: _____

Healthcare Provider: _____

Contact details or stamp

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (continues) (Echemendia et al. 2017) (developed by the Concussion in Sport Group).

INSTRUCTIONS

Words in *Italics* throughout the SCAT5 are the instructions given to the athlete by the clinician

Symptom Scale

The time frame for symptoms should be based on the type of test being administered. At baseline it is advantageous to assess how an athlete "typically" feels whereas during the acute/post-acute stage it is best to ask how the athlete feels at the time of testing.

The symptom scale should be completed by the athlete, not by the examiner. In situations where the symptom scale is being completed after exercise, it should be done in a resting state, generally by approximating his/her resting heart rate.

For total number of symptoms, maximum possible is 22 except immediately post injury, if sleep item is omitted, which then creates a maximum of 21.

For Symptom severity score, add all scores in table, maximum possible is 22 x 6 = 132, except immediately post injury if sleep item is omitted, which then creates a maximum of 21x6=126.

Immediate Memory

The Immediate Memory component can be completed using the traditional 5-word per trial list or, optionally, using 10-words per trial. The literature suggests that the Immediate Memory has a notable ceiling effect when a 5-word list is used. In settings where this ceiling is prominent, the examiner may wish to make the task more difficult by incorporating two 5–word groups for a total of 10 words per trial. In this case, the maximum score per trial is 10 with a total trial maximum of 30.

Choose one of the word lists (either 5 or 10). Then perform 3 trials of immediate memory using this list.

Complete all 3 trials regardless of score on previous trials.

"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order." The words must be read at a rate of one word per second.

Trials 2 & 3 MUST be completed regardless of score on trial 1 & 2.

Trials 2 & 3:

"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."

Score 1 pt. for each correct response. Total score equals sum across all 3 trials. Do NOT inform the athlete that delayed recall will be tested.

Concentration

Digits backward

Choose one column of digits from lists A, B, C, D, E or F and administer those digits as follows:

Say: *"I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."*

Begin with first 3 digit string.

If correct, circle "Y" for correct and go to next string length. If incorrect, circle "N" for the first string length and read trial 2 in the same string length. One point possible for each string length. Stop after incorrect on both trials (2 N's) in a string length. The digits should be read at the rate of one per second.

Months in reverse order

"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November ... Go ahead"

1 pt. for entire sequence correct

Delayed Recall

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section.

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Score 1 pt. for each correct response

Modified Balance Error Scoring System (mBESS)[5] testing

This balance testing is based on a modified version of the Balance Error Scoring System (BESS)[5]. A timing device is required for this testing.

Each of 20-second trial/stance is scored by counting the number of errors. The examiner will begin counting errors only after the athlete has assumed the proper start position. The modified BESS is calculated by adding one error point for each error during the three 20-second tests. The maximum number of errors for any single condition is 10. If the athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once the athlete is set. Athletes that are unable to maintain the testing procedure for a minimum of five seconds at the start are assigned the highest possible score, ten, for that testing condition.

OPTION: For further assessment, the same 3 stances can be performed on a surface of medium density foam (e.g., approximately 50cm x 40cm x 6cm).

Balance testing – types of errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 sec

"I am now going to test your balance. Please take your shoes off (if applicable), roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty second tests with different stances."

(a) Double leg stance:

"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."

(b) Single leg stance:

"If you were to kick a ball, which foot would you use? [This will be the dominant foot] *Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."*

(c) Tandem stance:

"Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

Tandem Gait

Participants are instructed to stand with their feet together behind a starting line (the test is best done with footwear removed). Then, they walk in a forward direction as quickly and as accurately as possible along a 38mm wide (sports tape), 3 metre line with an alternate foot heel-to-toe gait ensuring that they approximate their heel and toe on each step. Once they cross the end of the 3m line, they turn 180 degrees and return to the starting point using the same gait. Athletes fail the test if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or an object.

Finger to Nose

"I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended), pointing in front of you. When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose, and then return to the starting position, as quickly and as accurately as possible."

References

1. McCrory et al. Consensus Statement On Concussion In Sport – The 5th International Conference On Concussion In Sport Held In Berlin, October 2016. British Journal of Sports Medicine 2017 (available at www.bjsm.bmj.com)
2. Maddocks, DL; Dicker, GD; Saling, MM. The assessment of orientation following concussion in athletes. Clinical Journal of Sport Medicine 1995; 5: 32-33
3. Jennett, B., Bond, M. Assessment of outcome after severe brain damage: a practical scale. Lancet 1975; i: 480-484
4. McCrea M. Standardized mental status testing of acute concussion. Clinical Journal of Sport Medicine. 2001; 11: 176-181
5. Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports. 2003; 2: 24-30

ATTACHMENT VII. Sport Concussion Assessment Tool – 5th Edition (continues) (Echemendia et al. 2017) (developed by the Concussion in Sport Group).

CONCUSSION INFORMATION

Any athlete suspected of having a concussion should be removed from play and seek medical evaluation.

Signs to watch for

Problems could arise over the first 24-48 hours. The athlete should not be left alone and must go to a hospital at once if they experience:

- Worsening headache
- Drowsiness or inability to be awakened
- Inability to recognize people or places
- Repeated vomiting
- Unusual behaviour or confusion or irritable
- Seizures (arms and legs jerk uncontrollably)
- Weakness or numbness in arms or legs
- Unsteadiness on their feet.
- Slurred speech

Consult your physician or licensed healthcare professional after a suspected concussion. Remember, it is better to be safe.

Rest & Rehabilitation

After a concussion, the athlete should have physical rest and relative cognitive rest for a few days to allow their symptoms to improve. In most cases, after no more than a few days of rest, the athlete should gradually increase their daily activity level as long as their symptoms do not worsen. Once the athlete is able to complete their usual daily activities without concussion-related symptoms, the second step of the return to play/sport progression can be started. The athlete should not return to play/sport until their concussion-related symptoms have resolved and the athlete has successfully returned to full school/learning activities.

When returning to play/sport, the athlete should follow a stepwise, **medically managed exercise progression, with increasing amounts of exercise.** For example:

Graduated Return to Sport Strategy

Exercise step	Functional exercise at each step	Goal of each step
1. Symptom-limited activity	Daily activities that do not provoke symptoms.	Gradual reintroduction of work/school activities.
2. Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training.	Increase heart rate.
3. Sport-specific exercise	Running or skating drills. No head impact activities.	Add movement.
4. Non-contact training drills	Harder training drills, e.g., passing drills. May start progressive resistance training.	Exercise, coordination, and increased thinking.
5. Full contact practice	Following medical clearance, participate in normal training activities.	Restore confidence and assess functional skills by coaching staff.
6. Return to play/sport	Normal game play.	

In this example, it would be typical to have 24 hours (or longer) for each step of the progression. If any symptoms worsen while exercising, the athlete should go back to the previous step. Resistance training should be added only in the later stages (Stage 3 or 4 at the earliest).

Written clearance should be provided by a healthcare professional before return to play/sport as directed by local laws and regulations.

Graduated Return to School Strategy

Concussion may affect the ability to learn at school. The athlete may need to miss a few days of school after a concussion. When going back to school, some athletes may need to go back gradually and may need to have some changes made to their schedule so that concussion symptoms do not get worse. If a particular activity makes symptoms worse, then the athlete should stop that activity and rest until symptoms get better. To make sure that the athlete can get back to school without problems, it is important that the healthcare provider, parents, caregivers and teachers talk to each other so that everyone knows what the plan is for the athlete to go back to school.

Note: If mental activity does not cause any symptoms, the athlete may be able to skip step 2 and return to school part-time before doing school activities at home first.

Mental Activity	Activity at each step	Goal of each step
1. Daily activities that do not give the athlete symptoms	Typical activities that the athlete does during the day as long as they do not increase symptoms (e.g. reading, texting, screen time). Start with 5-15 minutes at a time and gradually build up.	Gradual return to typical activities.
2. School activities	Homework, reading or other cognitive activities outside of the classroom.	Increase tolerance to cognitive work.
3. Return to school part-time	Gradual introduction of school-work. May need to start with a partial school day or with increased breaks during the day.	Increase academic activities.
4. Return to school full-time	Gradually progress school activities until a full day can be tolerated.	Return to full academic activities and catch up on missed work.

If the athlete continues to have symptoms with mental activity, some other accomodations that can help with return to school may include:

- Starting school later, only going for half days, or going only to certain classes
- More time to finish assignments/tests
- Quiet room to finish assignments/tests
- Not going to noisy areas like the cafeteria, assembly halls, sporting events, music class, shop class, etc.
- Taking lots of breaks during class, homework, tests
- No more than one exam/day
- Shorter assignments
- Repetition/memory cues
- Use of a student helper/tutor
- Reassurance from teachers that the child will be supported while getting better

The athlete should not go back to sports until they are back to school/learning, without symptoms getting significantly worse and no longer needing any changes to their schedule.

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

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ABSTRACT

Background Information on ice hockey injuries at the international level is very limited. The aim of the study was to analyse the incidence, type, mechanism and severity of ice hockey injuries in men's international ice hockey tournaments.

Methods All the injuries in men's International Ice Hockey Federation World Championship tournaments over a 7-year period were analysed using a strict definition of injury, standardised reporting strategies and an injury diagnosis made by a team physician.

Results 528 injuries were recorded in games resulting in an injury rate of 14.2 per 1000 player-games (52.1/1000 player-game hours). Additionally, 27 injuries occurred during practice. For WC A-pool Tournaments and Olympic Winter Games (OWG) the injury rate was 16.3/1000 player-games (59.6/1000 player-game hours). Body checking, and stick and puck contact caused 60.7% of the injuries. The most common types of injuries were lacerations, sprains, contusions and fractures. A laceration was the most common facial injury and was typically caused by a stick. The knee was the most frequently injured part of the lower body and the shoulder was the most common site of an upper body injury. Arenas with flexible boards and glass reduced the risk of injury by 29% (IRR 0.71, (95% CI 0.56 to 0.91)).

Conclusions The incidence of injury during international ice hockey competition is relatively high. Arena characteristics, such as flexible boards and glass, appeared to reduce the risk of injury.

To cite: Tuominen M, Stuart MJ, Aubry M, *et al*. *Br J Sports Med* 2015;**49**:30–36.

INTRODUCTION

The International Ice Hockey Federation (IIHF), founded on 15 May 1908 in Paris, France, is the governing body of international ice hockey and inline hockey. The IIHF is comprised of 72 member associations, each of which is the national governing body for the sport of ice hockey. The IIHF also presides over ice hockey in the Olympic Games and the IIHF World Championships (WC) at all levels, that is, men, women, junior under-20, junior under-18 and women under-18. Each season, the IIHF, in collaboration with the local organising committee, runs Men's WC in the six different categories. The teams are qualified to the divisions and groups according to IIHF World ranking. Ice hockey is also the biggest team sport in the Olympic Winter Games (OWG).

Each ice hockey team typically consists of 22 players, including two wingers, one centre, two defencemen and a goalkeeper who are usually on the ice at the same time. The active playing time is three periods of 20 min each. In ice hockey, body contact is common and body checking is permitted in the men's game. Ice hockey is also associated with many other potential risk factors, such as unintended collisions, high velocity, rapid changes in direction and traumas from the boards, stick or puck. As a result, a wide variety of injuries ensue.[1] Facial injuries and concussion have been reported in epidemiological studies at other levels of the sport including in the National Hockey League (NHL; USA and Canada).[2 3] However, the risk, type, mechanism and severity of ice hockey injuries at the international elite level have not been well studied.

The purpose of this study was to assess the incidence, nature, causes and severity of ice hockey injuries among IIHF men's WC and Olympic Games between 2006 and 2013.

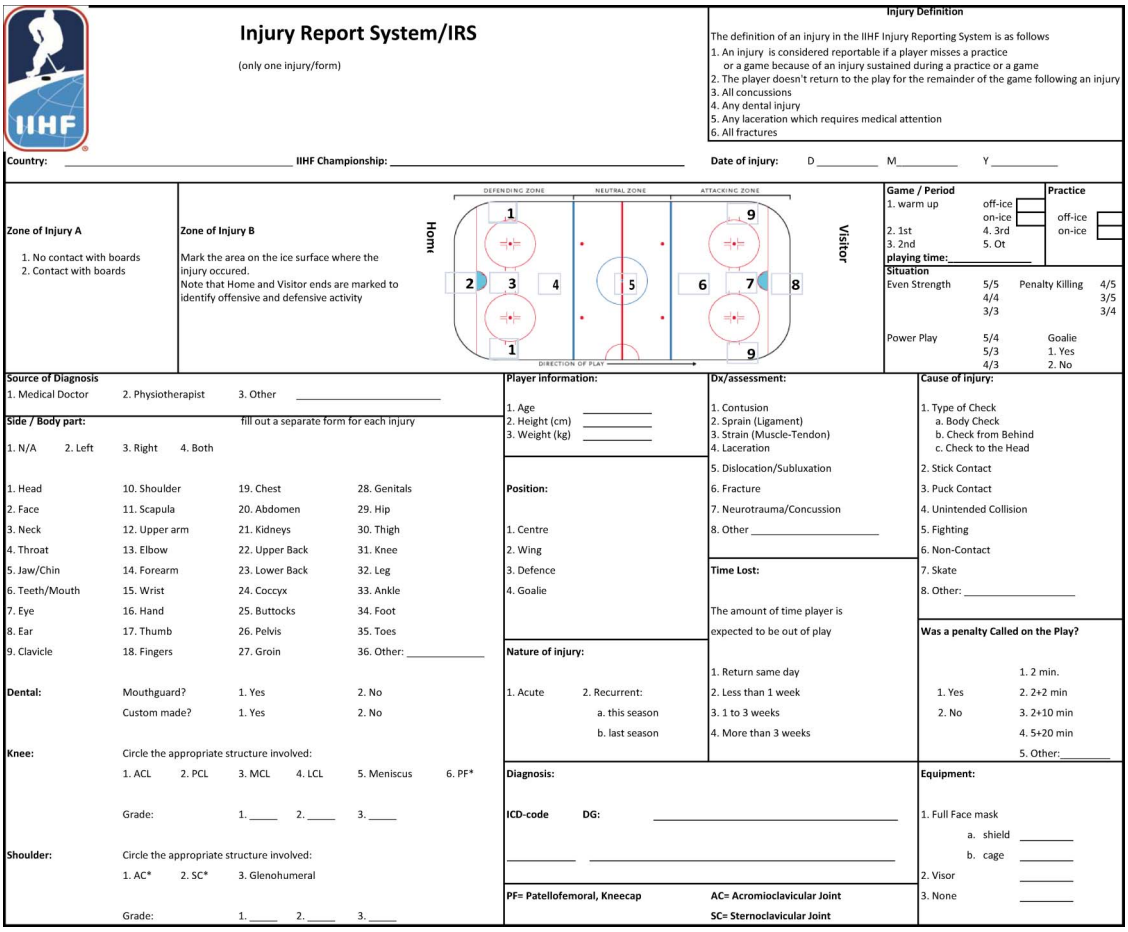
METHODS

During the seven ice hockey seasons between 2006–2007 and 2012–2013 (from 1 July 2006 to 30 June 2013) we registered, with permission from the IIHF, all ice hockey injuries from 32 men's WC (seven WC Tournaments, seven WC Division (Div) I Grade (Gr) A Tournaments, seven WC Div I Gr B Tournaments, two WC Div II Gr A Tournaments, seven WC Div II Gr B Tournaments, two WC Div III Tournaments), one OWG (2010) and eight Olympic Qualification Tournaments. A total of 844 games were played in the 41 Tournaments by 303 Teams (6666 players). A-pool level competitions consisted of 436 games in the eight tournaments played by 124 teams (2728 players).

A Team Medical Personnel Meeting before each tournament allowed the IIHF medical supervisor (MS) to review the definition of the injury, game injury report form (GIR) and the injury report system form (IRS) with the individual team physicians (figure 1).

The definition of an injury was made in accordance with accepted international ice hockey norms. An IRS was completed when one of the following criteria was observed:

- any injury sustained in a practice or a game that prevented the player from returning to the same practice or game;
- any injury sustained in a practice or a game that caused the player to miss a subsequent practice or game;



Injury Report System/IRS

(only one injury/form)

Injury Definition

The definition of an injury in the IIHF Injury Reporting System is as follows
1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player doesn't return to the play for the remainder of the game following an injury
3. All concussions
4. Any dental injury
5. Any laceration which requires medical attention
6. All fractures

Country: _____ IIHF Championship: _____ Date of injury: D_____ M_____ Y_____

Zone of Injury A
1. No contact with boards
2. Contact with boards

Zone of Injury B
Mark the area on the ice surface where the injury occured.
Note that Home and Visitor ends are marked to identify offensive and defensive activity

DEFENDING ZONE NEUTRAL ZONE ATTACKING ZONE
Home Visitor
DIRECTION OF PLAY

Game / Period
1. warm up
2. 1st
3. 2nd
playing time:_____
off-ice / on-ice
4. 3rd
5. Ot

Practice
off-ice / on-ice

Situation
Even Strength 5/5 4/4 3/3
Penalty Killing 4/5 3/5 3/4
Power Play 5/4 5/3 4/3
Goalie 1. Yes 2. No

Source of Diagnosis
1. Medical Doctor 2. Physiotherapist 3. Other _____

Side / Body part: fill out a separate form for each injury
1. N/A 2. Left 3. Right 4. Both

1. Head 2. Face 3. Neck 4. Throat 5. Jaw/Chin 6. Teeth/Mouth 7. Eye 8. Ear 9. Clavicle
10. Shoulder 11. Scapula 12. Upper arm 13. Elbow 14. Forearm 15. Wrist 16. Hand 17. Thumb 18. Fingers
19. Chest 20. Abdomen 21. Kidneys 22. Upper Back 23. Lower Back 24. Coccyx 25. Buttocks 26. Pelvis 27. Groin
28. Genitals 29. Hip 30. Thigh 31. Knee 32. Leg 33. Ankle 34. Foot 35. Toes 36. Other: _____

Dental: Mouthguard? 1. Yes 2. No
Custom made? 1. Yes 2. No

Knee: Circle the appropriate structure involved:
1. ACL 2. PCL 3. MCL 4. LCL 5. Meniscus 6. PF*
Grade: 1. ____ 2. ____ 3. ____

Shoulder: Circle the appropriate structure involved:
1. AC* 2. SC* 3. Glenohumeral
Grade: 1. ____ 2. ____ 3. ____

Player information:
1. Age _____
2. Height (cm) _____
3. Weight (kg) _____

Position:
1. Centre
2. Wing
3. Defence
4. Goalie

Nature of injury:
1. Acute 2. Recurrent: a. this season b. last season

Dx/assessment:
1. Contusion
2. Sprain (Ligament)
3. Strain (Muscle-Tendon)
4. Laceration
5. Dislocation/Subluxation
6. Fracture
7. Neurotrauma/Concussion
8. Other _____

Time Lost:
The amount of time player is expected to be out of play
1. Return same day
2. Less than 1 week
3. 1 to 3 weeks
4. More than 3 weeks

Diagnosis:
ICD-code DG: _____

PF= Patellofemoral, Kneecap
AC= Acromioclavicular Joint
SC= Sternoclavicular Joint

Cause of injury:
1. Type of Check
a. Body Check
b. Check from Behind
c. Check to the Head
2. Stick Contact
3. Puck Contact
4. Unintended Collision
5. Fighting
6. Non-Contact
7. Skate
8. Other: _____

Was a penalty Called on the Play?
1. Yes 2. No
1. 2 min.
2. 2+2 min
3. 2+10 min
4. 5+20 min
5. Other:_____

Equipment:
1. Full Face mask
a. shield _____
b. cage _____
2. Visor _____
3. None _____

Figure 1 Injury report system form of the International Ice Hockey Federation.

- a laceration that required medical attention;
- all dental injuries;
- all concussions;
- all fractures.

The team physician followed all the players on their team and reported all injuries to the MS using the GIR and IRS forms. Each injury required a separate IRS form and was reported only once. The GIR and IRS forms were both anonymous. The IIHF MS assigned to each championship was responsible for data collection. A GIR form was obtained from each team physician after every game to determine the number of injuries that satisfied the definition (figure 2). An IRS form was completed by the team physician for each individual injury. The IRS form detailed the period, location on ice, mechanism, anatomic location, severity and specific injury diagnosis. The anonymous forms were returned to the IIHF Medical Committee for insertion into a computer-based injury report system for ice hockey injuries (Medhockey).

Injury rate (IR) was expressed as the number of injuries per 1000 ice hockey player-games and per 1000 player-game hours. These two different injury rate definitions were used to allow comparison with other IIHF championships, hockey leagues and sports (football, soccer).

The number of player-games was based on 22 players competing for each team in a game. The player exposure to injury was determined by collective playing time; that is, all the players of the team were participating in the game, had an impact in the game and were at risk for injury during every moment of the game event. When calculating the incidence all the players of the team were included in the denominator.

The player-game injury rate was an average risk of one individual player per 1000 games (# injuries/# players (two teams)/# games×1000=injuries per 1000 player-games). The injury rate for 1000 player-game hours was based on a 60 min active game with five players and a goalie per team on the ice at the same time (# injuries/# players on ice same time (two teams)/# games×1000=number of injuries per 1000 player-game hours).

