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Assessing Concussion Potential in Youth Sports for the CPSC

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Traumatic Brain Injuries in Youth Sports



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This report is submitted in partial fulfillment of the requirements for the Degree of Bachelor of Science of the Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinion of the U.S. Consumer Product Safety Commission or Worcester Polytechnic Institute

Traumatic Brain Injuries in Youth Sports

An Interactive Qualifying Project Report
Submitted to the Faculty
of the
WORCESTER POLYTECHNIC INSTITUTE



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Abstract

Concussions are a leading cause of death and disability among children. We worked with the U.S. Consumer Product Safety Commission to identify causes of concussions in youth sports as well as opportunities to prevent them. We analyzed occurrence data from the Commission's NEISS database for youth aged 5-15 playing ten different sports, and we surveyed athletes playing those sports to assess their perceptions of risk, education, protection, and proper play in their sport. We determined which physical causes of concussions in particular sports presented the greatest potential for a reduction in concussions and recommended appropriate actions involving education and protection.

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Our group would like to thank Mark Kumagai, the Division Director of Mechanical Engineering and our primary liaison to our sponsoring agency, the Consumer Product Safety Commission. His guidance and support has helped our team develop a comprehensive and relevant project. Mr. Kumagai's contributions to our methods, data presentation, and organization of recommendations were instrumental in focusing project content and maximizing the usefulness of our report to the CPSC.

We would like to thank Suad Wanna-Nakamura, a Physiologist for the CPSC, who provided our team with initial direction for how we should categorize physical causes of concussions and what information the Commission has not previously investigated.

We would also like to thank Richard McCallion, a Mechanical Engineer at the CPSC, for his input and advice on our project, and providing our team with the contact information of industry representatives.

Through this information we were able to get in touch with [REDACTED]¹, the [REDACTED]. [REDACTED] provided our team with an invaluable perspective on current headgear technologies, helmet testing, and his opinions on the future solutions for concussion prevention. [REDACTED] expert observations and opinions were helpful, and we would like to thank him for his time. Finally, we would like to thank our project advisors from Worcester Polytechnic Institute, Professors Paul Davis and James Hanlan. Their guidance and feedback has aided our team in completing our report and presentation for the CPSC.

¹The identity of this interviewee has been withheld pending resolution of a possible conflict of interest.

Executive Summary

Traumatic head and brain injuries (TBI) result in approximately 2.5 million emergency room visits and contribute, at least partially, to more than 50,000 deaths per year (“Traumatic,” 2014). The Consumer Product Safety Commission (CPSC) has found in previous studies that traumatic brain injuries (TBI) are a leading cause of death and disability in children in the U.S. Youth sports and recreational activities account for approximately 13% of these occurrences (“Nonfatal,” 2011). Supporting the CPSC’s mission of protecting the public from unreasonable risk of injury or death due to consumer products, our study examined ten organized youth team sports found to have the highest number of concussion occurrences (“Nonfatal,” 2011).

Very little is known about the circumstances within youth sports and sports in general that result in a player sustaining a concussion. The majority of education campaigns meant to inform coaches, parents, and athletes about the dangers of concussions, about the importance of properly identifying a concussion, or about how to respond to a concussion devote little attention to prevention. Hence, our goal was an in-depth assessment of prevention methods within selected sports that presented significant potential for reducing TBI. To accomplish this goal, we established 3 objectives:

1. Identify the event(s) leading to concussions in youth sports.
2. Identify the relationship between prevention methods and concussion occurrence within a sport.
3. Determine the potential for sustaining concussions in individual sports as well as the effect each physical cause has on this potential.

Methods

To complete our first objective, we coupled the Commission’s NEISS database (occurrences of concussions in specific sports) with a survey of WPI athletes (player perceptions in each sport) to gain an understanding of the physical causes of concussions in sports and how they influenced concussion rates. By analyzing approximately 8,000 injury reports we were able to distinguish four physical causes of concussions in sports that were common in the anecdotal comments accompanying most injury reports. These four causes were falls, projectiles, contact, and stationary objects, and they applied across all the sports we studied. WPI athletes were surveyed to determine their perceptions of the frequency of these causes in each sport and the sport-specific gameplay situations in which they occurred.

<u>Cause</u>	<u>Example</u>
Falls: Player’s head collided with the ground	Player tripped in basketball, hitting head on ground
Projectiles: The head was struck with an airborne object	Baseball player hit in the head by a pitched ball
Contact: The head was impacted by a person or object controlled by a person	Player hit helmets with another player
Stationary: Collisions with a stationary object	Player skated into the boards in hockey game

Table 1: Physical Causes and Examples

To complete our second objective, the same collegiate athletes were surveyed to reveal their perceptions of the prevalence of prevention methods in each sport and their relationship to concussion occurrence. The following four key prevention methods were examined by relating prevalence of the prevention methods in a sport to the occurrence of concussions in that sport.

- Risk Awareness
- Education
- Protection

- Proper Play

While college-aged athletes were out of the scope of this project, their responses to our questions were most practically obtainable, and most of them were products of programs involving the youth sports we were studying.

Findings

We assessed the concussion potential of our selected sports using a novel approach that utilized fractional sport participation data derived from NFHS (National Federation of High Schools) participation figures, causal occurrence percentages from NEISS reports, and frequency of situational occurrences in regular sports' gameplay as reported by athletes. The resulting rankings of concussion potential are shown in descending order in table 2. Ice hockey's combination of low participation and relatively high concussion occurrence led to its having the highest concussion potential among the sports listed in that table.

<u>Ranking for Concussion Potential</u>	<u>Sport</u>
1	Ice Hockey
2	Football
3	Soccer
4	Basketball
5	Boy's Lacrosse
6	Wrestling
7	Girl's Lacrosse
8	Baseball
9	Softball
10	Field Hockey

Table 2: Ranking of Sports by Concussion Potential - Source: NEISS, NFHS, & Survey

We also evaluated risk by calculating a ratio for each sport based solely on occurrence rates by cause (fall, projectile, contact, stationary object) and participation. These risk ratios

produced approximately the same ranking of sports as in table 2. However, this ranking did not incorporate the added detail of situational causes.

The surveys of athletes produced three significant findings:

1. In all of the teams surveyed, athletes perceived their personal potential of sustaining a concussion to be lower than the overall concussion potential in their sport.
2. For every team that we surveyed, no more than 50% of the respondents knew of the CDC's "Heads Up" campaign or a comparable sport-specific concussion education program.
3. The three sports that presented the highest concussion potential exhibited the largest difference between personal concern and perceived concussion potential of the sport.

Recommendations

Based on this comprehensive analysis of recorded concussion occurrence and players' perceptions, we recommend that the Commission:

1. Improve the collection of relevant details of injuries reported at NEISS hospitals.

About 23% of the concussion reports we encountered did not contain enough information in the comments to determine a physical cause of injury. If a more structured reporting system were available, future studies on the situational causation of concussions could potentially produce more definitive findings and, hence, more precisely targeted remedies.

2. Work to create a consistent method for assessing the risks within youth sports.

Our work suggests a novel approach to assessing risk by weighting situational exposure to sport-specific risk across different youth sports; we found no

comparable methods for this type of study. Establishing such a widely accepted method of risk assessment could provide detailed evidence to guide changes in rules or protection within particular sports that could reduce the number of concussions experienced by young athletes.