The given injury rates refer to game injuries only (practice injuries excluded). In the present study, the subgroup 'flexible board and glass' was collected from the tournaments where boards comparable to those of NHL were used. The more flexible boards and glass were developed to improve player safety. To determine the association between the arena characteristics and occurrence of injuries, Poisson and Logistic regressions were used. Logistic regression was used when the number of the analysed injuries in each game was zero or one. In other statistical analyses, Poisson regression was applied to allow for several injuries per game. In these analyses, weighting with standardise active playing time was employed. Generalised estimating equations were used to determine association between the concussion and player position in A-pool tournaments.

RESULTS

Incidence of injuries

During the study period, 528 injuries in 511 incidents were reported in 844 games. Additionally, 27 injuries occurred during the practices. The injury rate per 1000 ice hockey player-games was 14.2 for all men's WC and the annual injury rate ranged between 12.2 (2011) and 17.5 (2008). For WC A-pool tournaments and OWG the injury rate was 16.3/1000 player-

Figure 2 Game injury report form of the International Ice Hockey Federation.

IIHF

IIHF Daily Injury Report Form

IIHF Championship: _____

National Association: _____

Date: _____ / _____ / _____ (dd/mm/yy)

Using this form, please report if there were any injuries sustained by any player on your team during the above-mentioned day during this IIHF Championship. We would ask that you also report if there were no injuries sustained by players on your team during this day of this IIHF Championship. If an injury was sustained during this day then an IIHF Injury Report Form must be completed and submitted to the IIHF Medical Supervisor or, in his absence, to the IIHF Directorate Chairman providing the details of the injury sustained.

The definition of an injury used by the IIHF for reporting purposes is as follows:

1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player does not return to the play for the remainder of the game following an injury
3. All concussions
4. All dental injuries
5. Any laceration which requires medical attention
6. All fractures

Please check (✓) the appropriate box below. Please provide the number of injuries sustained if you check article 'A'.

Injury Report	(✓)
A. During this day there were _____ (number) injuries sustained by our team.	
B. During this day there were no injuries sustained by our team	

Team Physician/Medical Representative: _____ (print name)

Signature: _____

Date: _____

FAIR PLAY AND RESPECT

November 2010

games and the annual injury rate ranged between 10.3 (2013) and 20.6 (2008). Injury rate per 1000 player-game hours was 52.1 for all men's WC and 59.6 for men's WC A-pool tournaments (figure 3).

Injuries by anatomic region

Injuries involved the head and face in 210 cases (39.8% of game injuries), the lower body in 162 cases (30.7%), the upper body in 115 cases (21.8%), and spine or trunk in 41 cases (7.8%). The injury rate for head and face injuries was 5.7/1000 player-games, for lower body 4.4, for upper body 3.1 and for spine and trunk 1.1, respectively. In men's WC A-pool tournaments the injury rate for head and face injuries was 7.0/1000 player-games, for lower body 4.6, for upper body 3.4 and for spine and trunk 1.2, respectively (table 1 and figure 4).

Head and face injuries

Head and facial injuries were the most commonly injured body parts (39.8%; IR 5.7) and the face was the most common location. Facial injuries comprised 72.4% of the head injuries in all men's WC with an injury rate of 4.1/1000 player-games (in men's WC A-pool 70.9%; IR 5.0). A laceration was diagnosed in 74.3% of the facial injuries and 59.3% of them was caused by stick. Injury rate for dental injuries was 0.5 (9.5% of the head injuries; in men's WC A-pool 0.7; 10.4%) and for eye injuries 0.1 (1.4%)/1000 player-games (in men's WC A-pool 0.2; 2.2%).

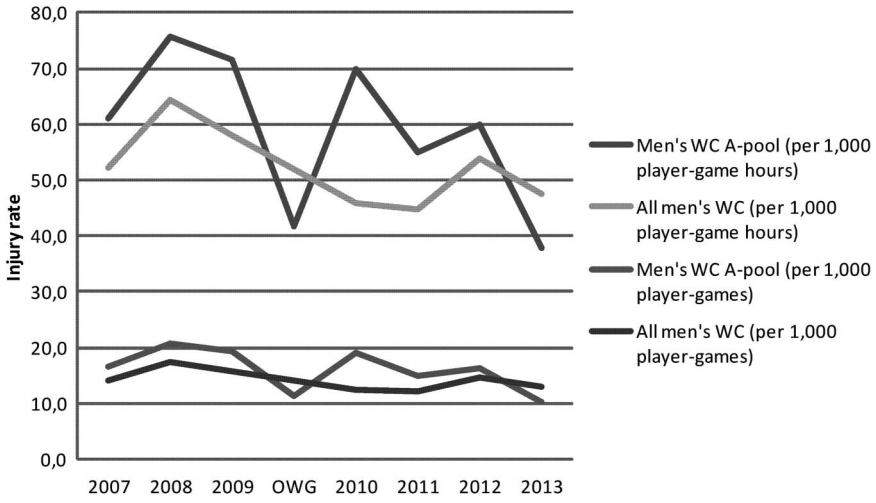


Figure 3 Annual ice hockey injury rates for all men's World Championship and men's World Championship A-pool tournaments.

Lower body injuries

The knee was the most common lower body injury with 46.9% of the lower body injuries affecting the knee (men's WC A-pool 49.4%). The injury rate for knee injuries was 2.0/1000 player-games (men's WC A-pool 2.3). Medial collateral ligament (MCL) sprain was the most common knee injury (56.6% of the knee injuries) and most of them were grade I injuries (51.2%). Meniscus tears comprised 14.5% and anterior cruciate ligament (ACL) disruption 10.5% of all knee injuries. Ankle and thigh injuries were the second and third most common lower body injuries.

Upper body injuries

The shoulder was the most common location for an upper body injury (49.6%; men's WC A-pool=50%). The injury rate for shoulder injuries was 1.5/1000 player-games (men's WC A-pool=1.7). Acromioclavicular (AC) joint sprain (50.9%) and glenohumeral joint injury (40.4%) were the most frequent diagnoses. The fingers (14.2%), wrist (10.8%) and hand (10.8%) injuries were in the second, third and fourth place in upper body injuries, respectively.

Injury types by diagnosis

The vast majority of injuries (92.8%) were acute in nature and this trend was consistent over the 7-year study period. Lacerations were the most common type of injury (26.1%). Sprains (21.8%) and contusions (15%) made up the next largest group. A fracture was diagnosed in 14% (men's WC A-pool=15.4%). The percentage of neurotrauma was 9.9% (men's WC A-pool=11.5%; figure 5).

Concussion

Concussions accounted for a small yet clinically important number (n=52, 9.9%) of injuries in the championships. The injury rate of concussion was 1.4/1000 player-games in all men's WC and 1.9 in men's A-pool tournaments. The most common cause for concussion was check to the head (51.9%). A penalty was called in only 32.7% of the events that caused a concussion. For those players diagnosed with a concussion, 11.5% returned to play in the same game (men's WC A-pool=5.6%). Estimated time loss was more than 3 weeks in 7.7% of the cases. The centre position had the highest risk of concussion, 25% (30.6% in men's WC A-pool), the defence position, 20.2% (15.3% in men's WC A-pool) and the wing position, 17.3% (19.4% in men's WC A-pool). The majority of concussions occurred during the first period (42.3%; 47.2% in men's WC A-pool).

Contact with the boards

The majority of injuries occurred away from the boards (68.5%). This trend was apparent in all championships and was similar over the 7-year study period. Shoulder injuries were the most common (27.3%) resulting from contact with the boards (63.2%). The majority of concussions occurred without board contact (55.8%).

Flexible boards and glass

There was 29% lower risk of an injury at the arenas where flexible boards and glass were used compared to arenas with traditional boards and glass (IRR 0.71, (95% CI 0.56 to 0.91)). The A-pool WC tournaments that were played in arenas with flexible boards and glass had a shoulder injury rate of 0.9/1000 player-games as compared to 2.2/1000 player-games when traditional boards and glass were in place (IRR 0.36, (95% CI 0.15 to 0.90); figure 6). In addition to these significant findings, there were fewer concussions when flexible boards and glass were used instead of traditional boards and glass (OR 0.43, (95% CI 0.18 to 1.01)). Also, there was a trend for a decrease in all other types of injuries at arenas with flexible boards and glass compared to arenas with traditional boards and glass (IRR 0.82, (95% CI 0.61 to 1.09)).

Causes of injury

The three most common causes of injuries were body checking (27.2%), and stick (21.1%) and puck (12.3%) contact. The majority of the injuries caused by stick were head injuries (76.9%). Penalties were assessed in 25.9% of stick injuries, 40% in checking to the head and 48.4% in hitting from behind injuries.

Injury severity

The majority of players who were injured returned to play within 1 week (53.8%); however, 14.5% of the injured players did not return for at least 3 weeks.

Player position, period and zone

Injuries were equally distributed according to player position: wing players suffered 37% of all injuries (two wings per team), centre 18.4% (one centre per team) and defence 36.8% (two defences per team). The goalkeeper was the least injured in all the positions (3.5%) despite the fact that the goalkeeper is on the ice for the entire game. In the A-pool tournaments, the proportion of concussions sustained by centre was about twice that of defence and wing (OR 2.01, (95% CI 0.87 to 4.66)). The second period had the highest percentage of injured players

Table 1 Ice hockey injuries by anatomic region in all men's World Championship games

	2007			2008			2009			2010			2011			2012			2013			TOT		
Anatomic region	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	2006–2013	IR per 1000 player-games	IR per 1000 player-game hours
Face	16	3.8	13.9	26	5.2	19.0	25	4.8	17.5	17	2.9	10.8	13	2.8	10.2	17	3.1	11.4	15	2.2	8.1	129	3.5	12.7
Knee	13	3.1	11.3	12	2.4	8.8	6	1.1	4.2	9	1.6	5.7	6	1.3	4.7	16	2.9	10.8	14	2.1	7.6	76	2.0	7.5
Shoulder +clavicle	6	1.4	5.2	5	1.0	3.7	15	2.9	10.5	7	1.2	4.5	11	2.4	8.6	6	1.1	4.0	9	1.3	4.9	59	1.6	5.8
Head	5	1.2	4.3	13	2.6	9.5	7	1.3	4.9	12	2.1	7.6	6	1.3	4.7	8	1.5	5.4	7	1.0	3.8	58	1.6	5.7
Fingers +thumb +hand	2	0.5	1.7	2	0.4	1.5	2	0.4	1.4	5	0.9	3.2	3	0.6	2.4	10	1.8	6.7	7	1.0	3.8	31	0.8	3.1
Ankle+leg	1	0.2	0.9	7	1.4	5.1	1	0.2	0.7	3	0.5	1.9	4	0.9	3.1	5	0.9	3.4	4	0.6	2.2	25	0.7	2.5
Groin+hip +pelvis	3	0.7	2.6	2	0.4	1.5	5	1.0	3.5	2	0.3	1.3	4	0.9	3.1	2	0.4	1.3	5	0.7	2.7	23	0.6	2.3
Teeth	1	0.2	0.9	5	1.0	3.7	2	0.4	1.4	8	1.4	5.1	0	0.0	0.0	1	0.2	0.7	3	0.4	1.6	20	0.5	2.0
Thigh	4	0.9	3.5	5	1.0	3.7	2	0.4	1.4	2	0.3	1.3				4	0.7	2.7	5	0.7	2.7	22	0.6	2.2
Chest+throat	2	0.5	1.7	2	0.4	1.5	2	0.4	1.4	3	0.5	1.9	2	0.4	1.6	3	0.5	2.0	5	0.7	2.7	19	0.5	1.9
Foot+toes	1	0.2	0.9	4	0.8	2.9	4	0.8	2.8	1	0.2	0.6	1	0.2	0.8	2	0.4	1.3	3	0.4	1.6	16	0.4	1.6
Neck+upper back+lower back	3	0.7	2.6	1	0.2	0.7	4	0.8	2.8	1	0.2	0.6	2	0.4	1.6	2	0.4	1.3	3	0.4	1.6	16	0.4	1.6
Wrist	2	0.5	1.7	1	0.2	0.7	4	0.8	2.8	1	0.2	0.6	2	0.4	1.6	1	0.2	0.7	2	0.3	1.1	13	0.4	1.3
Upperarm +forearm +elbow	1	0.2	0.9	1	0.2	0.7	3	0.6	2.1							3	0.5	2.0	4	0.6	2.2	12	0.3	1.2
Abdomen +genitals +kidneys				1	0.2	0.7				1	0.2	0.6	3	0.6	2.4				1	0.1	0.5	6	0.2	0.6
Eye				1	0.2	0.7	1	0.2	0.7				0	0.0	0.0				1	0.1	0.5	3	0.1	0.3
Total	60	14.2	52.1	88	17.5	64.3	83	15.9	58.1	72	12.5	45.8	57	12.2	44.8	80	14.7	53.8	88	13.0	47.6	528	14.2	52.1

Figure 4 Injury rate by anatomic region per 1000 player-games in men's ice hockey World Championship tournaments.

(34.6%) during the game. There were only a few injuries sustained during the warm up (0.8%) and overtime in the Championships. Only 5% of the injury situations occurred during practices. Players sustained injuries at the home zone (39.3%), visitor zone (35%) and neutral zone (20.2%).

DISCUSSION

This observational study followed 41 men's Ice Hockey WC tournaments over a 7-year period to determine the incidence, type, mechanism and severity of injuries. During the study period, 6666 players sustained 528 injuries in 844 games. The total injury rate was 52.1/1000 player-game hours for all men's WC and 59.6 for men's WC A-pool tournaments. Laceration was the most common injury followed by ligament sprain. The most commonly injured site was the head and face (39.8% of game injuries). The most common lower body injury involved the knee (46.9%) with the MCL (56.6% of all knee injuries) being the most frequent area. ACL injury was documented in 10.5% of cases. The most common upper body injury involved the shoulder (49.6%) with the AC joint most frequently involved (50.9% of all shoulder injuries). Body checking (27.2%) and stick contact (21.1%) were the most common

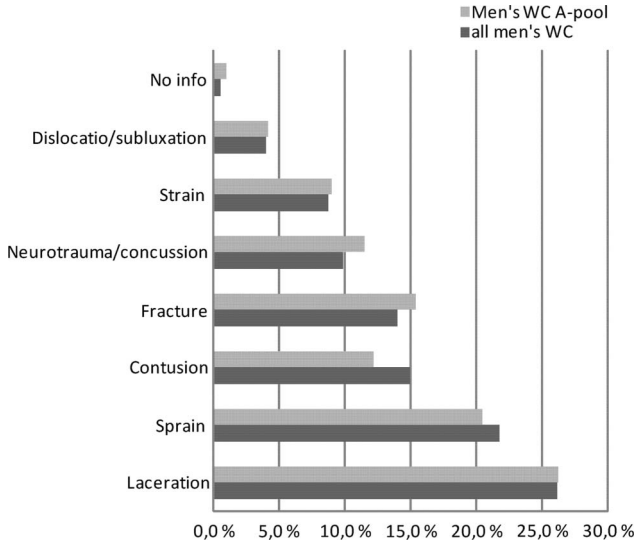


Figure 5 Injury distribution by diagnosis in the men's World Championship games.

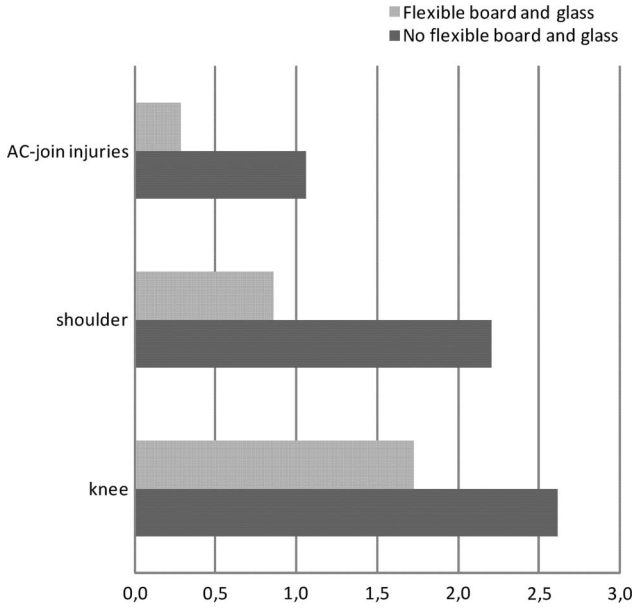


Figure 6 Injury rate at the shoulder, acromioclavicular and knee per 1000 player-games in men's World Championship A-pool tournaments. Flexible versus non-flexible boards and glass.

causes of injuries. Of the players diagnosed with a concussion, 11.5% returned to play in the same game (men's WC A-pool=5.6%). The majority of concussions occurred before the 2012 Zurich Consensus Guidelines, which do not allow return to play in the same game.

Strengths of this study include the large number of players in the cohort, who were followed at the highest level of international competition over a 7-year period. Also, injury was clearly defined and detailed information was collected with the two validated questionnaires.[4] In addition, the MS at each tournament ensured 100% compliance with data collection and the team physicians completed each injury report confirming the accuracy of the injury diagnosis.

Injury incidence rates were estimated by collective playing time since individual on-ice exposure was not measured. In addition, we assumed that each game was played for 60 min. This approach did not take penalties and overtime into consideration. To determine association between the arena characteristics and occurrence of injuries, weighting with standardised active playing time was used.

Lorenzon reported that in Swedish ice hockey the injury rate was 78.4/1000 player-game hours.[5] In Finland, Mölsä observed the incidence of game injury in the Division I league to be 36/1000 player-game hours and 66/1000 player-game hours in the National League.[6] Injuries were classified as major in 5% of the patients, and there were fractures in 8% and head or face involvement in 18% of them.[6] In another study, Mölsä reported that the injury rate increased significantly from 54/1000 player-game hours in the 1970s to 83/1000 player-game hours in the 1990s.[7] Rate of contusions, sprains and strains increased significantly with each decade. Checking and unintentional collision with an opponent were the common mechanisms of injury.[7]

Benson *et al*,[8] reported that the estimated incidence of concussions in NHL was 1.8/1000 player-game hours, where the athlete-exposure time was estimated based on a roster of 18 skaters and one goalie playing in each team per game. The proportion of concussions sustained by centre was about twice that of defencemen and wingers. The present study supports the NHL findings of Benson *et al*.[8] The reported differences in the

injury rates are likely due to different study designs, including the definition of injury and measurement of player exposure.

Injury risk in ice hockey has been compared to other sports. In our study, the injury rate was 52.1/1000 player-game hours in men's ice hockey world championships. In contrast, injury rates were reportedly 112 injuries per 1000 player-game hours in male handball[9] and 40.1 injuries per 1000 player-game hours in male soccer.[10] In World Football Tournaments 1998–2010, the injury rate was 77.3 injuries per 1000 player-game hours but it included not only male games but also female and junior games.[11] However, between-sports comparison of injury risk is difficult because of inconsistent study methodology including differences in definition of injury and estimation of exposure.

In conclusion, our 7-year follow-up study showed that the risk of injury during international ice hockey tournaments was relatively high. The head, face, shoulder and knee are the most vulnerable body sites. Arena characteristics, such as flexible boards and glass, seem to reduce the risk of injury in general and of the upper body specifically. Improved knowledge of the risk factors and mechanisms of ice hockey injuries are needed for initiation of preventive strategies.

What are the new findings?

- The incidence of ice hockey injuries is at the same level as reported for other team sports.
- Arena characteristics, such as flexible boards and glass, reduce the risk of injury in general and for the upper body specifically.
- The face is the most common head injury location. A laceration is diagnosed in three-quarters of the facial injuries and three-fifths of them are caused by hockey sticks.
- Every 10th player diagnosed with a concussion returned to play during the same game.

How might it impact on clinical practice in the near future?

- Knowledge of the risk factors and mechanisms of ice hockey injuries are needed to initiate systematic injury prevention.
- Arenas with flexible boards and glass make ice hockey safer.
- Further research is necessary to determine if facial injuries in ice hockey can be reduced by enforcing existing rules or mandating full facial protection.
- Possible rule changes should be considered to reduce risk of concussion. More education is needed for diagnosis and treatment of concussion; the return to play protocol needs wider adoption.

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REFERENCES

1 Laprade RF, Surowiec RK, Sochanska AN, *et al*. Epidemiology, identification, treatment and return to play of musculoskeletal-based ice hockey injuries. *Br J Sports Med* 2014;48:4–10.
2 Hutchison MG, Comper P, Meeuwisse WH, *et al*. A systemic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? *Br J Sports Med* 2013. Published Online First: 13 June 2013. doi:10.1136/bjsports-2013-092234
3 Hutchison MG, Comper P, Meeuwisse WH, *et al*. A systemic video analysis of National Hockey League (NHL) concussions, part II: how concussions occur in the NHL. *Br J Sports Med* 2013. Published Online First: 13 June 2013. doi:10.1136/bjsports-2013-092235
4 Stuart MJ, Smith AM. Principles of ice hockey injury research. In: Ashare AB, ed. *Safety in ice hockey: third volume, ASTM STP 1341*. West Conshohocken, PA: American Society for Testing and Materials, 2000:19–31.
5 Lorentzon R, Werden H, Pietilä T. Incidence, nature, and causes of ice hockey injuries: a three year prospective study of a Swedish elite ice hockey team. *Am J Sports Med* 1988;16:392–6.
6 Mölsä J, Airaksinen O, Näsman O, *et al*. Ice hockey injuries in Finland. A prospective epidemiologic study. *Am J Sports Med* 1997;25:495–9.
7 Mölsä J, Kujala U, Näsman O, *et al*. Injury profile in ice hockey from the 1970s through the 1990s in Finland. *Am J Sports Med* 2000;28:322–7.
8 Benson BW, Meeuwisse WH, Rizos J, *et al*. A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. *CMAJ* 2011;183:905–11.
9 Langevoort G, Myklebust G, Dvorak J, *et al*. Handball injuries during major international tournaments. *Scand J Med Sci Sports* 2007;17:400–7.
10 Dvorak J, Junge A, Derman W, *et al*. Injuries and illnesses of football players during the 2010 FIFA World Cup. *Br J Sports Med* 2011;45:626–30.
11 Junge A, Dvorak J. Injury surveillance in World Football Tournaments 1998–2012. *Br J Sports Med* 2013;47:782–8.

Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games

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ABSTRACT

Background We report the incidence, type, mechanism and severity of ice hockey injuries in women's international ice hockey championships.

Methods All injuries in the International Ice Hockey Federation World Women's Championship, World Women's under-18 Championship and Olympic Winter Games tournaments were analysed over an 8-year period using a strict injury definition, standardised reporting and team physician diagnosis.

Results 168 injuries were recorded in 637 games over an 8-year period resulting in an injury rate (IR) of 6.4 per 1000 player-games and 22.0/1000 player-game hours. The IRs were 2.7/1000 player-games for the lower body, 1.4 for the upper body, 1.3 for the head and face and 0.9 for the spine and trunk. Contusion was the most common injury followed by a sprain. The most commonly injured site was the knee (48.6% of lower body injuries; IR 1.3/1000 player-games). The Medial collateral ligament sprain occurred in 37.1% and ACL rupture in 11.4% of knee injuries. A concussion (74.3%; IR 1.0/1000 player-games) was the most common head injury.

Conclusions and recommendations The risk of injury to female ice hockey players at World Championship and Olympic tournaments was about half of that observed in the men's Championships. Full facial protection decreases the risk of lacerations and should be continued in all future female tournaments. More effective prevention strategies for knee, ankle and shoulder injuries are needed in women's ice hockey. Improved concussion education is necessary to promote more consistent diagnosis and return to play protocols.

INTRODUCTION

Twenty-eight countries competed in the 2014 International Ice Hockey Federation (IIHF) World Women's Championship (WWC) programme and 19 in the World Women under-18 Championships (WWC U18) category. The IIHF, in collaboration with the local organising committee, runs WWC in the five different divisions and WWC U18 in three different divisions. The teams were qualified to the divisions and its subgroups according to IIHF World ranking. Women's ice hockey has been part of the Olympic Winter Games (OWG) since 1998.

Each ice hockey team typically consists of 20–22 players (depending of the level and age group of the tournament), including two wingers, one centre, two defencemen and a goalkeeper, who are usually on the ice at the same time. The active playing time is three periods of 20 min each. Despite the fact that body checking is not permitted in women's ice hockey at any level, ice hockey is associated with many potential risks, such as unintended collisions, high velocity, rapid changes in direction and traumas from the boards, stick or puck.[1] Concussions, contusions, sprains and strains occur in female ice hockey.[2 3] However, the risk, type, mechanism and severity of women's ice hockey injuries at the international elite level have not been well studied.

We aimed to report the incidence, nature, causes, severity and time-trend of injuries in women's international ice hockey, using standardised epidemiological methods.[4] Our larger goal is to promote athlete's health and reduce the risk of injuries.[5]

METHODS

During the eight ice hockey seasons between 2006–2007 and 2013–2014 (from 1 July 2006 to 30 June 2014) we registered, with the permission from the IIHF, all ice hockey injuries from the 39 female ice hockey tournaments. Twenty-five of them were WWC, including 2010 and 2014 OWG, and 14 were WWC U18 (table 1). A total of 637 games were played in the 39 tournaments by 259 teams (5344 players). WWC competitions consisted of 393 games in the 25 tournaments played by 163 teams (3376 players), and WWC U18 competitions consisted of 14 tournaments played by 96 teams (1968 players).

A team medical personnel meeting before each tournament allowed the IIHF medical supervisor (MS) to review the definition of the injury, game injury report (GIR) form and the injury report system (IRS) form with the individual team physicians (figure 1). The definition of an injury was made in accordance with accepted international ice hockey norms. An IRS form was completed when one of the following criteria was observed:

- Any injury sustained in a practice or a game that prevented the player from returning to the same practice or game;
- Any injury sustained in a practice or a game that caused the player to miss a subsequent practice or game;
- A laceration that required medical attention;
- All dental injuries;
- All concussions;
- All fractures.

The team physician followed all the players on the team and reported all injuries to the MS using the GIR form. GIR was obtained from each team

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Table 1 Investigated tournaments in World Women's Championship (WWC) and World Women's under-18 Championship (WWC U18)

Tournaments	Group	Number of tournaments
WWC		
WWC		6
Olympic Winter Games (OWG) (2010, 2014)		2
Olympic qualification tournaments (QT)		3
WWC division I (WWC Div I)	No groups	2
	Group A	3
	Group B	1
WWC Div II	No groups	2
	Group A	1
	Group B	2
WWC Div III		1
WWC Div IV		2
Total		25
WWC U18		
WWC U18		8
WWC U18 Div I	No groups	4
	Group A	1
WWC U18 Div I QT		1
Total		14

physician after every game to verify the number of injuries that satisfied the definition (figure 2). Each injury also required completion of a more detailed IRS form by the team physician. The GIR and IRS forms were both anonymous. The IIHF MS assigned to each championship was responsible for data collection. The IRS form was filled only once for each injury and included detailed information on the period, location on ice, mechanism, anatomic location, severity and specific injury diagnosis. The anonymous forms were returned to the IIHF Medical Committee for insertion into a computer-based IRS for ice hockey injuries (Medhockey, Medisport Ltd, Finland).

Injury rate (IR) was expressed as the number of injuries per 1000 ice hockey player-games and per 1000 player-game hours. These two different IR definitions were used to allow comparison with other IIHF championships, hockey leagues and sports (handball, soccer).[6–10]

The population-at-risk or player exposure to injury was determined by an estimation of collective playing time. The number of player-games was based on 20–22 players competing for each team in a game, depending on the specific level and year of a given tournament. Only the participating athletes were included in the denominator when calculating incidence of injury.

The player-game IR was an average risk of one individual player per 1000 games (number of injuries/number of players (2 teams)/number of games×1000= number of injuries per 1000 player-games). The IR for 1000 player-game hours was based on a 60-min active game with five players and a goalie per team on the ice at the same time (number of injuries/number of players on ice same time (2 teams)/number of games×1000= number of injuries per 1000 player-game hours).

Practice injuries were excluded because there were few documented injuries (n=10); therefore, the given IRs refer to game injuries only. Time loss was used as a proxy for severity of an injury. Risk ratios (RRs) and 95% CIs for player position-wise concussion were calculated by comparing concussions at one position to concussions at all others positions.

RESULTS

Incidence of injury

During the study period, 168 injuries were reported in 637 games. The IR per 1000 ice hockey player-games was 6.4 for all female tournaments (WWC U18, WWC and OWG). The annual IR ranged between 4.5 (2014) and 11.2 (2010). For WWC U18 tournaments, the IR was 7.5/1000 player-games, and the annual IR ranged between 4.2 (2012) and 11.2 (2013). For WWC tournaments, the IR was 5.7/1000 player-games and the annual IR ranged between 3.6 (2011) and 11.3 (2010; figure 3). IR per 1000 player-game hours was 22.0 for all female tournaments, 25.6 for WWC U18 tournaments, 19.7 for WWC tournaments and 29.8 for OWG.

Injuries by anatomic region

Injuries involved were the head and face in 35 cases (20.8% of game injuries), the lower body in 72 cases (42.9%), the upper body in 37 cases (22%) and spine or trunk in 24 cases (14.3%). The IR for head and face injuries was 1.3/1000 player-games, for lower body 2.7, for upper body 1.4, and for spine and trunk 0.9, respectively. In WWC U18 tournaments, the IR for head and face injuries was 1.9/1000 player-games, for lower body 3.1, for upper body 1.5, and for spine and trunk 1, respectively. In WWC tournaments, the IR for head and face injuries was 1.0/1000 player-games, for lower body 2.5, for upper body 1.3, and for spine and trunk 0.9, respectively (table 2 and figure 4).

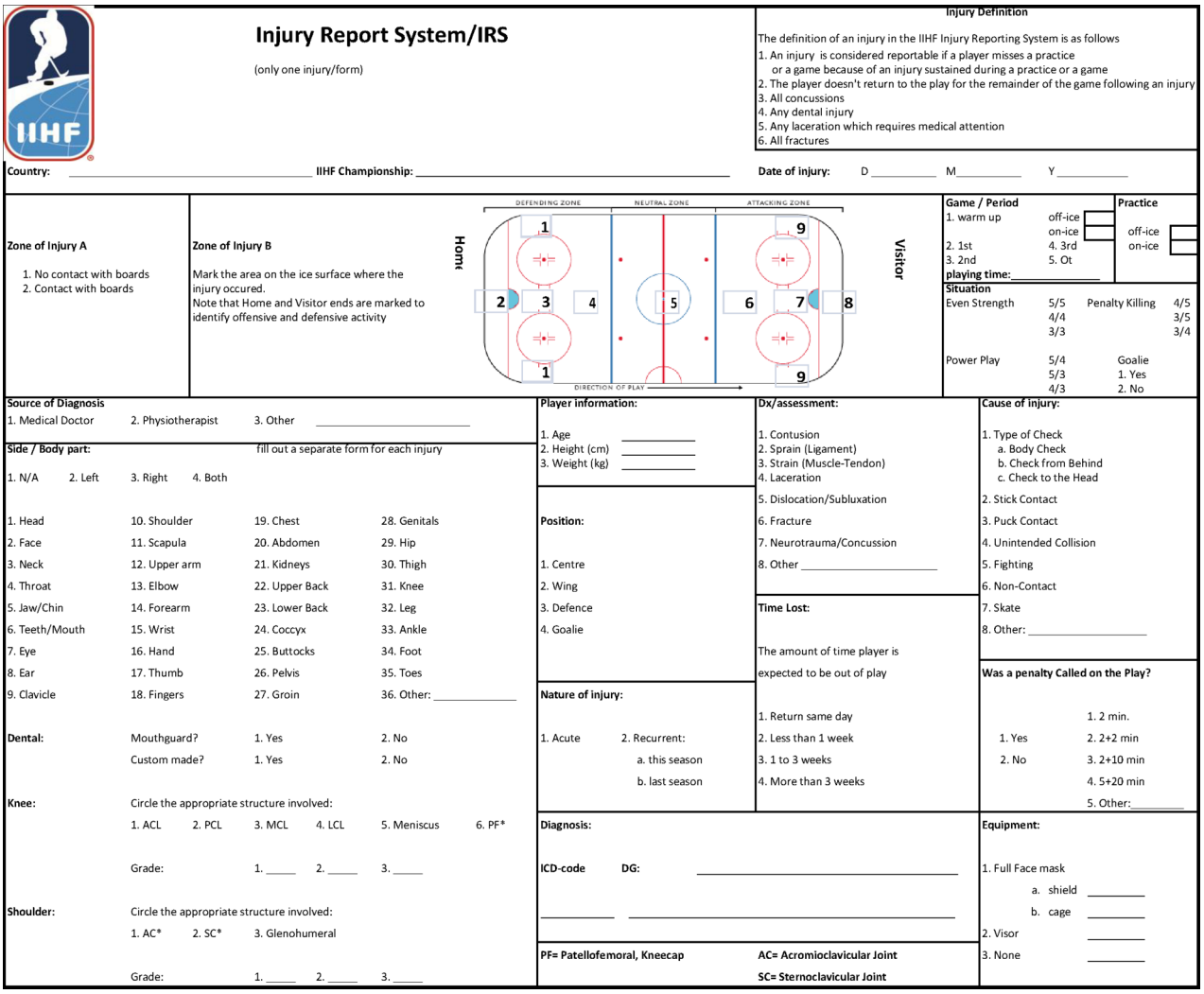
1. *Head and face injuries*: Concussion was the most common head injury (74.3%; IR 1.0/1000 player-games). There were 8.6% lacerations and 5.7% dental injuries (IR 0.1). There were no eye injuries. In all female tournaments, 17.1% of the head and face injuries were facial injuries, with an IR of 0.2/1000 player-games (WWC U18 21.1%; IR 0.4; WWC 13.3%; IR 0.1).
2. *Lower body injuries*: The knee was the most frequent site of lower body injury (48.6%). The knee IR was 1.3/1000 player-games. Medial collateral ligament (MCL) sprain (37.1%) and knee contusion (28.6%) were the most common knee injuries. ACL rupture occurred in 11.4% of all knee injuries. Ankle (27.8%; IR 0.8) and thigh injuries (8.3%; IR 0.2) were the second and third common lower body injuries.
3. *Upper body injuries*: The shoulder was the most common location for an upper body injury (32.4%). The shoulder IR was 0.5/1000 player-games. Acromioclavicular joint sprain (50%) was the most frequent diagnosis. Wrist (18.9%) and elbow (18.9%) injuries were the second and third most common upper body injuries.

Injury types by diagnosis

The vast majority of injuries (80.8%) were acute in nature and this trend was consistent over the 8-year study period. A contusion was the most common type of injury (28.0%), followed by a sprain (20.8%), concussion (15.5%), strain (11.9%) and laceration (5.4%; figure 5).

Concussion

Concussions accounted for a small yet clinically important number (n=26, 15.5%) of injuries in the championships. The concussion IR was 1.0/1000 player-games in all female tournaments, 1.4 in WWC U18 tournaments and 0.7 in WWC tournaments. The two most common causes for concussion were unintended collision (34.6%) and body check (30.8%).



Injury Report System/IRS

(only one injury/form)

Injury Definition

The definition of an injury in the IIHF Injury Reporting System is as follows
1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player doesn't return to the play for the remainder of the game following an injury
3. All concussions
4. Any dental injury
5. Any laceration which requires medical attention
6. All fractures

Country: _____ IIHF Championship: _____ Date of injury: D_____ M_____ Y_____

Zone of Injury A
1. No contact with boards
2. Contact with boards

Zone of Injury B
Mark the area on the ice surface where the injury occured.
Note that Home and Visitor ends are marked to identify offensive and defensive activity

DEFENDING ZONE NEUTRAL ZONE ATTACKING ZONE
Home Visitor
DIRECTION OF PLAY

Game / Period
1. warm up
2. 1st
3. 2nd
playing time:_____
off-ice
on-ice
4. 3rd
5. Ot

Practice
off-ice
on-ice

Situation
Even Strength 5/5 4/4 3/3
Penalty Killing 4/5 3/5 3/4
Power Play 5/4 5/3 4/3
Goalie 1. Yes 2. No

Source of Diagnosis
1. Medical Doctor 2. Physiotherapist 3. Other _____

Side / Body part: fill out a separate form for each injury
1. N/A 2. Left 3. Right 4. Both

1. Head 2. Face 3. Neck 4. Throat 5. Jaw/Chin 6. Teeth/Mouth 7. Eye 8. Ear 9. Clavicle
10. Shoulder 11. Scapula 12. Upper arm 13. Elbow 14. Forearm 15. Wrist 16. Hand 17. Thumb 18. Fingers
19. Chest 20. Abdomen 21. Kidneys 22. Upper Back 23. Lower Back 24. Coccyx 25. Buttocks 26. Pelvis 27. Groin
28. Genitals 29. Hip 30. Thigh 31. Knee 32. Leg 33. Ankle 34. Foot 35. Toes 36. Other: _____

Dental: Mouthguard? 1. Yes 2. No
Custom made? 1. Yes 2. No

Knee: Circle the appropriate structure involved:
1. ACL 2. PCL 3. MCL 4. LCL 5. Meniscus 6. PF*
Grade: 1. _____ 2. _____ 3. _____

Shoulder: Circle the appropriate structure involved:
1. AC* 2. SC* 3. Glenohumeral
Grade: 1. _____ 2. _____ 3. _____

Player information:
1. Age _____
2. Height (cm) _____
3. Weight (kg) _____

Position:
1. Centre
2. Wing
3. Defence
4. Goalie

Nature of injury:
1. Acute 2. Recurrent: a. this season b. last season

Dx/assessment:
1. Contusion
2. Sprain (Ligament)
3. Strain (Muscle-Tendon)
4. Laceration
5. Dislocation/Subluxation
6. Fracture
7. Neurotrauma/Concussion
8. Other _____

Time Lost:
The amount of time player is expected to be out of play
1. Return same day
2. Less than 1 week
3. 1 to 3 weeks
4. More than 3 weeks

Cause of injury:
1. Type of Check a. Body Check b. Check from Behind c. Check to the Head
2. Stick Contact
3. Puck Contact
4. Unintended Collision
5. Fighting
6. Non-Contact
7. Skate
8. Other: _____

Was a penalty Called on the Play?
1. Yes 2. No
1. 2 min. 2. 2+2 min 3. 2+10 min 4. 5+20 min 5. Other:_____

Diagnosis:
ICD-code DG: _____

PF= Patellofemoral, Kneecap AC= Acromioclavicular Joint SC= Sternoclavicular Joint

Equipment:
1. Full Face mask a. shield _____ b. cage _____
2. Visor _____
3. None _____

Figure 1 Injury report system form of the International Ice Hockey Federation.

A penalty was called in only 25.0% of the events when a concussion was caused by body check. For those players diagnosed with a concussion, 11.5% returned to play in the same game. The majority of concussions occurred before the 2012 Zurich Consensus Guidelines, which do not allow return to play in the same game. The centre position (IR 1.6/1000 player-game hours) had the highest risk of concussion, followed by defence position (IR 0.5) and wing (IR 0.4). RR for concussion on centre position versus all other positions was 4.29 (95% CI 1.99 to 9.24). The majority of concussions occurred during the second (30.8%) and third (34.6%) periods.

Contact with the boards

The majority of injuries occurred away from the boards (61.1%). This trend was apparent in all championships and was similar over the 8-year study period. Head and knee injuries resulting from contact with the boards were the most common (18.6%, respectively). The majority of concussions occurred without board contact (65.4%).

Causes of injury

Injuries were caused by unintended collision (26.3%), body checking (24.6%) and puck contact (12.0%). The majority of the injuries caused by stick were lower body injuries (70.0%). Penalties were assessed in 24.4% of body check injuries, 40.0% in checking to the head and 50.0% in hitting from behind injuries.

Injury severity

The majority of players who were injured returned to play within 1-week (58.1%); however, 9.6% of the injured players did not return for at least 3 weeks. The most severe injuries were wrist and hand fractures and knee sprains.

Player position, period and zone

Injuries were equally distributed according to player position: wing 37.7% (2 wings per team), centre 24.0% (1 centre per team) and defence 30.5% (2 defences per team). The goalkeeper was the least injured of all positions (6.6%). In the women's tournaments, the proportion of concussions sustained by centre was about four times higher than that of other positions (RR 4.29, (95% CI 1.99 to 9.24)). There were no significant differences between player positions concerning other injuries. The second and third period had the highest percentages of injured players (35.3%; 37.1%) during the game. There were only a few injuries sustained during warm up (2.3%) and overtime (1.7%). Only 5.6% of the injury situations occurred during the practices. Players sustained injuries at the home zone (39.5%), visitor zone (31.7%) and neutral zone (19.8%).

DISCUSSION

This observational study followed 39 women's Ice Hockey World Championship tournaments over an 8-year period, to determine the incidence, type, mechanism and severity of

Figure 2 Game injury report form of the International Ice Hockey Federation.

IIHF

IIHF Daily Injury Report Form

IIHF Championship: _____

National Association: _____

Date: _____ / _____ / _____ (dd/mm/yy)

Using this form, please report if there were any injuries sustained by any player on your team during the above-mentioned day during this IIHF Championship. We would ask that you also report if there were no injuries sustained by players on your team during this day of this IIHF Championship. If an injury was sustained during this day then an IIHF Injury Report Form must be completed and submitted to the IIHF Medical Supervisor or, in his absence, to the IIHF Directorate Chairman providing the details of the injury sustained.

The definition of an injury used by the IIHF for reporting purposes is as follows:

1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player does not return to the play for the remainder of the game following an injury
3. All concussions
4. All dental injuries
5. Any laceration which requires medical attention
6. All fractures

Please check (✓) the appropriate box below. Please provide the number of injuries sustained if you check article 'A'.

Injury Report	(✓)
A. During this day there were _____ injuries sustained by our team. (number)	
B. During this day there were no injuries sustained by our team	

Team Physician/Medical Representative: _____ (print name)

Signature: _____

Date: _____

FAIR PLAY AND RESPECT

November 2010

injuries. During the study period, 5344 players sustained 168 injuries in 637 games. The total IR was 22.0/1000 player-game hours for all female tournaments. Contusion was the most common type of injury followed by ligament sprain. The lower body was injured most frequently (42.9% of game injuries). In all female tournaments, 74.3% of the head and face injuries were concussions, which were the most common diagnoses in female ice hockey, followed by knee and ankle sprains.