3. Further study opportunities to prevent concussions in ice hockey.

Ice hockey led our study in both concussion potential and ratio of concussion occurrence to participation. Two potential avenues of prevention are helmet effectiveness and education on proper play and high-risk situations. Our surveys indicated that misuse of helmets may be prevalent in ice hockey; less than 50% of athletes surveyed reported checking for correct fit or for dents and cracks each time a helmet was used. Education on proper play and high-risk situations could reduce the frequency of collisions with the boards and contact with other players that contributed over 80% of the concussion potential in ice hockey. Effective communication of the risks of common game-play situations and training in ways to avoid those situations could reduce the rate of concussions in this sport.

4. Conduct further research, perhaps in collaboration with other agencies or groups, into public awareness of high-risk situations and overall concussion risk present in individual sports.

Our surveys revealed that no more than 50% of athletes in any sport were aware of the CDC's "Heads Up" campaign or any comparable sport-specific campaigns. In each sport surveyed, players generally perceived their personal risk of sustaining a concussion to be lower than the overall risk in their sport. As there is not yet enough data to confirm the prevalence of these misperceptions among the

entire population of youth athletes, we recommend that the Commission study public awareness of concussion risk in sports.

5. Study the effect of age on helmet performance in collaboration with ASTM and other SDO's.

The inconsistency among sports of helmet replacement and reconditioning (see Appendix C) points to the need for research into the effect of helmet lifespan on a helmet's effectiveness. Helmets that are old or not properly reconditioned are likely to be less effective in absorbing concussion-causing impacts ("Rawlings," 2012). We advise further research by the CPSC or other concerned entities to determine the effects of age on helmets. If research establishes that extending the lifespan of helmets significantly reduces their protection, we recommended standards for replacement or reconditioning, similar to those in football, be established for other sports.

Authorship

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2.2	Traumatic Brain Injuries	Matthew Lesonsky	All
2.3	Current Methods of Concussion Prevention	Clare Doolin	All
2.4	Educational Programs on Concussions	Ethan Collins	All
2.5	Risk Assessments as a Basis for Education	Tyler Burns	All
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3.2	Prevention Methods in Sports that Reduced Concussions	Ethan Collins	All
3.3	Concussion Potential for Young Athletes	Matthew Lesonsky	All
4	Chapter 4: Findings	Matthew Lesonsky	All
4.1	NEISS Data Collection	Matthew Lesonsky	All
4.2	Survey Data Collection Results	Clare Doolin	All
4.3	Concussion Potential Rating Per Sport	Matthew Lesonsky	All
4.4	Baseball Findings	Matthew Lesonsky	All
4.5	Basketball Findings	Matthew Lesonsky	All
4.6	Boy's Lacrosse Findings	Matthew Lesonsky	All
4.7	Field Hockey Findings	Matthew Lesonsky	All
4.8	Football Findings	Matthew Lesonsky	All
4.9	Girl's Lacrosse Findings	Clare Doolin	All
4.10	Ice hockey Findings	Clare Doolin	All
4.11	Soccer Findings	Clare Doolin	All
4.12	Softball Findings	Clare Doolin	All
4.13	Wrestling Findings	Clare Doolin	All
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5.3	Research Hockey Safety	Tyler Burns Matthew Lesonsky	All
5.4	Public Awareness	Tyler Burns	All
5.5	Helmet Lifespan	Tyler Burns Matthew Lesonsky	All

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Chapter 1: Introduction

Traumatic head and brain injuries result in approximately 2.5 million emergency room visits and contribute, at least partially, to greater than 50,000 deaths per year (“Traumatic,” 2014). A traumatic brain injury, or TBI, is an injury which occurs from an impact to the head that causes a sudden displacement of the brain. The Centers for Disease Control (CDC) has identified this injury as a major problem facing the United States in the 21st century. While a large number of TBIs are a result of accidents such as those involving motor vehicles, the CDC has identified youth sports as a major contributor to the number of traumatic brain injuries experienced among adolescents up to nineteen years of age. Furthermore, the number of emergency department visits for sport-related injuries which resulted in diagnoses of TBI has increased by 57% from 2001-2009 for this age bracket (“Traumatic,” 2014).

The United States Consumer Product Safety Commission (CPSC) identified intervention in youth sports as an endeavor with potential to severely limit the nearly 250,000 TBIs diagnosed each year (“Nonfatal,” 2011). The CPSC is an independent federal regulatory agency tasked with protecting the public from unreasonable injury or death associated with consumer product use. The CPSC accomplishes its mission through education, safety standard activities, regulation, and enforcement (Commission, 2011). Children have the choice to play a multitude of sports, which all inherently present different situations that can result in TBIs. While some of these situations may be unrelated to use of a specific product, such as helmets or similar protection, there is no doubt that CPSC could stimulate some changes in youth athletics to reduce the abundance of injuries.

Concussions and TBIs in football have been widely publicized in the media and have received commensurate attention to bring about a reduction in injuries. One of the largest

programs undertaken was the Heads Up campaign by the CDC in which it published various informational documents targeted at athletes, parents, coaches, and physicians to assist in the diagnosis and identification of concussions. While these fliers are very descriptive and helpful in finding brain injuries, they do little to actually prevent the occurrence of such injuries.

Some manufacturers of helmets have taken the issue upon themselves by beginning research and designing innovative helmets to reduce the risk of injury. However, there is little conclusive evidence at this time as to whether or not these protective devices actually reduce the rate of TBI among athletes.

The current state of brain injury prevention in youth sports is a relatively uncharted field. While some work has been accomplished on the diagnosis and identification of the injury within specific sports, little has been done in the way of prevention among the plethora of youth sports available to children. Therefore, our project was aimed to complete a risk evaluation of youth sports and to identify those which present a high occurrence of traumatic brain injuries. From this assessment, we identified major contributing physical causes as well as preventative methods within each sport that presented the greatest potential for a reduction in injury occurrences. In order to achieve this goal we completed the following objectives:

1. Identify the physical event(s) leading to concussions in youth sports;
2. Identify the relationship between prevention methods and concussion occurrence in a sport;
3. Determine the potential for sustaining concussions in individual sports as well as the effect each physical cause has on this potential.

Our study will help the CPSC recognize those high-risk situations in youth sports that may be brought on by incorrect product use, lack of awareness, or changes in practices,

regulations, or policies. Since little research has been conducted on children's athletics programs as a whole, the completion of our project will identify specific areas that require further investigation.

Chapter 2: Background

The complexities accompanying traumatic brain injuries have led to much public scrutiny and research. However, there is little consensus on what the actual mechanism of injury causing these are and how to most effectively combat them. Agencies such as the Centers for Disease Control and the Consumer Product Safety Commission have been actively addressing this growing public health issue in the United States.

2.1: The United States' Consumer Product Safety Commission

The Consumer Product Safety Commission (CPSC), is an independent government agency tasked with protecting the public from the potential danger associated with consumer products. It fulfills its mission through three primary activities: research on potentially hazardous products; imposing standards to protect the public; and informing consumers of, and possibly banning, potentially unsafe products. The Commission reported in its 2002 annual performance report that “many of the largest contributors to the annual toll of head injuries were recreation and sports related activities”, (Commission, 2002, p. 5) but thus far, it has had neither the time nor resources to identify physical causes of concussions and preventative methods of sports on which to focus research, regulation and outreach (Commission, 2002).