Quality of the data

The strengths of this study include the large number of players competing at the highest level of international competition over an 8-year period. The number of events was determined with a strict injury definition that incorporated time lost and specific diagnosis, standardised nomenclature and a reliable data collection instrument.[4] Detailed information was collected with the two structured questionnaires.[11]

Data collection was reliable and accurate because team physicians diagnosed the injuries. Coverage of all injuries was ascertained by the MSs who collected study forms after each game. They followed all the games during a tournament, and enquired about possible injuries and players who were missing from the team roster. Injury incidence rates were estimated by collective playing time since individual on-ice exposure could not be measured. We assumed that six players were on the ice for each team during a 60 min game. This method does not take penalties or overtime into consideration.

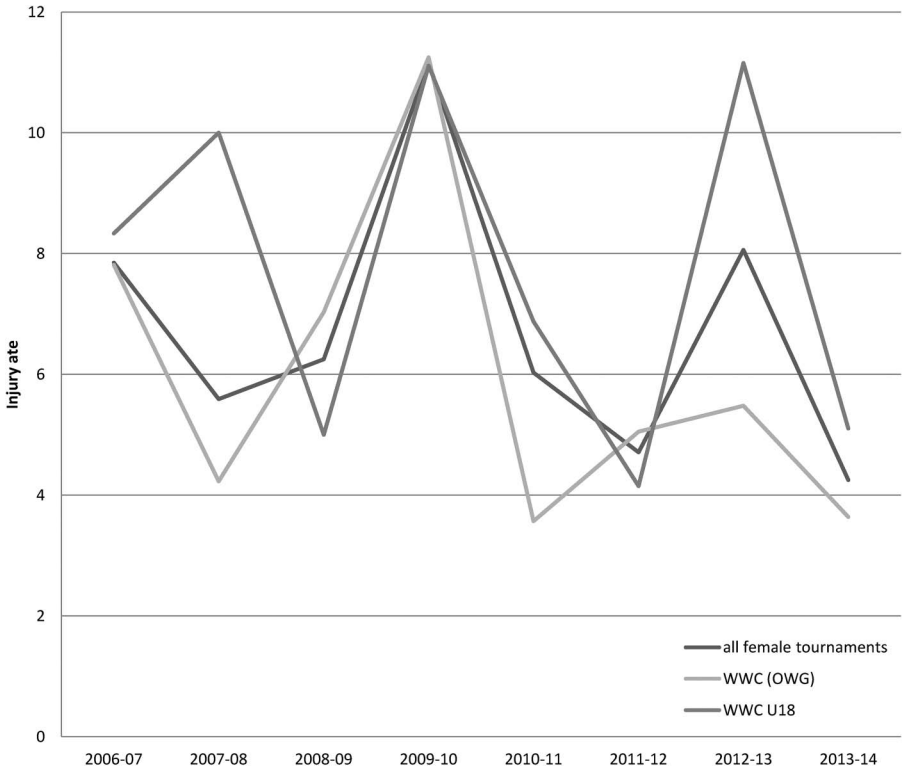


Figure 3 Annual ice hockey injury rates per 1000 player-games for all female tournaments, WWC and WWC U18 (OWG, Olympic Winter Games; WWC, World Women's Championship; WWC U18, World Women's under-18 Championship).

In a similar study of men's international ice hockey, the total men's IR was 52.1/1000 player-game hours for all World Championships (WC) and 59.6 for WC A-pool tournaments.[12] In men, the most commonly injured sites were the head and face (39.8% of game injuries; IR 5.7/1000 player-games). Laceration, especially facial laceration, was the most common injury type (26.1% of all injuries). In the present study, a laceration was diagnosed only in 5.4% of all injuries due to the fact that full facial protection is mandatory at all levels of female ice hockey.[13] In men's tournaments, the most common lower body injury involved the knee (46.9%; IR 2.0/1000 player-games), with the MCL (56.6% of all knee injuries) being the most frequently injured anatomic structure. ACL injury was documented in 10.5% of all knee cases. The knee IR for women during games was 1.3 (WWC U18 IR 1.8; WWC IR 1.0) and 28.6% of knee injuries were contusions. In the present study, the shoulder IR for women (IR 0.5) was clearly lower than the rate in men's tournaments (IR 1.5). In contrast, the ankle IR for women (IR 0.8) was higher than that for men (IR 0.6). The risk of concussion for women during international competition was lower

Table 2 Ice hockey injuries by anatomic region in all female tournaments, WWC and WWC U18

	WWC (OWG)			WWC U18			All female tournaments		
Anatomic region	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours
Face	2	0.1	0.4	2	0.2	0.7	4	0.2	0.5
Knee	17	1.0	3.6	18	1.8	6.1	35	1.3	4.6
Shoulder+clavicle	8	0.5	1.7	4	0.4	1.4	12	0.5	1.6
Head	14	0.9	3.0	15	1.5	5.1	29	1.1	3.8
Fingers+thumb+hand	6	0.4	1.3	2	0.2	0.7	8	0.3	1.0
Ankle+leg	13	0.8	2.8	8	0.8	2.7	21	0.8	2.7
Groin+hip+pelvis	6	0.4	1.3	3	0.3	1.0	9	0.3	1.2
Teeth	0	0.0	0.0	2	0.2	0.7	2	0.1	0.3
Thigh	5	0.3	1.1	1	0.1	0.3	6	0.2	0.8
Chest+throat	3	0.2	0.6	2	0.2	0.7	5	0.2	0.7
Foot+toes	2	0.1	0.4	1	0.1	0.3	3	0.1	0.4
Neck+upper back+lower back	8	0.5	1.7	7	0.7	2.4	15	0.6	2.0
Wrist	3	0.2	0.6	4	0.4	1.4	7	0.3	0.9
Upperarm+forearm+elbow	5	0.3	1.1	5	0.5	1.7	10	0.4	1.3
Abdomen+genitals+kidneys	1	0.1	0.2	1	0.1	0.3	2	0.1	0.3
Eye	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Total	93	5.7	19.7	75	7.5	25.6	168	6.4	22.0

IR, injury rate; OWG, OWG, Olympic Winter Games; WWC, World Women's Championship; WWC U18, World Women's under-18 Championship.

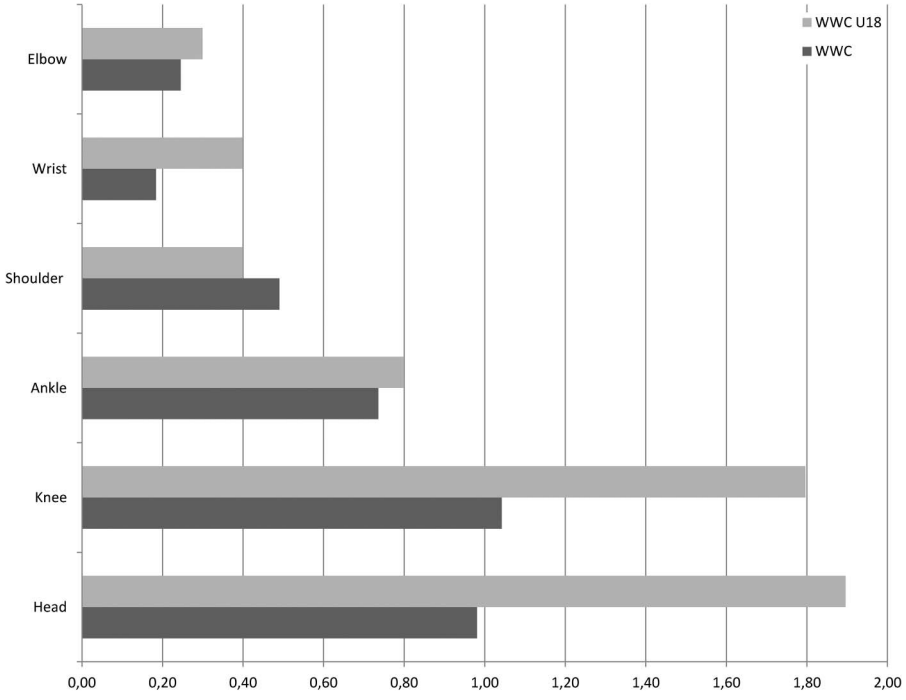


Figure 4 Injury rate by anatomic region per 1000 player-games in World Women's Championship and World Women's under-18 Championship.

than that in men's tournaments but was similar, in the WWC U18 level, to men's tournaments: 1.4/1000 player-games in all men's WC and 1.9 in men's A-pool tournaments compared with 1.0/1000 player-games in all female tournaments, 1.4 in WWC U18 tournaments and 0.7 in WWC tournaments.

Comparison with women's hockey data in National Collegiate Athletic Association (NCAA) and elsewhere

Agel and Harvey reported an IR of 12.1/1000 athlete-exposure (AE) in women's National Collegiate Athletic Association ice hockey games. The AE was determined by the number of athletes participating in a game or practice regardless of duration or type of exposure. Concussions were the most common type of injury followed by the hip/groin and ankle. The average rate of concussion over a 7-year period was 0.82/1000 AEs. Body checking and unintentional collision with an opponent were the common mechanisms of injury.[14] Schick and Meeuwisse reported that the IR for female players was 7.77 per 1000 AEs. Ninety-six per cent of injuries were related to contact mechanisms. Concussions were the most common injury, followed by ankle sprains and adductor muscle strains.[2]

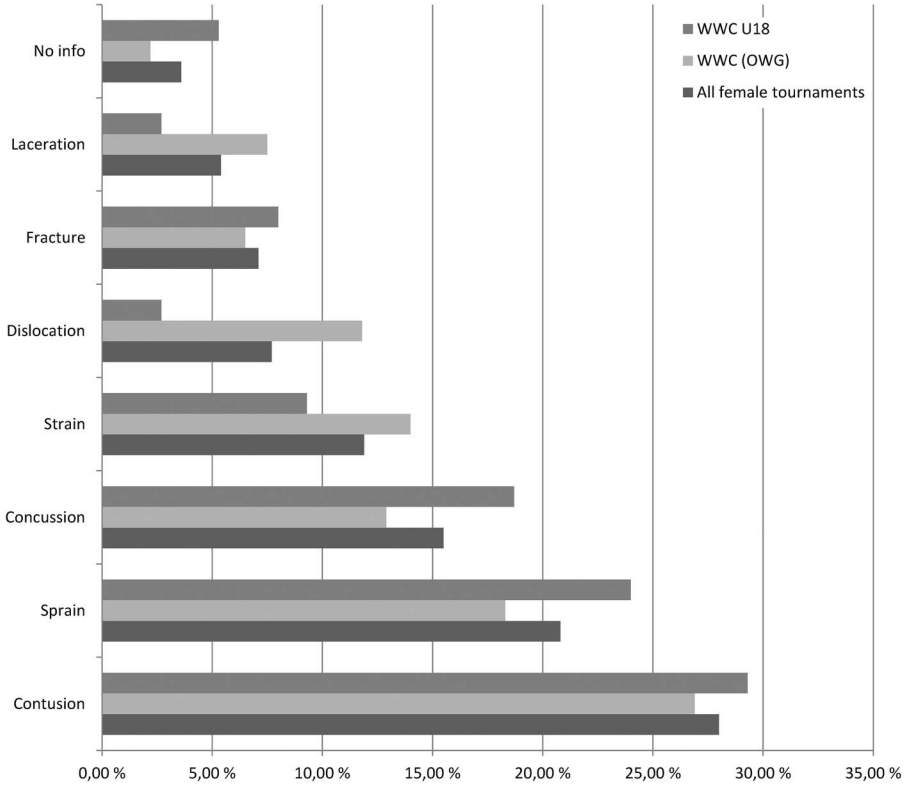


Figure 5 Injury distribution by diagnosis in all female tournaments, WWC and WWC U18 (OWG, Olympic Winter Games; WWC, World Women's Championship; WWC U18, World Women's under-18 Championship).

Injury risk in ice hockey can be compared with other sports. In the present study, the IR was 22.0/1000 player-game hours in women's ice hockey World Championships. In contrast, the IRs have been reported to be 103/1000 player-game hours in female handball,[6] and 67.4/1000 player-game hours in female soccer.[7] In women's World Football tournaments from 1998 to 2012, the IR was 65.4/1000 player-game hours.[8] IRs for the different women's team sports during the 2004 Olympic Games were: soccer 70/1000 player hours, handball 145/1000 player hours and basketball 100/1000 player hours.[9] Pasanen *et al*[10] reported that the injury incidence in Finnish woman's floorball was 40.3/1000 player-game hours. However, the comparison between sports with respect to injury risk is difficult because of the different study methodology, differences in definition of injury and estimation of exposure.

In summary, this 8-year study showed that the risk of injury during women's international ice hockey tournaments was substantially lower than the risk in men's games. Moreover, the IR in female ice hockey appears to be lower than that in other women's team sports. The knee, head, ankle and shoulder are the most vulnerable body sites. Improved knowledge on the risk factors and mechanisms of ice hockey injuries are needed for initiation of effective preventive strategies.

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Contributors MT, MJS, MA, PK, KT and JP contributed to study conception and design. MT carried out the literature search and coordinated and managed all parts of the study. MT, MJS and MA conducted data collection and performed preliminary data preparations. MT and KT conducted data analyses and all the authors contributed to the interpretation of data. MT and JP wrote the first draft of the paper and all the authors provided substantive feedback on the paper and contributed to the final manuscript. All the authors have approved the submitted version of the manuscript. MT is the guarantor.

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Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

What are the new findings?

- The overall injury rate in women's World Championships and Olympic Winter Games was 22.0 per 1000 player-game hours.
- The risk of injury in female ice hockey is about half of that reported in men's ice hockey.
- Lower body injuries are most common. The knee, head and ankle are the three most common injured anatomic sites. ACL disruption comprised 11.4% of all knee injury cases.
- Concussion was the most common head and face injury. The centre position has fourfold the risk ratio for concussion compared with wing or defence.
- One of 10 players diagnosed with a concussion returned to play during the same game.
- A laceration occurred in only 8.6% of the head and face injuries; all players wear full facial protection.

How might it impact on clinical practice?

- Continued use of a full face mask is recommended.
- More effective prevention strategies for knee, ankle and shoulder injuries are needed in female ice-hockey, including neuromuscular exercises.[15]
- Improved concussion education will promote more consistent diagnosis, treatment and return to play protocols. Further research is necessary to determine if improved skills and physical performance of the players can reduce the risk of concussion.
- Body checking is not allowed in women's hockey and this rule should not be changed in the future.

REFERENCES

1 Laprade RF, Surowiec RK, Sochanska AN, *et al*. Epidemiology, identification, treatment and return to play of musculoskeletal-based ice hockey injuries. *Br J Sports Med* 2014;48:4–10.
2 Schick DM, Meeuwisse WH. Injury rates and profiles in female ice hockey players. *Am J Sports Med* 2003;31:47–52.
3 Decloe MD, Meeuwisse WH, Hage BE, *et al*. Injury rates, types, mechanism and risk factors in female youth ice hockey. *Br J Sports Med* 2014;48:51–6.
4 Clarsen B, Bahr R. Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! *Br J Sports Med* 2014;48:510–12.
5 Engebretsen L, Bahr R, Cook JL *et al*. The IOC Centres of Excellence bring prevention to sports medicine. *Br J Sports Med* 2014;48:1270–5.
6 Langevoort G, Myklebust G, Dvorak J, *et al*. Handball injuries during major international tournaments. *Scand J Med Sci Sports* 2007;17:400–7.
7 Junge A, Dvorak J. Injuries in female football players in top-level international tournaments. *Br J Sports Med* 2007;41(Suppl 1):i3–7.
8 Junge A, Dvorak J. Injury surveillance in World Football tournaments 1998–2012. *Br J Sports Med* 2013;47:782–8.
9 Junge A, Langevoort G, Pipe A, *et al*. Injuries in team sport tournaments during the 2004 Olympic Games. *Am J Sports Med* 2006;34:565–76.
10 Pasanen K, Parkkari J, Kannus P, *et al*. Injury risk in female floorball: a prospective one-season follow-up. *Scand J Med Sci Sports* 2008;18:49–54.
11 Stuart MJ, Smith AM, "Principles of Ice Hockey Injury Research," Safety in Ice Hockey: Third Volume, ASTM STP 1341. In: Ashare AB, ed. *American Society for Testing and Materials*. West Conshohocken, PA: American Society for Testing and Materials, 2000:19–31.
12 Tuominen M, Stuart MJ, Aubry M, *et al*. Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *Br J Sports Med* 2015;49:30–6.
13 LaPrade RF, Burnett QM, Zarzour R, *et al*. The effect of the mandatory use of face masks on facial lacerations and head and neck injuries in ice hockey. A prospective study. *Am J Sports Med* 1995;23:773–5.
14 Agel J, Harvey EJ. A 7-year review of men's and women's ice hockey injuries in the NCAA. *Can J Surg* 2010;53:319–23.
15 Leppänen M, Aaltonen S, Parkkari J, *et al*. Interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. *Sports Med* 2014;44:473–86.

Injuries in world junior ice hockey championships between 2006 and 2015

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ABSTRACT

Background Detailed injury data are not available for international ice hockey tournaments played by junior athletes. We report the incidence, type, mechanism and severity of injuries in males under ages 18 and 20 at junior ice hockey World Championships during 2006–2015.

Methods All injuries in the International Ice Hockey Federation World Junior under-20 (WJ U20) Championship and under-18 (WJ U18) Championship were collected over a 9-year period using a strict injury definition, a standardised injury reporting system and diagnoses made by a team physician.

Results 633 injuries were recorded in 1326 games over a 9-year period, resulting in an injury rate (IR) of 11.0 per 1000 player-games and 39.8/1000 player-game hours. The IRs in all tournaments were 4.3/1000 player-games for the head and face, 3.2 for the upper body, 2.6 for the lower body and 1.0 for the spine and trunk. A laceration was the most common injury type followed by a sprain. Lacerations accounted for 80% (IR 3.6) of facial injuries in WJ U20 tournaments. The shoulder was the most common injury site (IR 2.0) in WJ U18 tournaments. Board contact was the mechanism for 59% of these shoulder injuries. Concussion was the most common head and face injury (46%; IR 1.2) in WJ U18 tournaments.

Conclusions and recommendations The risk of injury among male junior ice hockey players was lower than the reported rates in adult men but higher than that in women. Facial lacerations were common in U20 junior players (WJ U20) since most wear only partial facial protection (visor). The IR for shoulder injuries was high in U18 junior players (WJ U18). Suggested strategies for injury prevention include full facial protection for all players and flexible board and glass for all junior tournaments.

INTRODUCTION

Thirty-nine countries competed in the 2015 International Ice Hockey Federation (IIHF) Male World Junior under-20 (WJ U20) Championships and 43 in the Male World Junior under-18 (WJ U18) Championships. The IIHF collaborated with the local organising committees to organise the A-pool and three other divisions. Divisions I and II of WJ U20 tournaments and all divisions of WJ U18 tournaments were divided into subgroups A and B. The teams were qualified for the divisions and its subgroups according to IIHF World ranking.

Ice hockey is associated with many potential risk factors for injury, such as unintended collisions; high velocity; rapid changes in direction; and contact with the boards, stick or puck.[1] Full facial protection is mandatory for players under 18 years old. Partial facial protection (visor) is allowed for junior players aged over 18 years. The ice hockey injury research at other levels of competition has shown that most injuries occur in a game, including lacerations, contusions, sprains and concussions.[2–6] Injuries in junior ice hockey at the international level have scarcely been studied. Knowledge of injuries should help to create effective prevention strategies for reducing the risk of injury,[7] and help organisers plan medical services during tournaments.

The aim of the present study was to investigate the incidence, nature, causes, severity and time trend of injuries in the WJ U20 and U18 ice hockey tournaments between 2006 and 2015.[8]

METHODS

During the nine ice hockey seasons between 2006 and 2007 and 2014 and 2015 (1 July 2006 to 30 June 2015), we registered, with permission from the IIHF, all ice hockey injuries from the 69 male junior ice hockey championships. There were 36 WJ U20 and 33 WJ U18 Championships. A total of 1326 games were played in the 69 tournaments by 487 teams (10 518 players). WJ U20 competitions consisted of 695 games in 36 tournaments played by 254 teams (5476 players) and WJ U18 competitions consisted of 631 games in 33 tournaments played by 233 teams (5042 players).

A team medical personnel meeting before each tournament allowed the IIHF Medical Supervisor (MS) to review the definition of the injury, game injury report (GIR) form and the injury report system (IRS) form with the individual team physicians (figure 1). The definition of an injury was made in accordance with the accepted international ice hockey norms. Minor injuries that allowed the athlete to continue playing and did not require medical attention were not included. An IRS form was completed when one of the following criteria was observed:

- Any injury sustained in a practice or a game that prevented the player from returning to the same practice or game;
- Any injury sustained in a practice or a game that caused the player to miss a subsequent practice or game;
- A laceration which required medical attention;
- All dental injuries;
- All concussions;
- All fractures.