To study patterns of injury occurrences, the Commission's EPIdemiology Retrieval (EPIR) data access system integrates data from multiple sources, including the National Electronic Injury Surveillance System (NEISS), the In-depth Investigation database (INDP), the Injury or Potential Injury Incident database (IPII), and the Death Certificate database (DTHS). The NEISS system utilizes injury reports from a representative sample of hospital emergency departments to provide countrywide, statistically valid estimates of product-related injuries (Commission, 2012). The INDP compiles and organizes Commission records of field

investigations and telephone interviews that provide interpersonal context to data found in other databases. The IPII integrates news clips, hotline calls, internet complaints, compliance reports, reports from the Medical Examiner and Coroner Alert Program (MECAP), and Federal and state agency referrals to identify patterns of injury hazards that require study. The DTHS collects approximately 5,000 death certificates annually from all 50 states, which CPSC staff code for use in analyses of causes of death. The Commission staff use all of these sources extensively to identify injury trends related to consumer products and the conditions under which they occur (Commission, 2012).

Using such data as a starting point, the Commission supports the development of effective voluntary standards. Product specific Voluntary Standard Development Organizations (SDOs)—comprised of industry, Commission, and consumer representatives—develop standards beginning with a recommendation by Commission staff for further regulation based on product incident reports. The SDO then organizes a technical assessment and drafts a standard, which is released for public feedback, including expert advice and clarifying analyses from the Commission staff. Upon completion of this feedback period, the voluntary standard typically is agreed upon by the SDO and becomes the industry norm despite its lacking the force of law (Commission, 2011).

When a voluntary standard is being ignored, the Commission uses a process similar to the creation of voluntary standards, again utilizing input from consumers, industry groups, and government partners to create mandatory safety standards. These regulations usually cover performance criteria and safety warnings, which are required to appear on consumer products (Commission, 2011). Once in effect, these standards are nationally recognized and must be met throughout the manufacturing, distribution, and selling processes. Failure to adhere to these

federal standards can result in civil or criminal penalties. As with voluntary standards, the Commission's starting point remains a comprehensive analysis of product incident data.

2.2: Traumatic Brain Injuries

Traumatic brain injuries (TBI) are extremely serious injuries that affect millions of Americans annually. The most understood reasons for these injuries are bumps, blows, or jolts to the head (or body) that produce sudden accelerations, causing a displacement of the brain and potentially bruising due to impact with the skull ("Traumatic Brain Injuries," 2014; "Concussion," 2011). TBIs incorporate a large range of head/brain injuries and are classified by their severity. The scale of severity ranges from mild to severe with symptoms ranging from a brief change in mental status to extended periods of unconsciousness or amnesia after the initial injury ("Traumatic Brain Injuries," 2014). Severe traumatic brain injuries can potentially lead to coma or death. However, mild traumatic brain injuries (MTBI) are much more common, making up nearly three-quarters of all brain injuries ("Concussion," 2011; Karen & Esther, 2010).

The term *concussion*, while having the same causes as TBI, is often used interchangeably with MTBI as concussions are rarely life-threatening in their severity. Common symptoms of concussions include chronic headaches, weakness, numbness, decreased coordination, nausea or vomiting, or slurred speech. After the symptoms have subsided, concussions can potentially lead to life-long struggles such as difficulty concentrating and loss of memory (Cantu, Nowinski, & Robbins, 2014).

Traumatic brain injuries, and their various delineations, are expected to be the "third largest cause for global disease burden by 2020" (Whyte, Benton, & Whyte, 2013). In 2013 alone, 1.7 million Americans were diagnosed with a TBI. In addition to this number, another four million traumatic brain injuries are estimated to be unreported or undiagnosed within athletics ("Concussion," 2011; Jordan, 2013). Youth sports single-handedly accounted for

upwards of 250,000 of the reported TBIs annually, making up nearly thirteen percent of all reported brain injuries in the United States at that time, according to the CDC's morbidity and mortality report released in October of 2011 ("Nonfatal," 2011). Furthermore, over one-fifth of brain injuries experienced by children older than five years of age are directly related to athletics (Harvey, 2013). It is well known how frequently concussions and TBIs occur; however the actual situational causes of these injuries are often unknown.

While major situational causes for TBI have yet to be identified, some overall circumstances have been flagged as potential reasons for a higher risk of brain injury within both high-contact and high velocity sports. High-contact (football, lacrosse, and hockey) and high velocity (basketball and soccer) sports contribute to roughly one-third of all head and brain injuries experienced by children less than 19 years old in sports or recreational environments (Broglia *et al.*, 2014; "Nonfatal," 2011). The CDC has recognized that throughout all brain injuries experienced in the United States, falls and contact ("struck by/against") are major contributors representing 40.5% and 15.5% of the total injuries, respectively ("Traumatic Brain Injuries in the United States," 2014). The following are examples of falls and contact in sports settings:

- Falls: players tripping and hitting their head onto the ground running after a ball
- Contact: two players' heads colliding in the air while jumping up for a header in soccer

In addition to these two causes mentioned by the CDC, other prevalent sources of injury are projectiles and collisions with stationary objects, as determined through the CPSC's NEISS database. Examples of these include hockey players getting hit in the head from an airborne puck and basketball players running into the backboard stanchion after shooting a layup. While it may be observed that falls, contact, projectiles and collisions with stationary objects produce

concussions, little research has been done to evaluate the increased potential for concussion based on the prevalence of these causes in sports.

2.3: Current Methods of Concussion Prevention

There are many methods currently used to address the concussion problem apparent in athletics, particularly youth sports. Two major approaches include wearing protective headgear and implementing policies to standardize concussion diagnosis, return to play protocols, and to reduce athlete exposure to high-risk situations.

2.3.1: Protective Headgear and its Limitations

The general public and media have identified helmets as a solution to the sports concussion epidemic. However, even the most advanced helmet technologies aren't designed to protect an athlete against concussions (██████████¹, personal communication, December 10, 2014). "While some helmets will reduce risk more than others, no helmet can eliminate risk," said Stefan Duma, Professor and head of the Virginia Tech -- Wake Forest School of Biomedical Engineering and Sciences (Rowson, 2012).

These observations do not mean that helmets aren't essential for the protection of players, as playing a game such as football or ice hockey without helmets would result in more numerous and severe brain/head injuries, including concussions. In sports such as football, receiving hits to the head is in the nature of the game, and improving helmet design becomes important to reduce the risk of concussion (Rowson, 2012). Concussions can be sustained when the brain experiences either a rotational or a linear acceleration (Rowson, 2011). However, football helmets are evaluated based only on linear accelerations and impact forces sustained by a model head form within the helmet when dropped or hit from various angles.

While not necessarily built to prevent concussions, compared to other protective headwear football helmets achieve the highest protection against linear impacts, and new models

have exhibited up to a 14% decrease in linear acceleration compared to baseline models from the 1990s, evidence of improvement in their design (Viano, 2012). The recent models of football helmets are high performing and may provide some protection from the causes of concussions. (██████████¹, personal communication, December 10, 2014).

In contrast, there is significant room for improvement in helmets to reduce injury risk in sports such as ice hockey. Ice hockey helmets are significantly less advanced than football helmets, and manufacturers do not devote many resources or much effort to complying with the voluntary helmet standards created by the National Operating Committee on Standards for Athletic Equipment (NOCSAE). The intent of the original ice hockey helmet design was to protect a player's head and face from being hit with a hockey puck (██████████¹, personal communication, December 10, 2014). However, other situations such as checking and colliding with the boards are much more prevalent and cause more concussions. Higher speeds further add to the risk of concussion from player collisions. We speculate use of inadequate helmets may actually lead to more aggressive play and more injuries because of athletes' false sense of protection.