The individual team physician followed all the players on their team and submitted the GIR form to the MS after each contest. The GIR form was used to verify the number of injuries that

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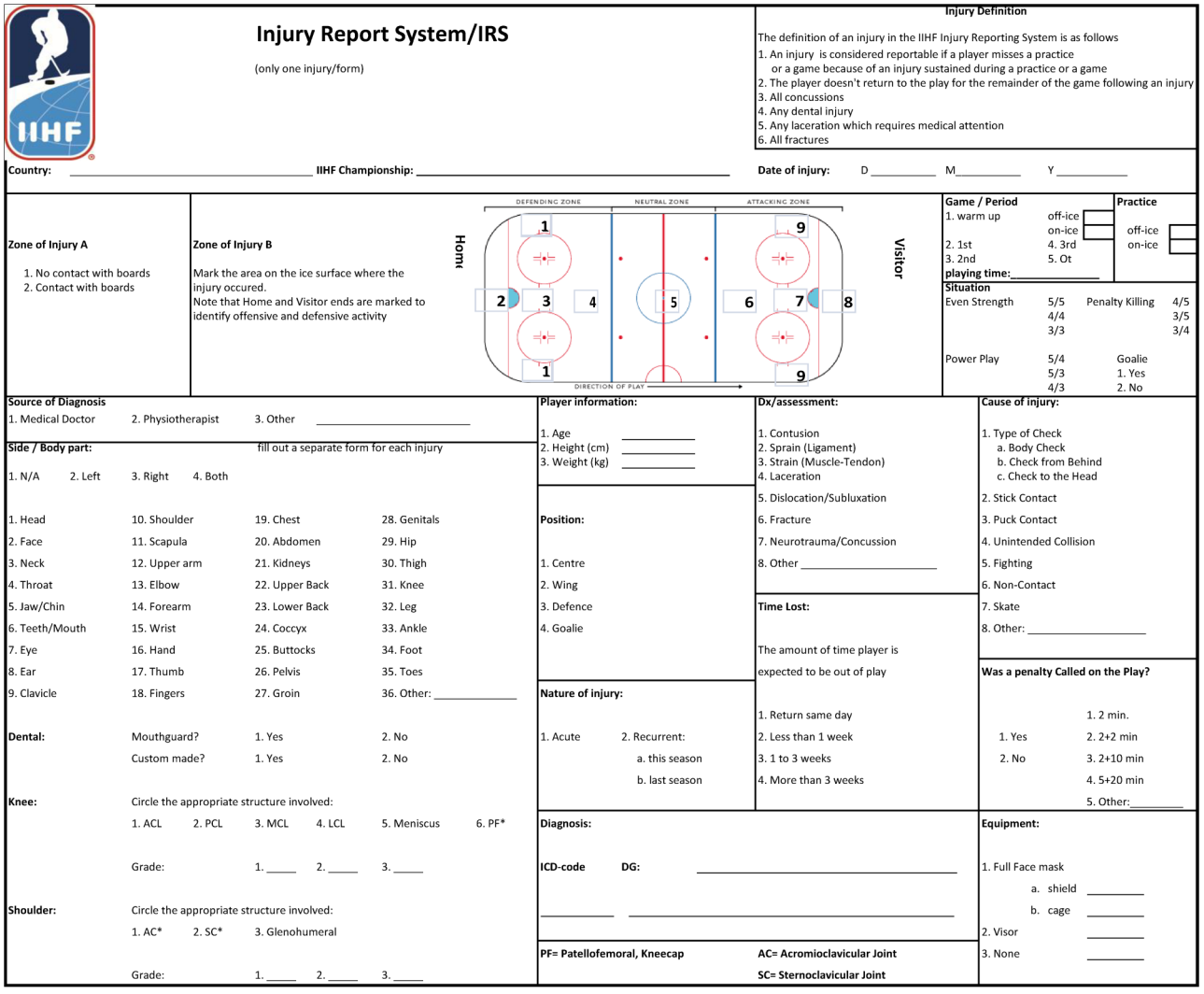


Figure 1 Injury report system form of the IIHF. DG, diagnosis; ICD, International Classification of Diseases; IIHF, International Ice Hockey Federation; MCL, medial collateral ligament; LCL, lateral collateral ligament; NA, not available; PCL, posterior cruciate ligament.

satisfied the definition (figure 2). The team physician was also required to complete a detailed injury report (IRS form) for every injury. The IRS form was returned to the MS during the tournament as soon as all the sufficient information had been obtained and the final diagnosis was confirmed. The IIHF MS assigned to each championship was responsible for data collection. The IRS form was filled out only once for each injury and included detailed information on the game period, ice location, mechanism, anatomic site, severity and specific injury diagnosis. The anonymous forms were returned to the IIHF Medical Committee for insertion into a computer-based IRS for ice hockey injuries (Medhockey, Medisport Ltd, Finland).

No separate ethics approval was needed for this register-based study since all information was collected anonymously. The study was conducted with written permission of the IIHF, who is the holder of the registry.

Injury rate (IR) was expressed as the number of injuries per 1000 ice hockey player-games and per 1000 player-game hours. These two different IR definitions were used to allow comparison with other IIHF championships, hockey leagues and sports (soccer, rugby, football, basketball).[9–16]

The population-at-risk or player exposure to injury was determined by an estimation of collective playing time. The number of player-games was based on 20–22 players competing for each team in a game depending on the specific level and year of a given tournament. Only the participating athletes were included in the denominator when calculating incidence of injury.

The player-game IR was an average risk of one individual player per 1000 games (# injuries/# players (2 teams)/# games×1000=injuries per 1000 player-games). The IR for 1000 player-game hours was based on a 60 min active game with five players and a goalie per team on the ice at the same time (# injuries/# players on ice same time (2 teams)/# games×1000=number of injuries per 1000 player-game hours).

Practice injuries were excluded because there were only a few documented injuries (n=18, 3%; WJ U20, n=12; WJ U18, n=6). The IRs refer to those injuries that occurred in game competition only. Time loss was used as a proxy to determine the injury severity. The severity was graded into four groups by the team physician according to the IRS form (figure 1).

The outcomes from A-pool tournaments are reported separately, because they represent the top-level international championships in each age group. The injury results are presented as total numbers, percentages and rates (injuries per 1000 player-games and per 1000 player-game hours).

IIHF

IIHF Daily Injury Report Form

IIHF Championship: _____

National Association: _____

Date: _____ / _____ / _____ (dd/mm/yy)

Using this form, please report if there were any injuries sustained by any player on your team during the above-mentioned day during this IIHF Championship. We would ask that you also report if there were no injuries sustained by players on your team during this day of this IIHF Championship. If an injury was sustained during this day then an IIHF Injury Report Form must be completed and submitted to the IIHF Medical Supervisor or, in his absence, to the IIHF Directorate Chairman providing the details of the injury sustained.

The definition of an injury used by the IIHF for reporting purposes is as follows:

1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player does not return to the play for the remainder of the game following an injury
3. All concussions
4. All dental injuries
5. Any laceration which requires medical attention
6. All fractures

Please check (✓) the appropriate box below. Please provide the number of injuries sustained if you check article 'A'.

Injury Report	(✓)
A. During this day there were _____ injuries sustained by our team. (number)	
B. During this day there were no injuries sustained by our team	

Team Physician/Medical Representative: _____ (print name)

Signature: _____

Date: _____

FAIR PLAY AND RESPECT

November 2010

Figure 2 Game injury report form of the International Ice Hockey Federation (IIHF).

RESULTS

Incidence of injury

During the study period, 633 injuries were reported in 1326 games. The IR per 1000 ice hockey player-games was 11.0 for all World Junior Championships. The annual IR ranged between 7.7 (2008) and 14.4 (2009). For WJ U20 tournaments, 361 injuries were reported in 695 games comprising 29 992 athletic game exposures. The IR was 12.0/1000 player-games (WJ U20 A-pool IR 13.2) and the annual IR ranged between 7.0 (2008) and 15.8 (2009; figure 3). For WJ U18 tournaments, 272 injuries were reported in 631 games comprising 27 334 athletic game exposures. The IR was 9.9/1000 player-games (WJ

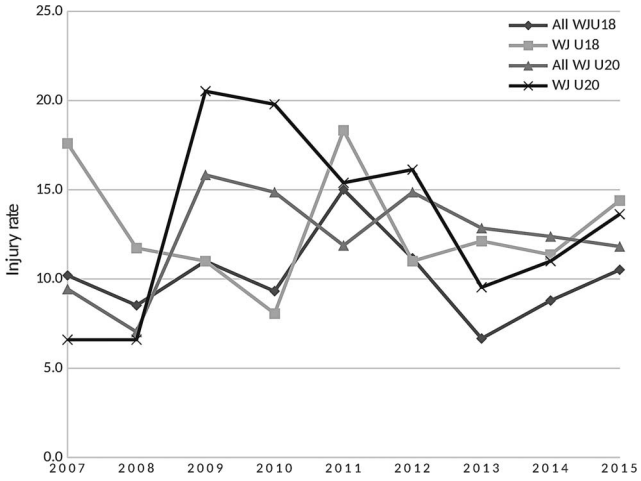


Figure 3 Annual ice hockey injury rates per 1000 player-games in all World Junior under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).

U18 A-pool IR 12.8) and the annual IR ranged between 6.7 (2013) and 15.0 (2011; figure 3). The IR per 1000 player-game hours was 39.8 for all WJ tournaments, 43.3 for WJ U20 tournaments and 35.9 for WJ U18 tournaments.

Injuries by anatomic region

In all World Junior Championship tournaments (U20 and U18), injuries involved the head and face in 244 cases (39% of game injuries), the upper body in 182 cases (29%), the lower body in 150 cases (24%), and spine or trunk in 57 cases (9%). The IR for head and face injuries in all tournaments was 4.3/1000 player-games (IR 15.3/1000 player-game hours), for upper body 3.2 (11.4/1000 player-game hours), for lower body 2.6 (9.4/1000 player-game hours), and for spine and trunk 1.0 (3.6/1000 player-game hours), respectively (table 1). Over the 9-year study period, there was a trend towards an increase in upper body injuries and decrease in lower body injuries (figure 4). IRs are shown separately in U20 and U18 age groups in tables 1 and 2, and figure 5.

Head and face injuries

The head and face were the most common sites of injury in WJ U20 tournaments (48%; IR 5.8/1000 player-games; 20.6/1000 player-game hours) and the face was the most common location (tables 1 and 2, and figure 5). Facial injuries comprised 76% of the head and face injuries in all WJ U20 Championships with an IR of 4.4 per 1000 player-games (in WJ U20 A-pool 78%; IR 5.6). A laceration was diagnosed in 80% (IR 3.6) of the facial injuries. Forty-one per cent of facial lacerations were caused by a stick and a penalty was called in 18% of them. The dental IR was 0.7 (11% of the head injuries; in WJ U20 A-pool 15%; IR 1.1). No eye injuries were reported.

In WJ U18 tournaments, concussion was the most common head and face injury (46%; IR 1.2/1000 player-games; 4.2/1000 player-game hours). Forty-four per cent of injuries were lacerations (IR 1.1) while 7% were dental injuries (IR 0.2). In WJ U18 tournaments, 47% of the head and face injuries involved the face with an IR of 1.2/1000 player-games. In WJ U18 A-pool tournaments, a laceration was the most common head and face injury (52%; IR 2.1) and the IR for concussion was 1.5 (36%).

Table 1 Anatomic regions divided to the body parts in World Junior under-18 Championships, World Junior under-20 Championships

Head and face	Head	Teeth/mouth
	Face	Eye
	Jaw/chin	Ear
Upper body	Clavicle	Forearm
	Shoulder	Wrist
	Scapula	Hand
	Upper arm	Thumb
	Elbow	Fingers
Lower body	Buttocks	Knee
	Groin	Leg
	Genitals	Ankle
	Hip	Foot
	Thigh	Toes
Spine/trunk	Coccyx	Kidney
	Neck	Chest
	Upper back	Abdomen
	Lower back	Pelvis
	Throat	

Upper body injuries

The shoulder was the most common location for an upper body injury in WJ U18 and U20 tournaments (58%). The shoulder IR was 1.8/1000 player-games (6.7/1000 player-game hours; tables 1 and 2). Acromioclavicular joint sprain (59%) was the most frequent diagnosis. In WJ U20 tournaments, the shoulder IR was 1.7 (WJ U20 A-pool IR 1.5). The IR in WJ U18 tournaments was 2.0 (WJ U18 A-pool IR 2.4). Finger (9%; IR 0.3) and wrist (8%; IR 0.3) injuries were the second and third most common upper body injuries.

Lower body injuries

The knee was the most frequent site of lower body injury in WJ U18 and U20 tournaments (33%). The knee IR was 0.9/1000 player-games (3.1/1000 player-game hours; tables 1 and 2). A medial collateral ligament (MCL) sprain (40%) was the most common knee injury. Disruption of the ACL was responsible for 6% of all knee injuries. Sixty-five per cent of knee injuries resulted from unintended or intended collisions. Ankle (23%; IR 0.6) and thigh injuries (22%; IR 0.6) were the second and third most common lower body injuries.

Injury types by diagnosis

The vast majority of injuries (90%) were acute in nature and this trend was consistent over the 9-year study period. A laceration was the most common type of injury (24%), followed by a contusion (22%), sprain (18%), concussion (10%) and fracture (10%; figure 6). In the U18 category, a sprain was the most common injury type while in the U20 age group a laceration was the most common type of injury.

Concussion

Concussions accounted for a small yet clinically important number (n=64, 10%) of injuries in the championships. The concussion IR was 1.1/1000 player-games (4.0/1000 player-game hours) in all WJ tournaments, 1.2 in WJ U18 tournaments (IR 1.5 in WJ U18 A-pool) and 1.0 in WJ U20 tournaments (IR 1.3 in WJ U20 A-pool; figure 6). The two most common causes for concussion were checking to the head (48%) and body check (23%). Illegal hits caused 63% of the concussions and a penalty was called in 53% of the events when checking to the

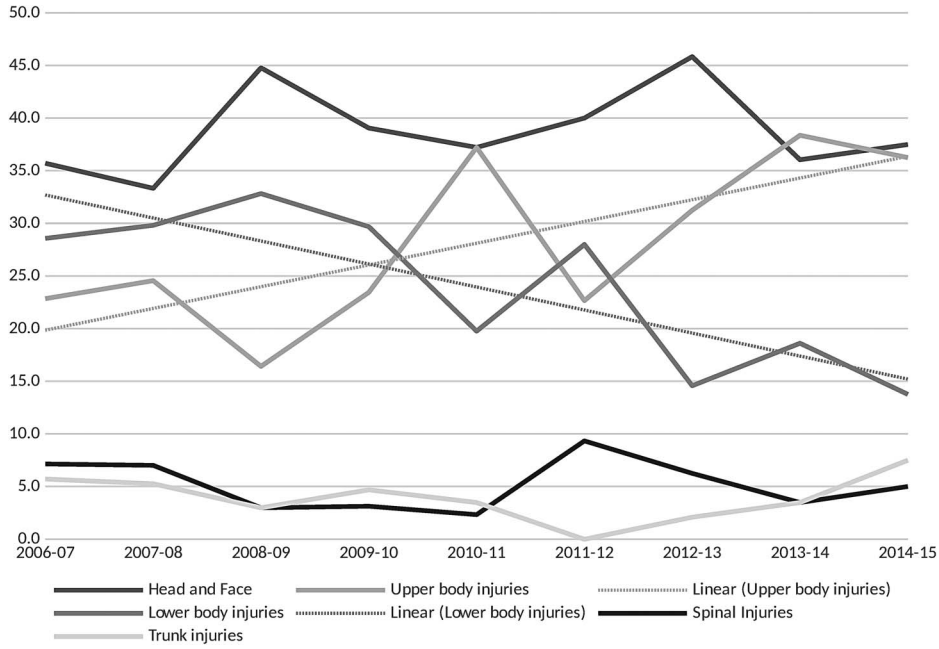


Figure 4 Annual percentage of head and face, upper body, lower body, and spinal and trunk injuries in World Junior Under-18 (WJ U18) Championships and World Junior under-20 (WJ U20) Championships including trend lines for upper body and lower body injuries.

head or checking from behind caused a concussion. For those players diagnosed with a concussion, 6% returned to play in the same game. The majority of concussions occurred before the 2012 Zurich Consensus Guidelines, which stated that a concussed athlete should not return to play in the same game. The wing position (IR 0.5/1000 player-game hours) had the highest risk of concussion, followed by defence position (IR 0.4) and centre (IR 0.1). The majority of concussions occurred during the third (38%) period.

Contact with the boards

The majority of injuries occurred away from the boards. This trend was apparent in all championships and was similar over the 9-year study period. In WJ U18 tournaments, 36% (IR 3.6; A-pool 4.4) of injuries occurred with board contact while in WJ U20 tournaments 24% (IR 2.9) of the injuries occurred in board contact (figure 7). Shoulder (30%) and head (18%) injuries were most common as a result of contact with the boards. Fifty-four per cent of shoulder injuries were caused by contact with the board (59% in WJ U18). The majority of concussions occurred without contact with the board (52%).

Causes of injury

Injuries were caused by body checking (32%), stick (13%) and puck contact (13%). There was an annual variation in injury causes without a clear time trend. The most common mechanisms for finger, hand and wrist injuries were puck (31%) and stick (18%) contact. In WJ U18 tournaments, body checking caused 39% (A-pool 37%) of all injuries while the stick accounted for only 3% (A-pool 3%). In WJ U20 tournaments, the stick caused 20% (A-pool 22%) of the injuries and the majority of them were to the head and face area (78%). Penalties were assessed 35% of the time for checking to the head injuries and 46% of the time for hitting from behind injuries.

Injury severity

The majority of players who were injured returned to play within 1 week (59%); however, 10% did not return for at least 3 weeks based on an estimate of time recovery. Most of the severe injuries were fractures (38%) and sprains (27%).

Player position, period and zone

Injuries were distributed according to player position as follows: wing 44% (2 wings per team) (WJ U18, 50%; WJ U20, 40%), centre 17% (1 centre per team; WJ U18, 16%; WJ U20, 18%) and defence 32% (2 defences per team; WJ U18, 29%; WJ U20, 35%). The goalkeeper was the least injured of all the players (3%). In WJ U18 tournaments, 50% of the injuries occurred in the wing position. The second and third periods had the highest percentages of injured players (34%, respectively) during the game. Players sustained injuries in the home zone (37%), visitor zone (38%) and neutral zone (17%).

DISCUSSION

This prospective, observational study followed 69 male junior ice hockey World Championship (WC) tournaments over a 9-year period to determine the incidence, type, mechanism and severity of injuries. During the study period, 633 injuries were reported in 10 518 players competing in 1326 games. The total IR was 11.0 per 1000 ice hockey player-games and 39.8 per 1000 player-game hours for all junior tournaments. A laceration was the most common type of injury followed by a contusion. The head and face were injured most frequently (48% of game injuries) in WJ U20 tournaments. The majority of these injuries involved the face (76%) and 80% of the facial injuries were lacerations. The upper body was the most commonly injured anatomic region (36% of game injuries) in WJ U18 tournaments.

The strength of this study includes the large number of players competing in each age group at the highest international level over a 9-year period. The number of injury events was determined with an accepted injury definition that incorporated a specific diagnosis, standardised nomenclature, a reliable data collection instrument and time lost from play.[7] Detailed information was collected with two structured and validated questionnaires.[17] Data collection was reliable because the MS

Table 2 Ice hockey injuries by anatomic region in WJ U18 Championships and WJ U20 Championships

	WJ U18			WJ U20			Together		
Anatomic region	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours	Number	IR per 1000 player-games	IR per 1000 player-game hours
Face	28	1.0	3.7	114	3.8	13.7	142	2.5	8.9
Knee	26	1.0	3.4	24	0.8	2.9	50	0.9	3.1
Shoulder+clavicle	56	2.0	7.4	50	1.7	6.0	106	1.8	6.7
Head	37	1.4	4.9	41	1.4	4.9	78	1.4	4.9
Fingers+thumb+hand	22	0.8	2.9	19	0.6	2.3	41	0.7	2.6
Ankle+leg	21	0.8	2.8	23	0.8	2.8	44	0.8	2.8
Groin+hip+pelvis	8	0.3	1.1	6	0.2	0.7	14	0.2	0.9
Teeth	5	0.2	0.7	19	0.6	2.3	24	0.4	1.5
Thigh	18	0.7	2.4	15	0.5	1.8	33	0.6	2.1
Chest+throat	7	0.3	0.9	8	0.3	1.0	15	0.3	0.9
Foot+toes	3	0.1	0.4	11	0.4	1.3	14	0.2	0.9
Neck+upper back +lower back	20	0.7	2.6	12	0.4	1.4	32	0.6	2.0
Wrist	10	0.4	1.3	5	0.2	0.6	15	0.3	0.9
Upperarm+forearm +elbow	9	0.3	1.2	11	0.4	1.3	20	0.3	1.3
Abdomen+genitals +kidneys	2	0.1	0.3	3	0.1	0.4	5	0.1	0.3
Eye	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Total	272	9.9	35.9	361	12.0	43.3	633	11.0	39.8

IR, injury rate; WJ U18, World Junior under-18; WJ U20, World Junior under-20.

verified the team roster and collected both the GIR and IRS forms after each game.