Alternative head protection products on the market claim to protect athletes against concussions without strong validation of their effectiveness. One of these products is the concussion headband which is marketed primarily to soccer players but is used by athletes in other sports such as basketball ("HALO," 2014). There is not enough substantiated evidence to prove that these headbands protect the wearer against concussions (Hanson, 2014). Many parents and players seem to have the attitude that even if the headbands are not effective, they provide more protection than nothing ("Concussions," 2010). However, some experts that we interviewed

disagree with this sentiment because, like low-quality helmets, these headbands may be giving athletes a false sense of protection leading to potential recklessness (Hanson, 2014).

2.3.2: Policies Regarding Concussions and Proper Play

State governments have produced legislation to reduce the number of cases of traumatic brain injuries in youth sports. The Lystedt Law, passed in Washington State in 2009, takes a three-step legislative approach to reducing concussions in sports by:

- Proactively introducing coaches, players, and parents to the concussion risks posed in various sports.
- Mandating removal of athletes at the first acknowledgement of concussive symptoms.
- Requiring a medical professional's clearance before an athlete is allowed to return.

Following the implementation of this groundbreaking law, 49 additional states adopted similar ordinances by 2013 (Andrews, 2014). While in theory the pillars of this law may be effective, the variations of the law from state to state have led to numerous inconsistencies in implementation and regulation, creating laws with diluted and ineffective objectives (Andrews, 2014; Lowrey & Morain, 2014). A more practical way to productively impact the concussion problem is to determine the causes and identify ways to improve equipment and proper play habits (Broglio *et al.*, 2014).

The CDC has identified the strategies most frequently used by school systems and sports organizations to implement additional rules and regulations regarding concussions. One of these strategies is to require that athletes have constant and easy access to medical attention from a professional, or quick access to a hospital or trauma center, in the event that they require it. Another strategy has been to implement policies regarding the upkeep of helmets to maintain their efficacy. The CDC and CPSC's joint "4 Quarters of Football Helmet Safety" informational

pamphlet recommends that helmets be reconditioned and recertified by a NAERA (National Athletic Equipment Reconditioning Association) conditioner every year. It also recommends that helmets aged 10 years or older be replaced, even after being recertified every year (“4,” 2014). Finally, some organizations may lessen youth players’ exposure to higher risk situations by limiting contact in practices for sports such as football (“Get,” 2014).

Rule changes may also be made if it seems that players are still too vulnerable to concussion from certain high-risk situations of gameplay (“Get,” 2014). It is the opinion of Professor Stefan Duma that the most effective strategies to reduce concussions are implementing rules for play and proper techniques, to “reduce the number of head impacts that players experience” (Rowson, 2012). In full-contact sports, checking increases the amount of player contact. In sports such as ice hockey and boy’s lacrosse, there are rules regarding proper checking. In ice hockey, checking that intentionally targets the head of a player is illegal (“Rule 48,” 2014). In addition, checking from behind, where a targeted player cannot defend himself is not allowed (“Rule 43,” 2014). The high rates of concussions in football from player contact have led to football players being taught to hit “heads up” and not lead with their heads in order to reduce injury (“Heads,” 2010).

In non-contact sports in which helmets are not worn, some rules have been introduced specifically to reduce player exposure to high-risk situations. For example, no checking is allowed in girl’s lacrosse except for stick checking (A defender can only make contact with the opponent’s stick in an attempt to knock out the ball) (“Stick,” 2014). To protect players against the danger of projectiles in field hockey, players can lift the ball into the air with their stick except when the referee determines the situation to be “dangerous” and assesses a penalty

(“Field,” 2014). Although penalties can be a disadvantage to a team, athletes’ failure to follow rules can decrease the effectiveness of rules in reducing concussions.

2.4: Educational Programs on Concussions

There are currently multiple educational campaigns on methods to identify, diagnose, and manage concussions in sports. However, there is not much done on specific concussion prevention in regards to individual sports or hazardous situations. Three educational campaigns that attempt to address a variety of different topics regarding concussions in youth sports are the CDC’s “Heads Up: Concussions in Youth Sports”, the CPSC’s “Nine Innings of Brain Safety in Baseball”, and the SLI’s (Sports Legacy Institute) “Safer Soccer Initiative”.

The “Heads Up” initiative attempts to address the issue of concussions in youth sports primarily through the distribution of informative materials concerning the signs and symptoms of a concussion, particularly in a sport setting, with little regard to in-depth prevention. “Heads Up” disseminated much of its information through separate coach, parent, and player fact sheets, which described overall signs that the coaching staff should notice, symptoms that an athlete should report, and the course of action that should be taken if a concussion was suspected.

The initiative did include limited information on prevention in some sport-specific fact sheets for lacrosse, football, and soccer that advised athletes to follow coaches’ safety rules and the rules of the sport. Only the fact sheets of these three sports go into detail beyond simply stating that a concussion results from a bump, blow or jolt to the head. For example the fact sheet for lacrosse warns that falls, being struck in the head with a stick or ball, or players colliding could result in a concussion. The football fact sheet describes the recommended technique of keeping the head up while tackling. The lacrosse sheet included instructions on how to hit to avoid contact with an opponent’s head.

“Heads Up” does not circulate much information on specific gameplay situations that produce concussions within sports. Hence, it fails to maximize increased awareness and subsequent caution surrounding those situations (“Heads Up Concussion in Football,” 2008; “Heads Up Concussion Facts for Athletes, Lacrosse,” 2008; “Heads Up Concussion Facts for Parents, Lacrosse,” 2008; “Heads Up Concussion Facts for Coaches, Lacrosse,” 2008; “Heads Up Concussion in Soccer, Athletes,” 2008; “Heads Up Concussion in Soccer, Coaches,” 2008).

The CPSC’s “Nine Innings of Brain Safety in Baseball” pamphlet addresses the importance of having a properly fitted and well-conditioned helmet in baseball. It outlines through nine steps the importance of smarter play, how to find a helmet that is the right size, how a helmet is intended to be worn, proper care that should be taken for the helmet, and ultimately when and why a helmet must be replaced. This program was aimed more towards prevention than the “Heads Up” initiative. It briefly touches upon the importance of avoiding hits to the head but does not describe the specific gameplay situations in which hits to the head are most likely to happen (Commission, 2013).

In contrast to the programs just described, the “Safer Soccer Initiative” directly addresses a specific gameplay situation that is resulting in a high number of concussions in soccer: the program identifies the act of heading a ball or colliding with a player, obstacle, or ground in an attempt to head the ball as the cause of at least 30% of concussions in soccer. Furthermore, the program discusses the lasting effects of concussions and sub-concussive impacts on everyday life. Further differentiating itself from these other programs, the “Safer Soccer Initiative” goes beyond just attempting to raise awareness of concussion consequences to suggest a widespread policy change to eradicate this danger: do not allow children below the age of 14 to head the ball (Cantu *et al.*, 2014).

Despite the three programs being aimed at different concussion-related topics in youth sports, they all express one key point: the danger of ignorance regarding concussions. The National Athletic Trainers' Association states that the best way to address concussions in youth sports is through education of all parties involved (Broglia *et al.*, 2014). However, to educate everyone, the specific gameplay situations that produce concussion in each sport have to be identified.