The limitations of this study include the fact that injuries were analysed in tournament games only and not in practice or training. Moreover, the injury reporting system relied on the individual team physician to record the mechanism and type of injury. A more accurate description of injury mechanism would require a detailed review of a multiangle video. A more consistent injury diagnosis would require the examination of every injured athlete at each tournament by a single experienced physician. Injury incidence rates were estimated by collective playing time since individual on ice exposure could not be measured. We assumed that six players were on the ice for each team during the 60 min game. Thus, this method did not take penalties or overtime into consideration. The severity of the injury was based on an estimate of time to return to play.

Comparable epidemiology with adult men's hockey

In a similar study of adult men's international ice hockey, the total rate was 52.1/1000 player-game hours for all WC and 59.6 for the WC A-pool tournaments.[18] The most commonly injured site was the head and face (40% of game injuries; IR 5.7/1000 player-games). Laceration, especially to the face, was the most common injury type (26% of all injuries). In this study of junior hockey players, the IR for facial lacerations and dental injuries was higher in WJ U20 tournaments than in the adult men's tournaments. In WJ U18 tournaments, a laceration was diagnosed only in 14% of all injuries, most likely due to the fact that full facial protection is mandatory in the U18 category. The transition to a half visor from full face protection in the U20 category increases the risk of injury.[19–23]

In the study of adult men's international ice hockey injuries, the most common lower body injury involved the knee (47%; IR 2.0/1000 player-games), with the MCL (57% of all knee injuries) being the most frequently injured anatomic structure.[18] ACL injury was documented in 11% of all knee injuries. The knee IR for juniors during games was lower (IR 0.9) than in men's games (IR 2.0) and 40% of their knee injuries were MCL sprains. In a similar study of women's international ice hockey, the IR for knee injuries in World Women's Championship U18 tournaments (IR 1.4) was higher than that in the male U18 tournaments (IR 1.0) even though body checking is not allowed in female tournaments. The reasons for a higher risk of knee injury in women are unknown, but could be due to differences in the physical strength and motor skills of the players.[24]

In this study, the concussion rate for juniors (IR 1.1) was lower than that for adult men (IR 1.4). The risk of shoulder injury for WJ U20 international competition was similar to that for the adult men's tournaments, but it was higher in the WJ U18 tournaments: 1.5/1000 player-games in all adult men's WC and 1.7 in men's A-pool tournaments compared with 1.7/1000 player-games (1.5 in A-pool) in WJ U20 tournaments and 2.0 (2.4 in A-pool) in WJ U18 tournaments. The higher risk of shoulder injuries in the U18 age group could be due to lower muscular strength or more frequent body checks and collisions with the boards.

Comparison of the juniors' WC ice hockey data with that in the USA and Canada

Stuart and Smith[2] reported an IR of 96.1/1000 player-game hours in elite Junior A ice hockey in North America. The game IR was highest in the third period. The IR for laceration was 32.4/1000 player-game hours. The anatomic region most often injured was the face (IR 38/1000 player-game hours).[2] This

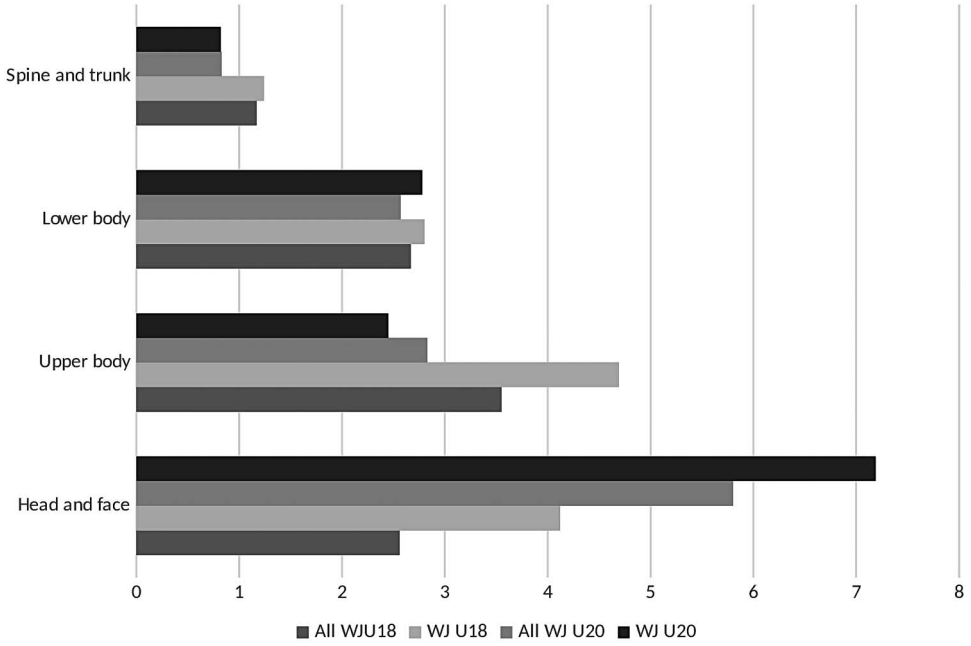
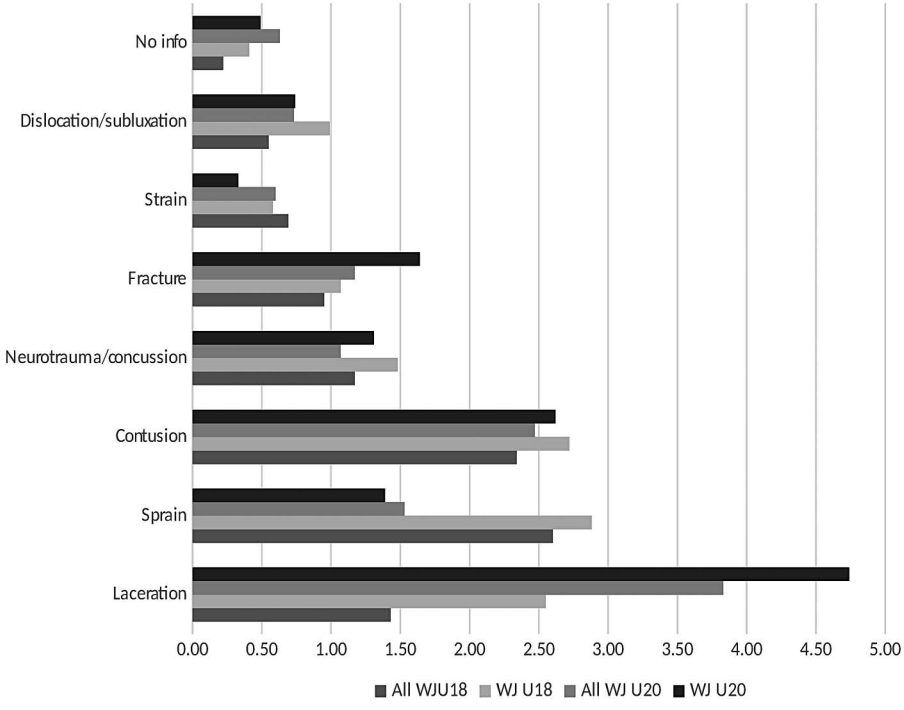


Figure 5 Injury rate by anatomic region per 1000 player-games in all World Junior under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).

Figure 6 Injury rate by diagnosis per 1000 player-games in all World Junior under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).



study was performed at a time when facial protection was not mandated in the US Hockey League for players aged 18 and older. The lack of any facial protection in a large number of athletes contributed to the high risk of facial trauma, especially lacerations.

Agel and Harvey reported an IR of 18.7/1000 athlete exposure (AE) in men's National Collegiate Athletic Association (NCAA) ice hockey games (term '1000 AE in games' corresponds to '1000 player-games' used in this study). AE was determined by the number of athletes participating in a game or practice regardless of duration or type of exposure. Concussions were the most common injury type followed by shoulder and knee injuries. The average rate of concussion over a 7-year period was 0.7/1000 AEs.[25] In another study, Agel *et al* reported a total IR of 16.3/1000 AEs in men's NAAC ice hockey games. More than one-third of all game injuries were to the upper extremity (34%). Lower extremity (34%) and head/neck injuries (15%) accounted for the majority of other game injuries. The IR for concussion was 1.5.[26] It is important to note that full facial protection has been a requirement for all NCAA ice hockey players since 1978.

Flik *et al* reported an IR of 13.8 per 1000 game AE in American Collegiate men's ice hockey. Only time-lost injuries were collected from the games and practices. Most of the

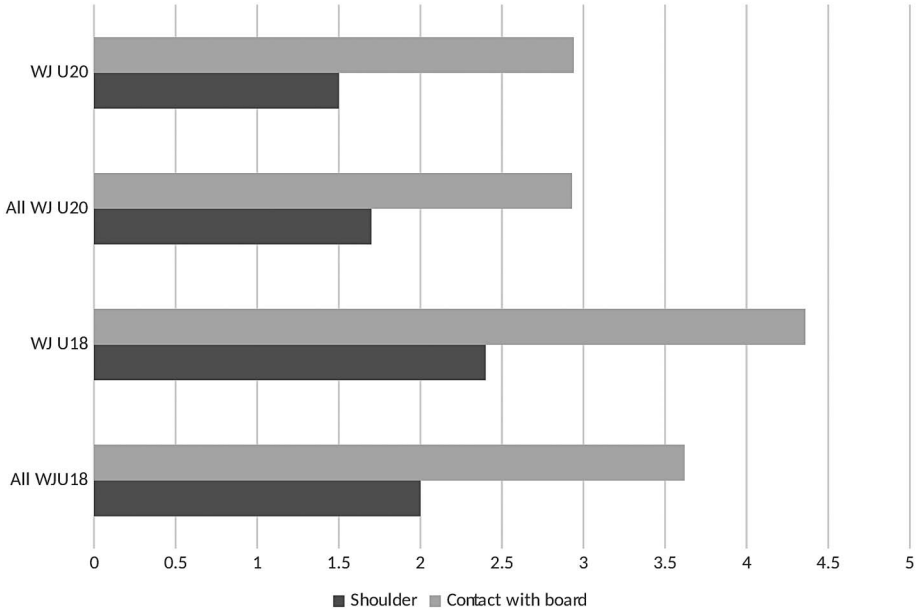


Figure 7 Injury rates for shoulder injuries and injuries occurred with board contact in all World Junior under-20 (WJ U20) Championships, WJ U20 Championships (A-pool), all World Junior under-18 (WJ U18) Championships and WJ U18 Championships (A-pool).

injuries occurred during the first and second periods and concussion was the most common diagnosis.[27]

In our study, the IR was 12.0/1000 player-games. The risk of injury for junior players competing in IIHF tournaments was lower than that reported for North American players. It is possible that differences in the style of play, officiating and ice surface size between North America and Europe help to explain the lower IR in the WC games.

Summary and conclusions

In summary, this 9-year study showed that the risk of injury to male junior ice hockey players under age of 20 during international tournaments was lower than the reported risk in adult men. Facial lacerations and dental injuries were common in the junior U20 Championships; therefore, full facial protection is recommended for these athletes. Injuries to the shoulder were common in juniors under 18 years. The risk for these injuries could be decreased by better protection and a more flexible board and glass.

What are the findings?

- The overall injury rate (IR) in the World Junior Championships was 11.0 per 1000 ice hockey player-games and 39.8 per 1000 player-game hours.
- Head and facial injuries were the most commonly injured body parts in World Junior under-20 (WJ U20) tournaments and laceration was the most common injury type.
- In World Junior under-18 (WJ U18) tournaments, concussion was the most common head and face injury. Laceration occurred in only 14% of all injuries (all U18 players wore full facial protection).
- The risk of shoulder injury in WJ U18 tournaments was higher than that in men's tournaments.
- The knee IR in junior games was considerably lower (IR 0.9) than that in men's games (IR 2.0). Forty per cent of juniors' knee injuries were medial collateral ligament sprains.
- In WJ U18 tournaments, 36% (IR 3.6; A-pool 4.4) of injuries occurred with board contact while in WJ U20 tournaments this figure was lower, 24% (IR 2.9).

How might it impact on clinical practice in the future?

- Full facial protection decreases the risk of facial lacerations and should be recommended for all junior tournaments.
- To prevent shoulder injuries involving contact with the boards, a more flexible board and glass should be used.
- Enforcing the existing stick rules may decrease the risk of facial injuries in age groups where only half face protection is used.
- More effective prevention strategies for shoulder and knee injuries are needed in junior ice hockey; there is evidence that neuromuscular exercises reduce knee injuries.[28]
- More effective prevention strategies for concussion are needed including strict officiating and continuous education of players, officials, coaches and physicians.

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Contributors MT, MJS, MA, PK and JP contributed to the study conception and design. MT carried out the literature search, and coordinated and managed all parts of the study. MT, MJS and MA conducted data collection and performed preliminary data preparations. MT conducted data analyses and all authors contributed to the interpretation of data. MT and JP wrote the first draft of the paper and all authors provided substantive feedback on the paper and contributed to the final manuscript. All authors have approved the submitted version of the manuscript. MT is the guarantor.

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Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 Laprade RF, Surowiec RK, Sochanska AN, *et al*. Epidemiology, identification, treatment and return to play of musculoskeletal-based ice hockey injuries. *Br J Sports Med* 2014;48:4–10.
2 Stuart MJ, Smith A. Injuries in Junior A ice hockey. A three-year prospective study. *Am J Sports Med* 1995;23:458–61.

3 Pinto M, Kuhn JE, Greenfield ML, *et al*. Prospective analysis of ice hockey injuries at the Junior A level over the course of one season. *Clin J Sport Med* 1999;9:70–4.
4 Gröger A. Ten years of ice hockey-related-injuries in the German Ice Hockey Federation—a ten year prospective study/523 international games. *Sportverletz Sportschaden* 2001;15:82–6.
5 Rishiraj N, Lloyd-Smith R, Lorenz T, *et al*. University men's ice hockey: rates and risk of injuries over 6-years. *J Sports Med Phys Fitness* 2009;49:159–66.
6 Ruhe A, Gänsslen A, Klein W. The incidence of concussion in professional and collegiate ice hockey: are we making progress? A systematic review of the literature. *Br J Sports Med* 2014;48:102–6.
7 Engebretsen L, Bahr R, Cook JL, *et al*. The IOC Centres of Excellence bring prevention to sports medicine. *Br J Sports Med* 2014;48:1270–5.
8 Clarsen B, Bahr R. Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! *Br J Sports Med* 2014;48:510–12.
9 Junge A, Cheung K, Edwards T, *et al*. Injuries in youth amateur soccer and rugby players—comparison of incidence and characteristics. *Br J Sports Med* 2004;38:168–72.
10 Junge A, Dvorak J. Injury surveillance in the World Football Tournaments 1998–2012. *Br J Sports Med* 2013;47:782–8.
11 Fuller CW, Molloy MG, Marsalli M. Epidemiological study of injuries in men's international under-20 rugby union tournaments. *Clin J Sport Med* 2011;21:356–8.
12 Mukherjee S. Head and face injuries during the men's field hockey Junior World Cup 2009. *Am J Sports Med* 2012;40:686–90.
13 Yard EE, Schroeder MJ, Fields SK, *et al*. The epidemiology of United States high school soccer injuries, 2005-2007. *Am J Sports Med* 2008;36:1930–7.
14 Agel J, Evans TA, Dick R, *et al*. Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. *J Athl Train* 2007;42:270–7.
15 Rechel JA, Yard EE, Comstock RD. An epidemiologic comparison of high school sports injuries sustained in practice and competition. *J Athl Train* 2008;43:197–204.
16 Dick R, Hertel J, Agel J, *et al*. Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *J Athl Train* 2007;42:194–201.
17 Stuart MJ, Smith AM. Principles of Ice Hockey Injury Research. In: Ashare AB, ed. *Safety in Ice Hockey: Third Volume, ASTM STP 1341*. West Conshohocken, PA: American Society for Testing and Materials, 2000:19–31.
18 Tuominen M, Stuart MJ, Aubry M, *et al*. Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *Br J Sports Med* 2015;49:30–6.
19 LaPrade RF, Burnett QM, Zarzour R, *et al*. The effect of the mandatory use of face masks on facial lacerations and head and neck injuries in ice hockey. A prospective study. *Am J Sports Med* 1995;23:773–5.
20 Stuart MJ, Smith AM, Malo-Ortiguera SA, *et al*. A comparison of facial protection and the incidence of head, neck, and facial injuries in Junior A hockey players. A function of individual playing time. *Am J Sports Med* 2002;30:39–44.
21 Benson BW, Mohtadi NG, Rose MS, *et al*. Head and neck injuries among ice hockey players wearing full face shields vs half face shields. *JAMA* 1999;282:2328–32.
22 Meeuwisse WH. Full facial protection reduces injuries in elite young hockey players. *Clin J Sport Med* 2002;12:406.
23 Asplund C, Bettcher S, Borchers J. Facial protection and head injuries in ice hockey: a systematic review. *Br J Sports Med* 2009;43:993–9.
24 Tuominen M, Stuart MJ, Aubry M, *et al*. Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. *Br J Sports Med* Published Online First: 7 Jul 2015. doi:10.1136/bjsports-2015-094647
25 Agel J, Harvey EJ. A 7-year review of men's and women's ice hockey injuries in the NCAA. *Can J Surg* 2010;53:319–23.
26 Agel J, Dompier TP, Dick R, *et al*. Descriptive epidemiology of collegiate men's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *J Athl Train* 2007;42:241–8.
27 Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. *Am J Sports Med* 2005;33:183–7.
28 Leppänen M, Aaltonen S, Parkkari J, *et al*. Interventions to prevent sports related injuries: a systematic review and meta-analysis of randomised controlled trials. *Sports Med* 2014;44:473–86.

Concussion in the international ice hockey World Championships and Olympic Winter Games between 2006 and 2015

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ABSTRACT

Background Concussions in sports are a growing concern. This study describes the incidence, injury characteristics and time trends of concussions in international ice hockey.

Methods All concussions in the International Ice Hockey Federation (IIHF) World Championships (WC) and Olympic Winter Games were analysed over 9 ice hockey seasons between 2006 and 2015 using a standardised injury reporting system and diagnoses made by the team physicians.

Results A total of 3293 games were played (169 tournaments, 1212 teams, 26 130 players) comprising 142 244 athletic game exposures. The average injury rate (IR) for concussion was 1.1 per 1000 ice hockey player-games for all IIHF WC tournaments. The IR was the highest in the men's WC A-pool tournaments and Olympic Games (IR 1.6). However, the annual IR for concussion in the men's tournaments has been lower than that in the World Junior tournaments since 2012. When a concussion occurred with contact to a flexible board, the IR was 0.2 per 1000 player games. In contrast, the IR was 1.1, if the board and glass were traditional (for the latter, RR 6.44 (95% CI 1.50 to 27.61)). In the men's tournaments, the trend of concussions caused by illegal hits decreased over the study period. After the 4th Consensus Statement on Concussion in Sport was published (2013), none of the concussed players in the men's WC returned to play on the day of injury.

Conclusions The annual risk of concussion in the men's WC has decreased during the study period. This was most likely due to a reduction in illegal hits. The risk of concussion was significantly lower if games were played on rinks with flexible boards and glass. Rink modifications, improved education and strict rule enforcement should be considered by policymakers in international ice hockey.

INTRODUCTION

Ice hockey is a collision sport executed on a hard ice surface surrounded by a perimeter of board and glass. Players reach high skating velocities and rapidly change direction. The fast-moving puck, swinging sticks and six players per team in a small space contributes to risk of concussion.[1–8]

The International Ice Hockey Federation (IIHF) is responsible for ice hockey at the Olympic Winter Games (Olympic Games) and coordinates the annual IIHF World Championships (WC) at all skill levels of men (WS), women (WW), juniors under-20 years (WJ U20), juniors under-18 years (WJ U18) and women under-18 years (WW U18). A total of 28 WC tournaments, 10 Olympic Qualification tournaments and a Youth Olympic tournament were held in collaboration with the local organising committees during the 2015–2016 season.