2.5: Risk Assessments as a Basis for Education

In order to properly educate parents, athletes, and coaches about the risks involved in sports, the risks themselves must be identified and their significance determined. This determination may be accomplished through the process of risk assessment.

Proper risk assessment is reliant on the identification of hazards and the risks present due to exposure to these hazards. An outlining of the processes involved in risk assessment can be found in Arnold Schecter's *Dioxins and Health Including Other Persistent Organic Pollutants and Endocrine Disruptors*. This report shows how Schecter use universal methods of risk assessment to determine the risk presented by exposure to certain chemicals. These standard methods for risk assessment are defined in Schecter's evaluation as "hazard identification, dose response assessment [the drug specific form of consequence assessment], exposure assessment, and risk characterization" ("Dioxins," 2012, p 582). Hazard identification recognizes what increases the subject's risk. Schecter indicates that epidemiological data is useful for such analysis, when it is available ("Dioxins", 2012). Consequence assessment analyzes how exposure to a hazard affects the risk to the subjected population. Exposure assessment analyzes the extent of a population's exposure to the previously identified hazards. Schecter is careful to note that exposure is impossible to assess without making assumptions due to the complexity involved in

its assessment. Risk characterization is the end result of the assessment and is composed of an integration of the exposure and consequence assessment results (“Dioxins”, 2012).

A contemporary example of this risk assessment method is currently being used at Virginia Tech to determine the comparable risks among varying football helmets. They have named their approach the Summation of Tests for the Analysis of Risk (STAR) system and have followed many of the same risk assessment strategies outlined by Schechter in *Dioxins...*. Their system has been noted to be successful at determining concussion potential among various helmets. The assessment method used in the creation the STAR system addresses the number of head impacts a player can theoretically safely sustain before sustaining a concussion, which is a novel way to approach concussion risk (“Adult Football”, 2012). This approach received positive reactions from the public, with some noting that “ratings provide parents with valuable biomechanical data intended to help them make educated decisions about which helmet to purchase” (“2014 Virginia”, 2014, p 1). The quantitative assessment of concussion risk for each analyzed helmet was performed using equation 2.1.

$$STAR = \sum_{L=1}^4 \left(\sum_{H=1}^6 E(L, H) \bullet R(a) \right)$$

Using NOCSAE style tests with the following nomenclature:
 L = helmet location, four total: front, top, side (combined), and rear
 H = drop height, six total: 60", 48", 36", 24", 12", and lowest
 E = exposure (function of drop height), number of impacts at that drop height for that location a player may experience in one year
 R = Concussion injury risk (function of peak acceleration)
 a = peak resultant acceleration

Equation 2.1: STAR Equation from: www.sbes.vt.edu/pdf/STARMethodology2012.pdf

The STAR score was produced by multiplying together exposure and risk values determined for various test situations. Exposure values were a function of impact location (L) and the test drop height (H) and are intended to simulate how often a particular impact (based upon severity and location) can result in a concussion to an individual using the helmet. The risk values (R) were a function of the peak acceleration in the test, shown in equation 2.2 (“Adult Football,” 2012).

$Risk = \frac{1}{1 + e^{-(\alpha x + \beta)}}$	<p>Where x = peak resultant linear acceleration in g $\alpha = 0.0508$ $\beta = -9.8047$</p>
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*Equation 2.2: Risk Equation Used with STAR from:
www.sbes.vt.edu/pdf/STARMethodology2012.pdf*

The effectiveness of the risk assessments produced for by the STAR system is indicated in the accuracy of the system’s comparisons between the risks present between helmets. STAR risk assessment indicated that there would be a 54% difference between the concussion risks in two helmets; a later study published in the *Journal of Neuroscience* reported that the actual difference between the concussion occurrences in players using the two helmets was 53.9% (“2014 Virginia,” 2014, p 2). The widespread acceptance of this study indicates that a specifically targeted form of the general risk assessment process is deemed effective by the scientific community (“Dioxins”, 2012).

Chapter 3: Methodology

The goal of this project, conducted for the US Consumer Product Safety Commission, was to complete a risk assessment of youth sports that present a high occurrence of traumatic brain injuries, particularly concussions. From this assessment we identified major prevention methods and physical causes of concussions within each sport that, if addressed, have the potential to reduce injury occurrences. In order to achieve this goal we achieved the following objectives:

1. Identify the event(s) leading to concussions in youth sports.
2. Identify the relationship between prevention methods, and concussion occurrence within a sport.
3. Determine the potential for sustaining concussions in individual sports as well as the effect each physical cause has on this potential.

This chapter will introduce the strategies we developed to collect, examine, and analyze data involved in our project.

3.1: Physical Causes in Sports Which Lead to Concussions

In order to carry out our first objective we had to define which sports would be involved in our investigation. By analyzing the CDC's Weekly Morbidity and Mortality Report (WMMR) from October 2011, we obtained a list of youth sports that presented high numbers of concussion occurrences ("Nonfatal," 2011). This list was further refined into ten youth, team sports with relatively consistent environmental conditions throughout their sport. For instance, biking was excluded due to its variable "playing" surface and the addition of other external factors such as motor vehicles. Based on the WMMR, we decided to study baseball, basketball, boy's lacrosse,

field hockey, football, girl's lacrosse, ice hockey, soccer, softball, and wrestling. Soccer and basketball were assessed without regard to gender due to the similarity between rules of play and gameplay situations for both boys' and girls' teams.

Statistical data on the number of concussions sustained in these sports and how these concussions occurred was obtained through the Commission's NEISS database. This surveillance database gathers statistical information on all inpatient visits to emergency rooms throughout the United States. To become a NEISS-recognized hospital, the medical center must have a minimum of six emergency room beds and a 24-hour emergency department. The one-hundred hospitals which the Commission uses for this database record roughly 500,000 injury-related reports annually. Each report is assigned a weight to represent the nation as a whole based on the reporting hospital's size and annual number of patients ("NEISS," 2001).

From this surveillance database we extracted injury reports from January 1, 2009, through December 31, 2013, thus ensuring the inclusion of results for each traditional sport season over five years. We limited our data by patient age (ages 5 through 15) because organized sports typically start no earlier than age 5 and subjects over the age of 15 were not considered to be children within the scope of this project. Our data collection was further limited to include only the individual sports encompassed in our study.

We organized the collected NEISS reports by sport and cause of injury and then categorized them further by gender and age. We applied the case weights provided in the reports so that our data would accurately represent the nation as a whole. The "comments" section of the reports were used to determine the physical circumstances which led to the concussion. In this report, we call those physical circumstances "causes"; they are described in table 3.1. Case weights—which reflect the number of cases nationally that each report represents—were used to

determine the number of injuries associated with each cause of concussion ("NEISS," 2001). Using this process of data collection, we retrieved approximately 8,000 relevant injury records, a sample representing nearly 200,000 patients being treated for concussions. These reports were exported from the database into an Excel file to more easily manage and analyze the data as our work progressed.

Initial observation of the reports revealed trends in concussion causation that fell into four overall categories based on specific events, represented by the following table:

<u>Cause</u>	<u>Example</u>
Falls: Player’s head collided with the ground	Player tripped in basketball, hitting head on ground
Projectiles: The head was struck with an airborne object	Baseball player hit in the head by a pitched ball
Contact: The head was impacted by a person or object controlled by a person	Player hit helmets with another player
Stationary: Collisions with a stationary object	Player skated into the boards in hockey game

Table 3.1: Physical Causes and Examples

The categorization of events in sports into the four causes (as shown in Table 3.1) allowed us to analyze the general causes of concussions (without sport-specific events such as “struck by basketball”, “hit by lacrosse stick”, etc.) across all sports in our study, thus permitting comparisons across sports.

While this method of retrieving data proved effective, it was not always simple to decipher the cause of the concussion from the comments within the reports. Qualified medical practitioners who recorded the data rarely used the same language across all reports, sometimes making it difficult to determine the cause category into which a case fell. Of course, the limitations of statistical sampling mean that the cases from the one-hundred qualified hospitals in

this database are not a perfectly accurate representation the entire United States. For the sake of our study, these minimal errors are unlikely to affect our findings.

We distributed a survey—further described in section 3.2—to student athletes in order to assess the prevalence of each physical cause in the sports studied. Responses received to this survey were used to produce frequency ratings based on athletes' perceptions of the occurrence of specific situations within their sport. The athletes were asked to rank the occurrence of each event on a seven-point scale, with the lowest occurrence being "never" and highest representing "almost every play/every play". Unlike data retrieved from reports filed within emergency departments, this approach permitted a comparison between the numbers of concussion occurrences and the (perceived) frequency of situations which commonly led to them. While this tactic gathered the data we needed, it would have been better to survey a large sample size of youth sport participants. Nonetheless, this approach afforded an initial understanding of situational frequency.

3.2: Prevention Methods in Sports that Reduced Concussions

Research into the topic of concussions in youth sports distinguished four primary prevention methods: proper play; education; protection; and risk awareness. Proper play is identified as a participant's knowledge and ability to understand the rules of their respective sport and perform to an appropriate level. Education encompasses instruction in the sport as well as outreach programs designed to prevent concussions in the various sports, such as "Heads Up" or "Nine Innings of Brain Safety in Baseball". Protection refers to the sports' requirement of protective headwear and its effectiveness. Risk awareness is the identification of athlete's perceived risk of their sport both personally and overall in the sport. Each prevention method was evaluated on both its presence within the sport and its effect on concussion occurrence.

In order to determine how each of these prevention methods affected the rates of concussion and traumatic brain injury in athletes, we surveyed a conveniently available sample of Worcester Polytechnic Institute (WPI) student athletes. Our surveys were distributed to twelve teams through team email aliases; we also informed coaches and the Athletic Director of our intentions to survey these teams. Surveys were given to both men's and women's teams in soccer and basketball, adding two teams to the scope of our survey. We allotted a week and a half to collect our responses from each team, and sent an additional follow up email after the first week to collect the most data possible.

While college-aged athletes are out of the scope of this project, the questions were based on prevention methods whose effects should carry through to the youth level and were therefore applicable to our investigation. Furthermore, many of these athletes had no doubt been part of the same youth programs we were studying.

The survey questions covered the following general topic areas; each topic area is accompanied by a phrase summarizing its relationship to our project.

- Whether athletes believed concussions to occur more often in games or practices;
 - Recommendations for remediation
- Identify the athlete's personal concern with sustaining a concussion from their sport;
 - Risk Awareness
- Identify the athlete's perceived level of risk for concussion inherent within their sport;
 - Risk Awareness
- Whether athletes were instructed on proper techniques to use while playing their sport;
 - Proper Play
- Whether protective headwear is available or used within sports, if not required;

- Protection and recommendations for remediation
- Does a trained individual adjust protective headwear upon distribution, and does the athlete check fit prior to play;
 - Proper play
- Identify specific circumstances and positions which are more prone to experience concussions;
 - Recommendations
- Athlete’s awareness of outreach programs regarding concussions.
 - Education

We tailored the general topics in the surveys to be specific for each particular sport. The full set of surveys that we administered is included in Appendix B. By comparing the responses individually by sport, we identified how apparent each prevention method (listed earlier in this section) was in each sport, and we ultimately evaluated how effectively each method addressed the issue of concussions within the different sports.

A range of interviews collected expert evaluations of prevention programs as well as expert assessments of the effectiveness of various kinds of protective equipment. Semi-structured and open-ended interviews with a snowball sample of interviewees—where interviewees referred additional candidates for interviews based on their expertise—began with Richard McCallion of the CPSC. This strategy of interviewing allowed the interviewees to reflect on their perceptions of each piece of protective equipment’s effectiveness and overall quality.

3.3: Concussion Potential for Young Athletes

To analyze the data gathered, we developed a novel approach to determine the potential for concussions based on best practices of risk assessment described in chapter 2.5. Our

assessment took into consideration participation statistics, the percent each physical cause contributed to concussion occurrence by sport, and situational frequency ratings as identified through surveys of WPI athletes. This method allowed us to compare the sports in a way that evaluated each physical causes' contribution to overall concussion potential. The evaluations obtained through equation 3.1 provided a way to compare concussion potential across the ten sports in our study.

$W_F(R_F) + W_P(R_P) + W_C(R_C) + W_S(R_S) = \text{Concussion Potential of Sport A}$	
<p>W_F— weighting of falls for sport A W_P— weighting of projectiles for sport A W_C— weighting of contact for sport A W_S— weighting of stationary obj. for sport A</p>	<p>R_F— frequency of falls in sport A R_P— frequency of projectiles in sport A R_C— frequency of contact in sport A R_S— frequency of stationary obj. in sport A</p>

Equation 3.1: Physical Concussion Potential Calculation

Participation statistics were gathered from the National Federation of High School's yearly participation survey for 2013-14, as it was readily available and contained all ten sports in our investigation. While not representative of our population of youth sports, these statistics allowed us to estimate the relative fraction of young athletes playing each sport studied. The percent each physical cause contributed to each sport's concussion occurrence was determined by dividing the overall occurrence of each cause (fall, projectile, contact, and stationary objects) within each sport by the total number of concussions in that sport (acquired from the NEISS database). This number was then multiplied by the percent of participants (from NFHS) who sustained concussions (from NEISS), to determine the weighted coefficient in our equation. The survey participants' average responses to our question asking "how often certain gameplay situations happened in their sport", were used as each sport's frequency rating for each cause (fall, projectile, contact, and stationary objects).

By multiplying these two values (weighted coefficient and frequency rating) and summing for each cause in a given sport, as shown in equation 3.1, we determined the overall physical concussion potential for that sport. The potential obtained for each sport through this process was then compared across all sports to create a ranking of the sports involved in our study. The greatest contributing element to each score was easily identified by analyzing the equation used to rank each sport's potential for concussion. These findings are detailed in chapter four.

The prevention methods defined in section 3.2 were evaluated through a more holistic approach to determine their relation to concussion and traumatic brain injury rates for each sport. We identified common perceptions about the prevalence of these methods in each sport and determined which were least appropriately addressed, thereby presenting the greatest potential for concussion reduction.

Since these sports are inherently different, we are unable to justify the exact contribution of each and every prevention method to reducing the number of concussions. For instance, a basketball organization might interpret the same educational program differently than a football team who is required to follow strict guidelines, however both organizations still technically have a program to educate the participants, coaches, and parents. Therefore, after surveying sports teams, we were able to identify tendencies and patterns among the prevention methods of proper play, education, protection, and risk awareness. From this data we determined whether the method was present, effective, or needed to be adjusted to better accommodate a sport. Findings of this analysis are detailed in chapter four.