In all WC tournament games, the active playing time is three periods of 20 min each. The main difference between male and female ice hockey rules is that body checking is legal in the men's game. Intentional body checking is not permitted in any level of women's ice hockey.[1 9–12] The equipment is similar for all ice hockey players, except facial protection. All female and male U18 players must wear full-facial protection (full cage or shield), but male players over 18-year of age are allowed to wear partial-facial protection (visor). In addition, mouth guard is mandatory in WJ U20 category for players wearing visor.[13] The exact size of a hockey rink and its sections (offensive zone, neutral zone and defensive zone) varies among arenas but not between sex, age or levels of tournament.[14] Modern rink materials have flexibility and the capacity to absorb the energy of players colliding with boards and perimeter glass; this has led to the gradual replacement of traditional rinks with modern flexible material.[15]

Concussion in sport is a clinical syndrome of traumatically induced transient disturbance of normal brain function. The lateral and temporal area of the head are the most common areas to be struck resulting in concussion. In ice hockey, concussion impacts are more likely to occur from contact with another body part or object rather than another head. Differences in mechanisms of injuries have been found between men and women.[10] The diagnosis of concussion relies on a clinician's evaluation. Injury mechanics, visible signs, reported symptoms, changes in cognitive and/or physical performance and exclusion of a more severe neurotrauma are the fundamentals of clinical assessment.[16–20] The systematic collection of all ice hockey injuries shows that concussion is one of the most common injury type resulting to missed participation in both sexes.[21–29] Furthermore, growing concerns on the possible lingering detrimental effects of concussion have addressed the need for preventive measures.[30]

We aimed to describe the incidence of concussions in international ice hockey. In addition, we examined and analysed possible contributing factors, including: (1) injury causes, (2) injury location on the ice, (3) the period of the game, (4)

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player position and (5) contact with the board at the time of the incident. We also examined the differences in concussion rates stratified by sex, age groups and the level of play to help develop concussion recognition and prevention programmes at all levels of play.[31]

METHODS

During the nine ice hockey seasons between 2006–2007 and 2014–2015 (from 1 July 2006 to 30 June 2015), we registered, with the permission from the IIHF, all ice hockey injuries from the 169 ice hockey tournaments. Forty-four of them were World Senior Championships (WS) (10 of them were A-pool tournaments), two Olympic Winter Games (Olympic Games), and eight Olympic Qualification tournaments. Seventy tournaments were World Junior under-18 and under-20 Championships (WJ U18; WJ U20) (19 of them were A-pool tournaments). Forty-three tournaments were women's World Championships (WW) (14 of them were A-pool tournaments) and two Olympic Games. Fifteen of the women's World Championships were women's under-18 tournaments (WW U18). A total of 3293 games were played in the 169 tournaments by 1212 teams (26 130 players) comprising 142 244 athletic game exposures.

Before each tournament, a team medical personnel meeting allowed the IIHF Medical Supervisor (MS) to review the definition of each injury, game injury report form (GIR) and the injury report system (IRS, figure 1) form with the individual team physicians. The definition of an injury was made in accordance with the accepted international ice hockey norms. Minor injuries that allowed the athlete to continue playing and did not require medical attention were not included. An IRS form was completed when one of the following criteria was observed:

- any injury sustained in a practice or a game that prevented the player from returning to the same practice or game;
- any injury sustained in a practice or a game that caused the player to miss a subsequent practice or game;
- a laceration which required medical attention;
- all dental injuries;
- all concussions;
- all fractures.

The individual team physician followed all the players on their team and submitted the GIR form to the MS after each contest. The GIR form was used to verify the number of injuries that satisfied the definition (figure 2). The team physician was also required to complete a detailed injury report (IRS form) for every injury. The IRS form was returned to the MS during

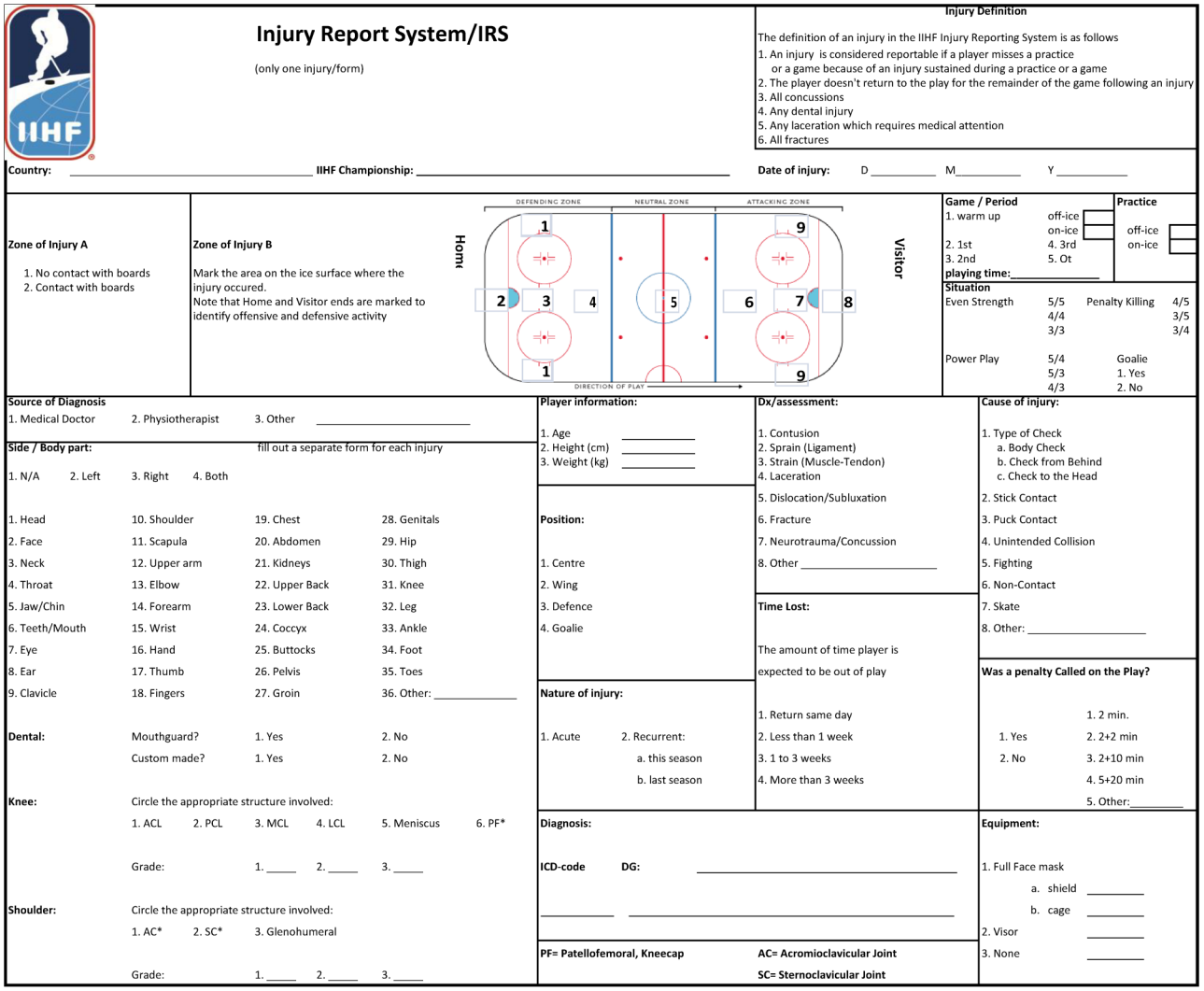

Figure 1 Injury report system form of the International Ice Hockey Federation.

the tournament as soon as all the sufficient information had been obtained and the final diagnosis was confirmed. The IIHF MS assigned to each championship was responsible for the data collection. The IRS form was filled out only once for each injury and included detailed information on the game period, ice location, mechanism, anatomic site, severity and specific injury diagnosis. The anonymous forms were returned to the IIHF Medical Committee for insertion into a computer-based IRS for ice hockey injuries (Medhockey, Medisport, Finland).

The injury rate (IR) was expressed as the number of injuries per 1000 ice hockey player-games and per 1000 player-game hours. These two different IR definitions were used to allow comparison with other ice hockey leagues, and other sports (rugby, football, basketball).[32–35]

The population-at-risk or player exposure to injury was determined by an estimation of the collective playing time. The number of player-games was based on 20–22 players competing for each team in a game depending on the specific level and year of a given tournament. Only the participating athletes were included in the denominator when calculating the incidence of injury.

The player-game IR was an average risk of injury for 1 individual player per 1000 games (# injuries/# players (2 teams)/# games×1000=injuries per 1000 player-games). The IR for 1000 player-game hours was based on a 60 min active game with five players and a goalie per team on the ice at the same time (# injuries/# players on ice same time (2 teams) / # games×1000=number of injuries per 1000 player-game hours).

Concussion was a clinical diagnosis made by a team physician. At the Team Medical Personnel Meeting, physicians were advised to follow the recommendations provided by the Consensus Statement on Concussion in Sport and were given

Figure 2 Game injury report form of the International Ice Hockey Federation.

IIHF

IIHF Daily Injury Report Form

IIHF Championship: _____

National Association: _____

Date: _____ / _____ / _____ (dd/mm/yy)

Using this form, please report if there were any injuries sustained by any player on your team during the above-mentioned day during this IIHF Championship. We would ask that you also report if there were no injuries sustained by players on your team during this day of this IIHF Championship. If an injury was sustained during this day then an IIHF Injury Report Form must be completed and submitted to the IIHF Medical Supervisor or, in his absence, to the IIHF Directorate Chairman providing the details of the injury sustained.

The definition of an injury used by the IIHF for reporting purposes is as follows:

1. An injury is considered reportable if a player misses a practice or a game because of an injury sustained during a practice or a game
2. The player does not return to the play for the remainder of the game following an injury
3. All concussions
4. All dental injuries
5. Any laceration which requires medical attention
6. All fractures

Please check (✓) the appropriate box below. Please provide the number of injuries sustained if you check article 'A'.

Injury Report	(✓)
A. During this day there were _____ injuries sustained by our team. (number)	
B. During this day there were no injuries sustained by our team	

Team Physician/Medical Representative: _____ (print name)

Signature: _____

Date: _____

FAIR PLAY AND RESPECT

November 2010

the Sport Concussion Assessment Tool (SCAT) to use as a tool in making the clinical diagnosis.[16–19] Concussions that occurred during practice were excluded because there were very few documented injuries (n=3, 2%); therefore, the given IRs in this study refer to game injuries only. Time loss was used as a proxy to determine the injury severity. The severity was graded into four groups by the team physician according to the IRS form (figure 1). Concussions caused by illegal contact were defined to checking to head (CTH), checking from behind, stick, fighting and body contact in female games. All other concussions were caused by legal reasons (figure 1).

The outcomes from A-pool tournaments are reported separately, because the tournaments represent the highest level of international championships in each age group. The injury results are presented as total numbers, percentages and rates (injuries per 1000 player-games and per 1000 player-game hours). Risk ratios (RRs) and 95% CIs for concussion were calculated by comparing traditional board and glass with flexible board and glass. RRs were also used to compare differences between the sexes. ORs and 95% CI were calculated to determine the association between player's positions, groups, causes, the arena characteristics and concussions. ORs were calculated for the senior women's WC and WW U18 tournaments separately.

RESULTS

Incidence of injury

Concussions accounted for 10% of all injuries in the championships, including 160 concussions reported in 3293 games. The average IR for concussion per 1000 ice hockey player-games was 1.1 for all IIHF WC. The annual IR ranged between 0.7 (2007) and 1.6 (2012). The results of the different groups can be found in table 1.

Annual IR for concussion

The time trend of concussions and annual IRs are shown in figure 3. The IR for concussion was highest in the men's world Championships A-pool tournaments and Olympic Games. In the men's tournaments, the IR for concussion decreased, especially in WS A-pool tournaments. The annual IR for concussion in the men's tournament has been lower than that in the WJ tournaments since 2012. The trends of annual IRs for concussion in WJ U18 and WJ U20 tournaments were slowly increasing (figure 3). In the WW tournaments, no clear time trend was observed.

Table 1 Injury rate for concussion per 1000 player-games and per 1000 player-hours in all World Championships (WC) at all skill levels of men (WS), women (WW), juniors under-20 years (WJ U20), WJ U20 A-pool, juniors under-18 years (WJ U18), WJ U18 A-pool, all WW, WW A-pool and WW U18 tournaments

	Number	Games	IR per 1000 player-games	IR per 1000 player-hours
All WC	160	3293	1.1	4.0
WS	65	1199	1.2	4.5
WS A-pool	46	650	1.6	5.9
WJ U20	34	725	1.1	3.9
WJ U20 A-pool	18	308	1.3	4.9
WJ U18	32	631	1.2	4.2
WJ U18 A-pool	18	276	1.5	5.4
All WW	29	738	0.9	3.9
WW A-pool	6	185	0.8	2.7
WW U18	15	265	1.4	4.7

Contact with the boards

The majority of concussions occurred away from the boards (56%; IR 0.6). This trend was apparent in all championships and was similar over the nine-season study period with the exception of the seasons 2007–2009. In the WJ U20 A-pool tournaments, 72% (IR 1.0) and in WW U18 tournaments 67% (IR 0.9) of concussions occurred without board contact. IR for concussions that occurred with board contact was highest in the WS A-pool (IR 0.7) and WJ U18 (IR 0.7) A-pool tournaments.

Flexible board and glass

The men's A-pool WC tournaments that were played in arenas with flexible board and glass had an overall concussion IR of 1.0 per 1000 player-games, when compared with 2.0 per 1000 player-games when traditional boards and glass were in place (for the latter, RR 2.07 (95% CI 1.06 to 4.04)). When concussion occurred with board contact, the IR was 0.2 per 1000 player games when flexible board and glass was used, compared with the IR 1.1 when traditional board and glass was used (for the latter, RR 6.44 (95% CI 1.50 to 27.61)). There were no differences between the IRs of concussions when the concussion occurred without board contact: traditional board and glass (IR 0.9) versus flexible board and glass (IR 0.8) (figure 4).

Causes of concussion

The most common situation leading to concussion was contact with another player (89%) (WS A-pool 91%). Concussions were caused mainly by a CTH (42%), body checking (23%), checking from behind (13%) and unintended collision (UC) (13%). Ninety per cent of the concussions caused by checking from behind occurred with contact to the board. The highest IR for concussion caused by CTH were in WJ U18 (56%) and WJ U20 A-pool (61%) tournaments (IR 0.8, respectively). In the WW tournaments, concussion was caused mainly by UC (34%; IR 0.3) and body checking (31%; IR 0.3). Fighting caused 3% of the concussions in all the tournaments and 7% in the WS A-pool tournaments (figure 5).

Sixty-six per cent of the concussions were caused by illegal contact. In all the tournaments, the trend of annual IR for concussion caused by illegal contact was slowly decreasing and the trend of annual concussion IR caused by legal reasons was slowly increasing. In the WS tournaments, the trend of the annual concussion rate caused by illegal contact was significantly decreasing, but the trend for legally caused concussion remained stable (figure 6). In the WJ tournaments, the trends of annual concussion rate caused by illegal or legal reasons were increasing (figure 7). Penalties were assessed in 31% of concussions. In 40% of concussion caused by CTH and in 50% of concussions caused by checking from behind, a penalty was called.

Injury severity

Nine per cent of the players who were diagnosed a concussion returned to play on the day of injury. In the WS tournaments, 14% of the concussed players returned to the same game (in the WS A-pool 8%) before the publication of the 2012 Zurich Consensus Statement (no return to play in the same game following a concussion).[19] Following the 4th Consensus Statement on Concussion in Sport was published (2013), publication none of the concussed players in WS tournaments returned to the same game. However, in other tournaments, the percentage of return during the same day were similar before and after 2012 Zurich Consensus Statement.

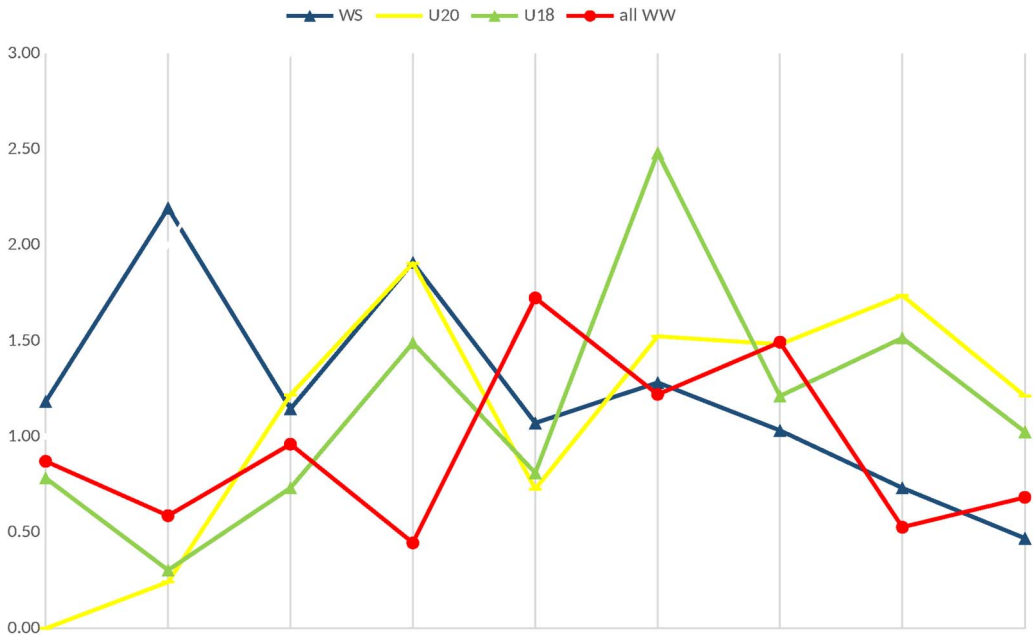

Figure 3 Annual injury rates per 1000 player-games for concussion in the World Senior, World Junior under-20 and under-18 and women's World Championships tournaments.

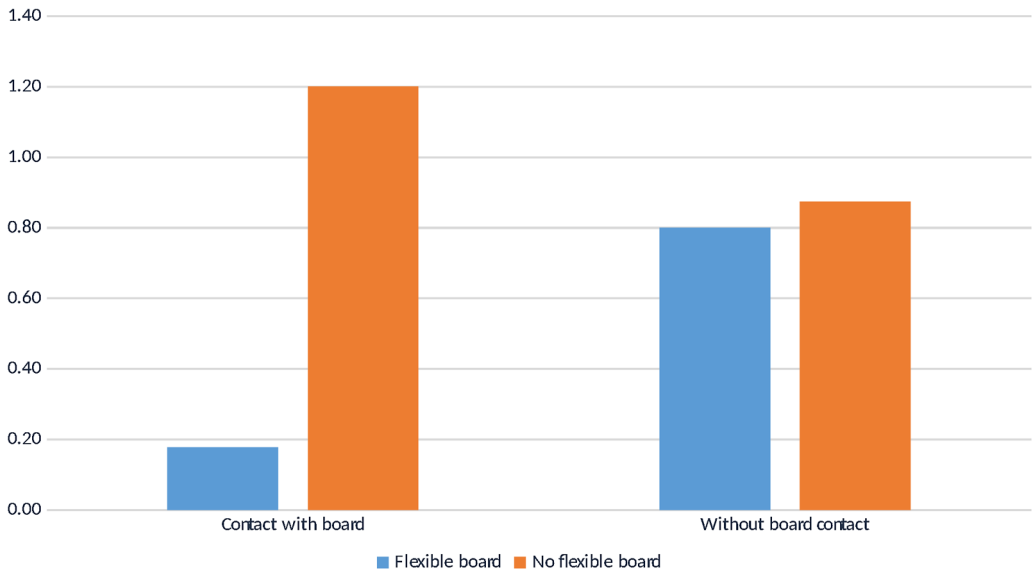

Figure 4 Injury rate for concussion per 1000 player-games when traditional or flexible board and glass was used and when concussion occurred with or without board contact.

Player position, period and zone

Concussions were distributed according to player position: wing 37% (WS A-pool 41%) (two wings per team), centre 23% (WS A-pool 26%) (one centre per team) and defence 38% (WS A-pool 33%) (two defences per team). The goalkeeper was the least injured of all positions (1%). In the WS A-pool tournaments, 67% of concussions occurred among forwards and 33% among defence. The centre had the highest concussion rate in the WS A-pool tournaments (IR 0.4) and women's tournaments (45%; IR 0.4). In the WJ U18 tournaments, wing (53%; IR 0.6; two wings per team) had the highest risk for concussion compared with the other positions.

There were no differences between the periods. Percentages of periods for concussed players were 33%, 31% and 31% during the games. Few concussions occurred during the warm up or overtime. In the WS A-pool games, 43% of the concussions occurred during the first period. The third period had the lowest IR. In the WJ U18 and WW tournaments, the lowest IR was during the first and the highest during the third period.

Players sustained concussions in the home zone (36%) (WS A-pool 41%), visitor zone (37%) (WS A-pool 35%) and neutral zone (23%) (WS A-pool 24%). In the WJ U20 A-pool tournaments, 28% of the concussions occurred in the neutral zone.

Concussion rate for men was higher than women, but the results were statistically non-significant (RR 1.29 (95% CI 0.87 to 1.91)). Results related to the player's position, cause of concussion and the arena characteristics are summarised in table 2.