There were limitations of this process. Due to the lack of quantitative, definitive data on the relative effects of various prevention methods, our results are purely qualitative and only

useful in comparing the sport programs to each other. Another limitation was that situational frequency ratings were determined based on athletes' perceptions of the prevalence of the different causes within their sports and could have been more accurate given a larger sample size. Overall identification of possible avenues to reducing the number of concussions, a central purpose of this work, was unaffected by these shortcomings.

Chapter 4: Findings

Through analysis of concussion case reports from the NEISS database and surveys distributed to collegiate athletes in various sports, we have discovered how particular causes and preventative methods of the ten sports studied impact concussion potential and occurrence. This data was the basis for many conclusions made about the patterns of concussion occurrence and the concussion potential from playing each of the ten sports. Physical causes (falls, projectiles, contact, and stationary objects) determined through the concussion case reports were further analyzed to reveal specific gameplay situations that led to concussion. Survey responses were used to determine the effects of preventative methods including concussion education efforts, proper play instruction, protective headwear's effectiveness, and the perception of risk. These findings will provide the basis for our recommendations in chapter five.

4.1: NEISS Data Collection

CASE LIST - ALL FIELDS		12/1/2014	Page 4
[REDACTED]		COLLECTION DATE: 01/13/2013	CASE WEIGHT: 5.7324
TASK NO:	[REDACTED]	PRODUCT 1: 1279	ICE HOCKEY (ACTIVITY, APPAREL OR EQUIPMENT)
AGE: 10	[REDACTED]	PRODUCT 2: 0	NO SECOND PRODUCT INVOLVEMENT
SEX: 1	MALE	DISPOSITION: 1	1=TREATED & RELEASED, OR EXAMINED & RELEASED WITHOUT T
BODY PART: 75	HEAD	FMV: 0	NO FIRE OR NO FLAME/SMOKE SPREAD
DIAGNOSIS: 52	CONCUSSION	LOCATION: 9	SPORTS OR RECREATION PLACE
DIAG OTHER:		OCCUPAT: 2	INJURY NOT OCCUPATIONAL OR WORK-RELATED
RACE: 0	N.S.	INTENT: 0	UNINTENTIONAL OR NOT STATED
COMMENTS :			
10YOM WAS PLAYING ICE HOCKEY, PT FELL HITTING BACK OF HEAD ON ICE, C/O HA AND NECK PAIN, DX CONCUSSION TO HEAD			

Figure 4.1: Example of NEISS Report - Source: NEISS

We collected a sampling of over 8,000 individual case reports of concussions from the CPSC's NEISS database. This sampling resulted in an estimate of nearly 200,000 concussions experienced nationally among youth ages five to fifteen old and the overall distribution of

concussions across our sports is shown in table 4.1. This data sample included all cases of reported concussions from the year 2009 through the year 2013. An example NEISS report can be seen in figure 4.1.

Sport	Number of HS Participants	Number of Concussions	% Participants Sustaining Concussions
Football	1,109,300	62,023	5.59%
Basketball	979,800	31,754	3.24%
Soccer	747,900	26,436	3.53%
Baseball	472,600	12,329	2.61%
Softball	378,200	6,141	1.62%
Wrestling	272,900	6,316	2.31%
Boys Lax	90,700	2,667	2.94%
Girls Lax	68,800	934	1.36%
Field Hockey	63,100	754	1.19%
Ice Hockey	36,500	4,498	12.32%

Table 4.1: High School Participants and Number of Concussions - Source: NFHS & NEISS

From each report we retrieved patient’s age, gender, and the weight assigned to the case report. The case weights indicate the number of actual injuries each report represents in order for NEISS to be statistically representative of national injury occurrences (“NEISS,” 2001). Each report also contains a physician’s comments describing the circumstances of the injury with varying degrees of detail. Based on key terms used in the comments we identified which of our four specific causes each injury report represented:

- **Falls**
 - terms such as fell, trip, ground, mat, floor, fall, ice, and turf
- **Projectiles**
 - terms such as balls, pitch, fly ball, thrown, with baseball
- **Contact**
 - terms such as bat, elbow, collide, helmet-to-helmet, punch, kick and knee
- **Stationary objects**
 - terms such as wall, board, goal, post, net, fence and cage

For reports that were not categorized into a cause group by these key terms, we manually read through and either listed them as unknown cause or assigned a cause based on the comment. The amount each cause contributed to overall concussions in a sport was determined for each of the ten sports. However, we excluded the cases without a discernible cause from the calculations as they did not reveal any new information about the physical causes. Additionally, when concussion totals are referenced, unknowns were not included due to lack of relevance in distinguishing situational causation. The physical causes of concussions were further compared by age, gender, and overall occurrence.

Statistics for the participation in each of our analyzed sports were taken from the NFHS (National Federation of State High School Associations) athletics participation survey results for the 2013-14 year and extrapolated to represent a five-year span equal to that of our reports. Youth sports participation statistics differ greatly among various sources and therefore the data they presented was less reliable. Although data from the NFHS represents high school students it was the most standard, accurate data that covered all of our sports and was therefore used to represent general participation statistics. Figure 4.2 shows the number of overall concussions that occurred for the age range of 5-15 years old, in addition to the total participation for each sport, in the high school setting, both for a five-year time span.

It is important to notice that wrestling exhibits a higher number of concussions than softball, a sport with higher participation. Likewise, ice hockey has a greater concussion occurrence than the three sports preceding it based on participation.

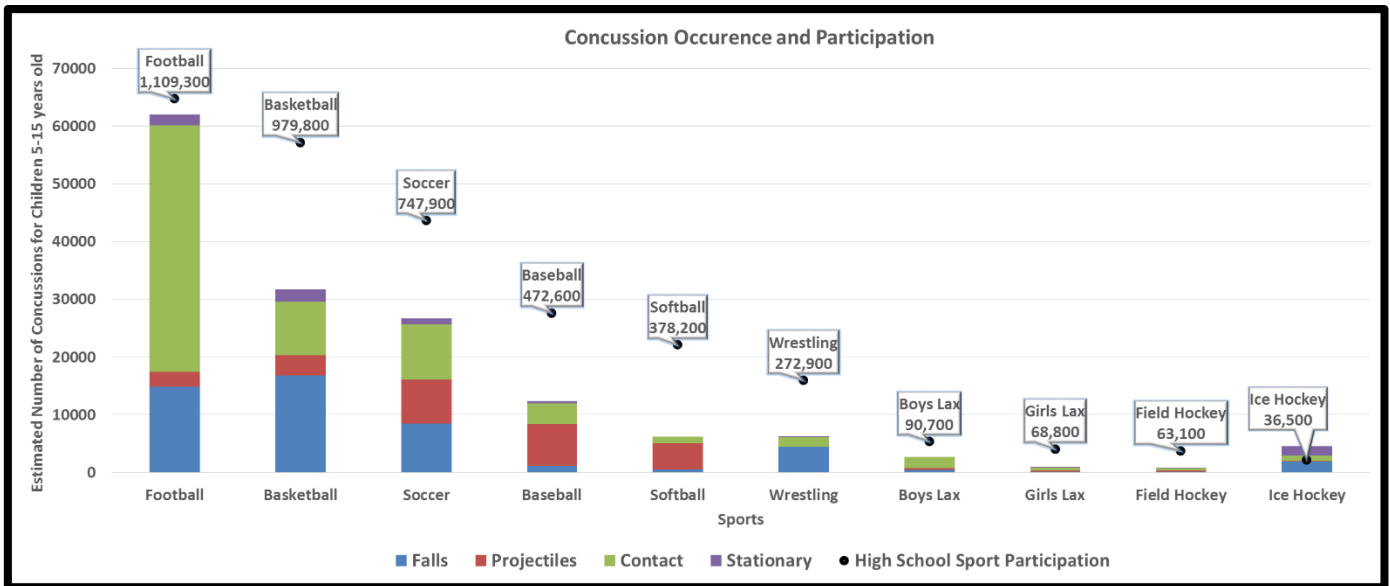


Figure 4.2: Concussion Occurrence by Cause and High School Participations - Source: NEISS & NFHS