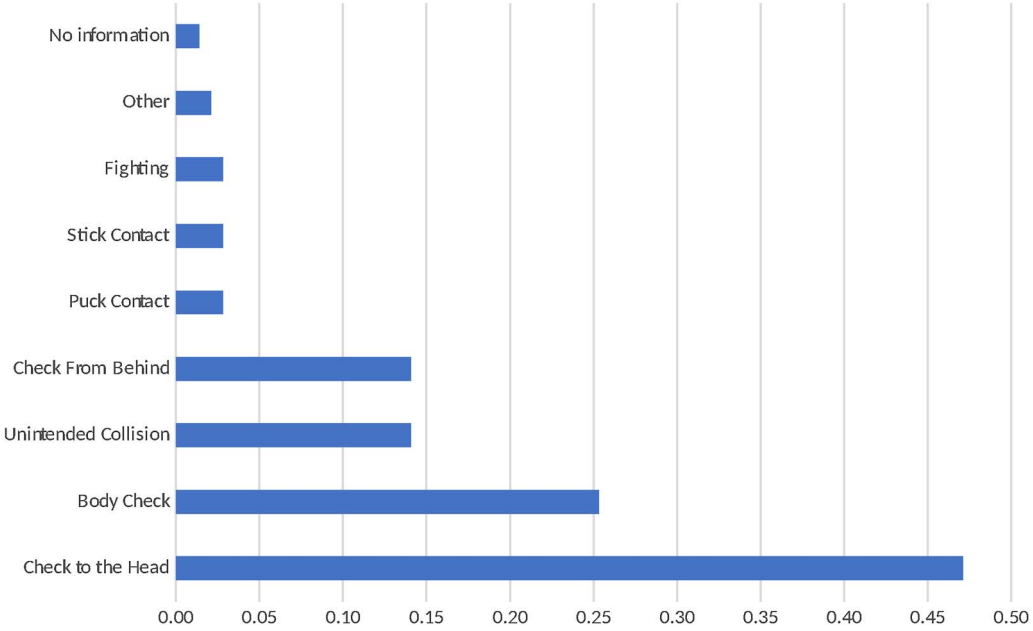

Figure 5 Injury rates per 1000 player-games for causes of concussions.

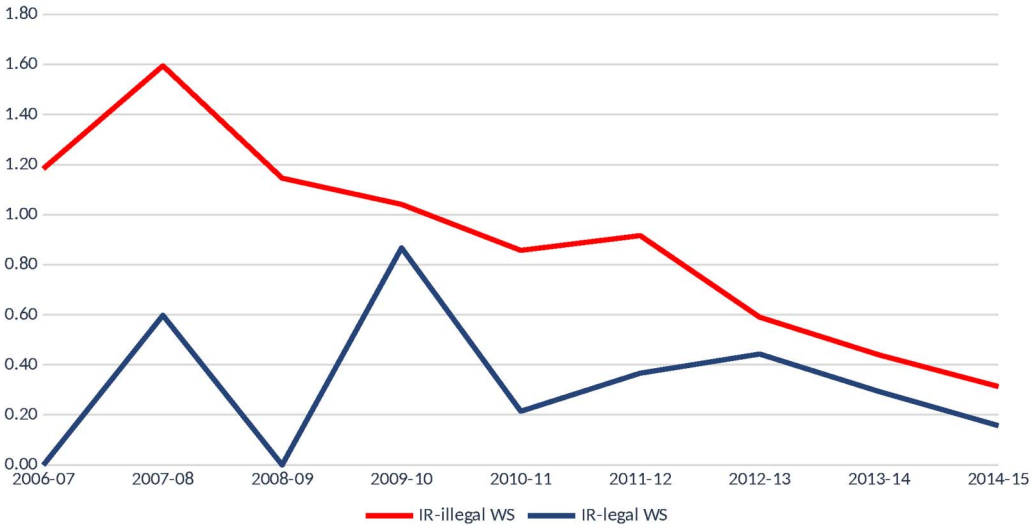

Figure 6 Annual injury rate per 1000 player-games for concussion in the World Senior Championships tournaments caused by legal or illegal hit.

DISCUSSION

Our prospective, observational study from 2006 to 2015 monitored 169 ice hockey World Championship tournaments and Olympic Games over 9 ice hockey seasons to determine the incidence and circumstances of concussion. The diagnosis accounted for 10% of all injuries in the championships, including 160 concussions in 26 130 players who competed in 3293 games. The concussion rate was 1.1 per 1000 ice hockey player-games and 4.0 per 1000 player-game hours. The highest concussion rate was in the WS tournaments (IR 1.2) and lowest in the WW tournaments (IR 0.9).

World senior A-pool tournaments results compared with the NHL studies

The injury risk for concussions in WS A-pool tournaments was similar to the National Hockey League (NHL). Benson *et al*[36] estimated the incidence of concussions in NHL as 1.8 per 1000 player-game hours, where the athlete-exposure time was estimated based on a roster of 18 skaters and 1 goalie playing in each team per game. The proportion of concussions sustained by a centre was about twice that of defencemen and wingers.[36] In our study, WS A-pool tournaments had a similar injury risk for concussion (IR 1.6) and the centre was the most injured position.

Hutchison *et al*[37 38] used systematic video analysis of NHL to report that 88% of concussions occurred due to contact with an opponent and 5% involved contact with a teammate. Eight per cent of concussions were due to fighting, although the incidence for this mechanism may be underestimated due to detection bias. Sixty-five per cent of the concussions were sustained by forwards, 32% by defencemen and 3% by goalies. The majority of the concussions occurred in the first period (47%). Concussions were distributed relatively equally in the second

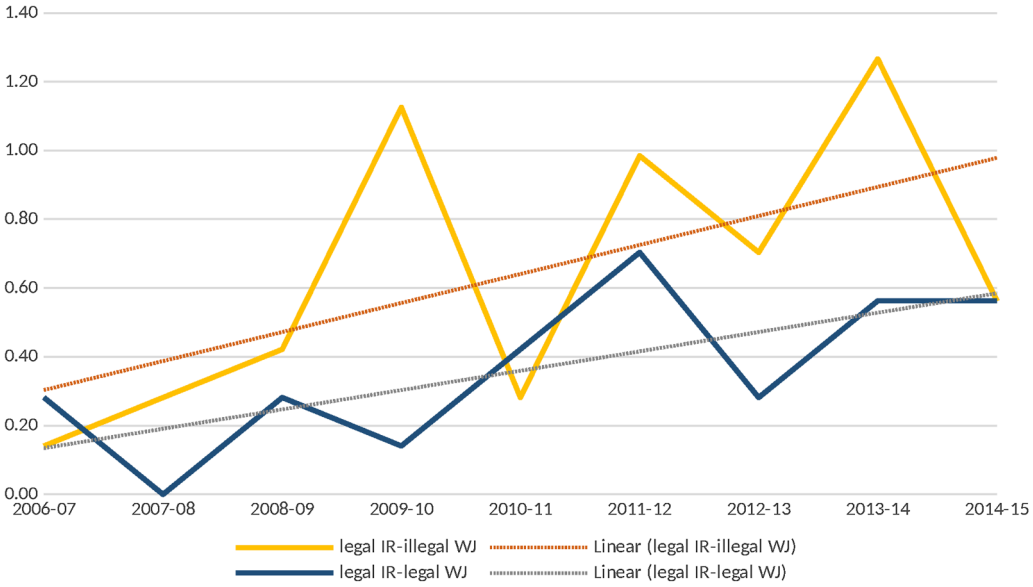

Figure 7 Annual injury rate per 1000 player-games for concussion in the WJ tournaments (World Junior under-20 and under-18 Championships) caused by legal or illegal hit.

(27.9%) and third (25.1%) periods. Forty-five per cent of concussions occurred in the defensive zone, 34% in the offensive zone and 21% in the neutral zone. The most common body part initially contacted by the hitter was the player's head (68%) with 22% of direct head contact from the shoulder, elbow or gloves. A penalty was called 29% of cases of concussions. The present findings from WS A-pool tournaments support the NHL findings by Hutchison *et al*.[37 38]

The IIHF and the NHL should work together to identifying common mechanisms and institute rules that will help prevent concussions. All hits to the head, whether intentional or unintentional, should be penalised consistent with recent rule changes by Hockey Canada and USA Hockey.

Changes in the annual risk of concussion

Concussion risk in World Senior tournaments has decreased and since 2012, the annual risk of concussion in those tournaments has been lower than that in World Junior tournaments. The concussion rate resulting from illegal hits decreased in the World Senior tournaments but has slowly increased in other tournaments. More attention is needed to decrease the concussion risk in World Junior tournaments caused by illegal hits. Further studies are needed to clarify the effect of improved rule enforcement, disciplinary panel suspensions, player education and attitude on reducing the risk of concussion.

Differences between periods, positions and sex

Most of the concussions at the men's highest level of competition occurred during the first period, when the players are maximally energised and able to apply more force with greater acceleration to contacts. This finding is contrary to the risk analysis in the WJ U18 and women tournaments in which the risk for concussion was least in the first period and highest in the third period when players are expected to be more tired. There may be also an increase in intensity in the third period because of its importance in determining the outcome of the game.

In the WW U18 tournaments, the centre had a statistically significant higher risk for concussion compared with the other positions and most of concussions were caused by body checking or a UC. These results may reflect the fact that girls do not have enough strength and awareness to avoid collisions and are not physically able to withstand a collision. Female sex has been associated with a higher risk of sport-related concussions.[3 9 11] Our study identifies a higher risk of concussion in men, but the result was not statistically significant.

Effect of flexible board and glass

More flexible rink materials and protective installation methods improve impact energy resorption, resulting in lower peak forces and greater stopping distances. These should decrease the risk of concussions.[15 39] This study is the first to report that the risk of concussion is lower when flexible boards and glass are in use. Installation of flexible board and glass is highly recommended to decrease the risk of concussion and shoulder injuries in all future tournaments, especially in WS and WJ U18 tournaments, where the IRs for shoulder injuries and concussions occurred contact with board were highest.[27 29]

Return to game on the day of injury

None of the concussed players since 2012 returned to the same game in the WS tournaments in keeping with the 4th Consensus Statement on Concussion in Sport (2013).[19] Conversely, the policy of returning to competition on the day of injury has not changed in other tournaments.[19] We recommend more thorough education on concussion management and effective injury prevention measures are especially needed for the WJ and WW tournaments.

Strengths and limitations

The strengths of this study include the large number of players competing at each age groups' highest international level over a nine-season period. All the injuries were systematically collected and the number of injury events was determined with an accepted injury definition that incorporated a specific diagnosis, standardised nomenclature, a reliable data collection instrument and time lost from play.[31] The detailed information was

Table 2 Association between player's positions, groups, causes, the arena characteristics and concussions

		WS		WS A		WJ U20		WJ U18		WW*		WW U18	
Variables	**Category**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Position	Defence	1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Wing	0.96	(0.56 to 1.66)	1.27	(0.65 to 2.50)	0.59	(0.28 to 1.24)	**2.47**	**(1.03 to 5.94)**	0.50	(0.12 to 1.98)	1.00	(0.20 to 4.94)
	Centre	1.07	(0.56 to 2.04)	1.59	(0.75 to 3.39)	0.53	(0.20 to 1.42)	1.14	(0.33 to 3.88)	1.66	(0.51 to 5.44)	**5.44**	**(1.45 to 20.41)**
	Goalie	**0.04**	**(0.00 to 0.61)**	0.06	(0.00 to 1.05)	**0.05**	**(0.00 to 0.87)**	0.28	(0.03 to 2.30)	0.15	(0.01 to 2.69)	0.66	(0.07 to 6.35)
Group		1.16	(0.78 to 1.75)	**1.55**	**(1.01 to 2.38)**	1 (referent)		1.09	(0.68 to 1.74)	0.62	(0.34 to 1.14)	1.22	(0.68 to 2.20)
Cause	Others	1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	CTH checking from behind body checking	**6.53**	**(4.03 to 10.58)**	**5.04**	**(2.82 to 9.02)**	**9.08**	**(4.63 to 17.79)**	**5.55**	**(2.77 to 11.09)**	1.27	(0.28 to 5.73)	0.54	(0.07 to 4.09)
		1.28	(0.65 to 2.49)	1.26	(0.57 to 2.80)	0.68	(0.22 to 2.03)	1.62	(0.67 to 3.92)	0.58	(0.08 to 4.48)	0.24	(0.01 to 4.00)
		1.59	(0.85 to 2.97)	1.96	(0.98 to 3.93)	**2.94**	**(1.41 to 6.13)**	1.30	(0.50 to 3.36)	2.11	(0.58 to 7.63)	**5.35**	**(1.87 to 15.29)**
Board	Flexible			1 (referent)									
	Traditional			**2.17**	**(1.11 to 4.25)**								
Concussion with board contact	Flexible			1 (referent)									
	Traditional			**6.73**	**(1.57 to 28.85)**								

CTH, check to the head.
Statistically significant results are indicated in bold.
*WW and WW U18 results are calculated separately.

collected with the two structured and validated questionnaires.[40] The data collection was reliable as the MSs verified the team roster and collected (and reviewed) the GIR and IRS forms after each game.

The limitations of the study were that injuries were analysed in tournament games only and not in practice or training. The injury reporting system relied on the individual team physician to record the mechanism and type of injury. A more accurate description of the injury mechanisms would require a detailed review of the multiangle game videos. A more consistent and detailed injury diagnosis would require examination of every injured athlete at each tournament by a single experienced physician in concussion. Injury incidence rates were estimated by collective playing time since individual on-ice exposure could not be feasibly measured. We assumed that six players were on the ice for each team during the 60 min game. Thus, this method did not take penalties, overtime or time-lost injuries during a game into consideration.[41] The severity of the injury was also based on an estimate of the time to return to play written by the team physician.

What are the findings?

- The overall concussion rate in the International Ice Hockey Federation World Championships and Olympic Winter Games was on average 1.1 per 1000 ice hockey player-games and 4.0 per 1000 player-game hours.
- The overall risk of concussion was highest in the men's tournaments. However, the concussion rate in the men's tournaments has been decreasing over the 9-year period and since 2012, annual risk of concussion in the men's tournaments has been lower than in the junior tournaments.
- The concussion rate caused by illegal hits has been decreasing in the men's tournaments but slowly increasing in the other tournaments.
- After the 4th Consensus Statement on Concussion in Sport was published (2013), none of the concussed players returned to play on the day of injury in the men's tournaments. In other tournaments, the conclusions from the Consensus Statement have not been followed as players have returned to play on the day of injury. As this paper goes to press, the 5th Consensus Statement on Concussion in Sport is being finalised (2017 publication, *Br J Sports Med*).
- The risk of concussion was significantly lower when the game was played on an ice rink with a flexible board and glass.

How might it impact on clinical practice in the future?

- Flexible boards and glass should be used in ice hockey to help prevent concussions.
- Enforcing the existing rules, including head checks and checking from behind, may decrease the risk of concussion.
- More effective prevention strategies for concussions are needed, especially in junior and women's ice hockey tournaments.
- Improved education of players, officials, coaches and physicians may mitigate concussion risk.

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REFERENCES

1 Brainard LL, Beckwith JG, Chu JJ, *et al*. Gender differences in head impacts sustained by collegiate ice hockey players. *Med Sci Sports Exerc* 2012;44:297–304.
2 Gessel LM, Fields SK, Collins CL, *et al*. Concussions among United States high school and collegiate athletes. *J Athl Train* 2007;42:495–503.
3 Marar M, McIlvain NM, Fields SK, *et al*. Epidemiology of concussions among United States high school athletes in 20 sports. *Am J Sports Med* 2012;40:747–55.
4 Noble JM, Hesdorffer DC. Sport-related concussions: a review of epidemiology, challenges in diagnosis, and potential risk factors. *Neuropsychol Rev* 2013;23:273–84.
5 Ruhe A, Gänsslen A, Klein W. The incidence of concussion in professional and collegiate ice hockey: are we making progress? A systematic review of the literature. *Br J Sports Med* 2014;48:102–6.
6 Schulz MR, Marshall SW, Mueller FO, *et al*. Incidence and risk factors for concussion in high school athletes, North Carolina, 1996–1999. *Am J Epidemiol* 2004;160:937–44.
7 Wennberg RA, Tator CH. Concussion incidence and time lost from play in the NHL during the past ten years. *Can J Neurol Sci* 2008;35:647–51.
8 Zuckerman SL, Kerr ZY, Yengo-Kahn A, *et al*. Epidemiology of Sports-Related Concussion in NCAA Athletes from 2009–2010 to 2013–2014: incidence, recurrence, and mechanisms. *Am J Sports Med* 2015;43:2654–62.
9 Covassin T, Moran R, Elbin RJ. Sex differences in reported concussion injury rates and time loss from participation: an update of The National Collegiate Athletic Association Injury Surveillance Program from 2004–2005 through 2008–2009. *J Athl Train* 2016;51:189–94.
10 Delaney JS, Al-Kashmiri A, Correa JA. Mechanisms of injury for concussions in university football, ice hockey, and soccer. *Clin J Sport Med* 2014;24:233–7.
11 Dick RW. Is there a gender difference in concussion incidence and outcomes? *Br J Sports Med* 2009;43(Suppl 1):i46–50.
12 Wilcox BJ, Machan JT, Beckwith JG, *et al*. Head-impact mechanisms in men's and women's collegiate ice hockey. *J Athl Train* 2014;49:514–20.
13 Asplund C, Bettcher S, Borchers J. Facial protection and head injuries in ice hockey: a systematic review. *Br J Sports Med* 2009;43:993–9.
14 Wennberg R. Effect of ice surface size on collision rates and head impacts at the World Junior Hockey Championships, 2002 to 2004. *Clin J Sport Med* 2005;15:67–72.
15 Poutiainen P, Peltonen J, Isolehto J, *et al*. Comparison of impact characteristics of four different ice hockey arena dasher boards. *Eur J Sport Sci* 2014;14:11–8.
16 Aubry M, Cantu R, Dvorak J, *et al*, Concussion in Sport Group. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med* 2002;36:6–10.
17 McCrory P, Johnston K, Meeuwisse W, *et al*. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med* 2005;39:196–204.
18 McCrory P, Meeuwisse W, Johnston K, *et al*. Consensus Statement on Concussion in Sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *Br J Sports Med* 2009;43(Suppl 1):i76–90.
19 McCrory P, Meeuwisse WH, Aubry M, *et al*. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med* 2013;47:250–8.
20 Harmon KG, Drezner JA, Gammons M, *et al*. American Medical Society for Sports Medicine position statement: concussion in sport. *Br J Sports Med* 2013;47:15–26.
21 Agel J, Harvey EJ. A 7-year review of men's and women's ice hockey injuries in the NCAA. *Can J Surg* 2010;53:319–23.
22 Agel J, Dompier TP, Dick R, *et al*. Descriptive epidemiology of collegiate men's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *J Athl Train* 2007;42:241–8.
23 Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. *Am J Sports Med* 2005;33:183–7.
24 Keightley M, Reed N, Green S, *et al*. Age and competition level on injuries in female ice hockey. *Int J Sports Med* 2013;34:756–9.
25 Matic GT, Sommerfeldt MF, Best TM, *et al*. Ice hockey injuries among United States high school athletes from 2008/2009–2012/2013. *Phys Sportsmed* 2015;43:119–25.
26 Schick DM, Meeuwisse WH. Injury rates and profiles in female ice hockey players. *Am J Sports Med* 2003;31:47–52.
27 Tuominen M, Stuart MJ, Aubry M, *et al*. Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *Br J Sports Med* 2015;49:30–6.
28 Tuominen M, Stuart MJ, Aubry M, *et al*. Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. *Br J Sports Med* 2016;50:1406–12.
29 Tuominen M, Stuart MJ, Aubry M, *et al*. Injuries in world junior ice hockey championships between 2006 and 2015. *Br J Sports Med* 2017;51:36–43.
30 McCrory P, Meeuwisse WH, Kutcher JS, *et al*. What is the evidence for chronic concussion-related changes in retired athletes: behavioural, pathological and clinical outcomes? *Br J Sports Med* 2013;47:327–30.
31 Engebretsen L, Bahr R, Cook JL, *et al*. The IOC Centres of Excellence bring prevention to sports medicine. *Br J Sports Med* 2014;48:1270–5.
32 Dick R, Hertel J, Agel J, *et al*. Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *J Athl Train* 2007;42:194–201.
33 Gardner A, Iverson GL, Levi CR, *et al*. A systematic review of concussion in rugby league. *Br J Sports Med* 2015;49:495–8.
34 Gardner EC. Head, face, and eye injuries in collegiate women's field hockey. *Am J Sports Med* 2015;43:2027–34.
35 Padaki AS, Cole BJ, Ahmad CS. Concussion incidence and return-to-play time in National Basketball Association players: results from 2006 to 2014. *Am J Sports Med* 2016;44:2263–8.
36 Benson BW, Meeuwisse WH, Rizos J, *et al*. A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. *CMAJ* 2011;183:905–11.
37 Hutchison MG, Comper P, Meeuwisse WH, *et al*. A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? *Br J Sports Med* 2015;49:547–51.
38 Hutchison MG, Comper P, Meeuwisse WH, *et al*. A systematic video analysis of National Hockey League (NHL) concussions, part II: how concussions occur in the NHL. *Br J Sports Med* 2015;49:552–5.
39 Barth JT, Freeman JR, Broshek DK, *et al*. Acceleration-deceleration sport-related concussion: the gravity of it all. *J Athl Train* 2001;36:253–6.
40 Stuart MJ, Smith AM. Principles of ice hockey injury research. In: Ashare AB, ed. *Safety in ice hockey: third volume, ASTM STP 1341*. West Conshohocken, PA: American Society for Testing and Materials, 2000:19–31.
41 Stovitz SD, Verhagen E, Shrier I. Misinterpretations of the 'p value': a brief primer for academic sports medicine. *Br J Sports Med* 2016;bjsports-2016-097072. Published Online First: 24 Nov 2016.