4.2: Survey Data Collection Results

Our surveys were sent to twelve athletics teams at Worcester Polytechnic Institute, representing the ten sports in our investigation, with basketball and soccer being sent to both boys' and girls' teams. The main limitation of our surveying practice was that we surveyed college athletes at a selective Division III University; therefore, some economic or social groups may not have been represented in our surveys. Furthermore, these athletes likely participated in youth programs before doing so at the college level, experiences that may have led to more exposure to certain areas addressed in our survey, such as concussion education. This increased exposure to such education could have resulted in their survey results failing to reflect the educational awareness of all youth athletes.

A better approach to evaluating these topics would have been through direct contact with youth athletes, but due to time, ethical, and financial constraints this method proved to be unfeasible. However, we assumed that preventative methods of proper play, education, risk awareness, and protection are similar amongst the two age groups and therefore the data collected was applicable to patterns of concussion potential in youth sports.

Specific questions based on topics described in section 3.2 are listed in their entirety in Appendix B. The goals were to determine frequency of specific gameplay situations as well as athletes' understanding, knowledge, and perception of:

- **Education** – effectively conveying information to the public about concussion awareness and treatment, as well as the concussion potential of situations in sports. An example question on education from our surveys is “Are you aware of the CDC’s “Heads Up” Campaign and its efforts?”
- **Proper play** – the importance of athletes following implemented rules and techniques in their sport. An example question on proper play from our surveys is “Is there one particular position most likely to produce concussions? Why?”
- **Risk Awareness** – athletes’ perception of concussion potential for a certain sport or situation to be. An example question on risk awareness from our surveys is “On a scale of 1-5, how concerned are you about getting a concussion while playing your sport?”
- **Protection** - helmets and headgear available for athletes, and their requirement in some sports in addition to their upkeep and proper use. An example question on protective equipment from our surveys is “Do you make sure your helmet fits tightly enough and is positioned properly on your head before every use?”

Response rates and sample sizes for each survey are recorded in table 4.2, and should be referenced regarding sample size/response rates for overall graphs. The average response rate for our surveys was 52%. Low response percentages from sports such as men's soccer and men's basketball (around 30%) may have led to less conclusive results for their respective sports. The

sample sizes labeled with an asterisk were estimations using last year’s roster data or assessments based on approximate team size reported by athletes.

<i><u>Sport</u></i>	<i><u>Response Rate</u></i>	<i><u>Sample Size</u></i>
<i>Baseball</i>	36%	*39
<i>Women's Basketball</i>	72%	18
<i>Men's Basketball</i>	36%	21
<i>Men's Lacrosse</i>	57%	*30
<i>Field Hockey</i>	82%	22
<i>Football</i>	55%	89
<i>Women's Lacrosse</i>	39%	*18
<i>Ice Hockey</i>	40%	*35
<i>Women's Soccer</i>	52%	29
<i>Men's Soccer</i>	24%	33
<i>Softball</i>	80%	20
<i>Wrestling</i>	52%	25

Table 4.2: Survey Response Rate and Sample Size by Sport - Source: Surveys

4.2.1: Risk of Head Injury by Venue

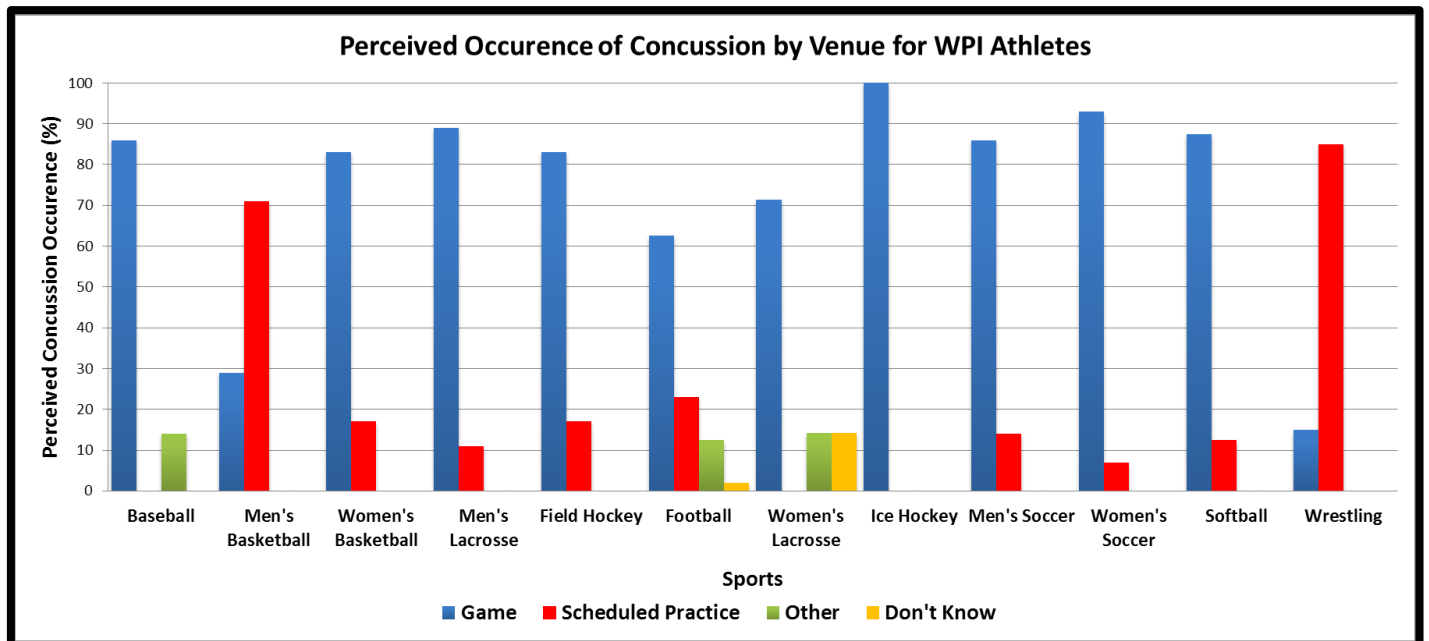


Figure 4.3: Perceived Occurrence of Concussions by Venue for WPI Athletes - Source: Survey

In almost all sports, games were reported as the most likely venue to sustain a concussion. We speculate that this relationship may be because of aggressive play and heightened competition within games. However, in men's basketball and wrestling the majority of athletes reported that concussions occurred most often during practices. These trends are shown in figure 4.3. Concussions may occur most in practices because of differences in coaching strategies or practice drills which may present a higher potential compared to other sports.

4.2.2: Helmet Fit, Condition, and Proper Use

In the helmeted sports we included in our study (baseball, men's lacrosse, football, ice hockey, and softball), it was clear from our data that football helmets received the most attention in regards to replacement protocol. All football players who responded to our survey reported that their helmets had been properly fitted by an equipment manager upon distribution to the athletes. The athletes' responses to whether or not their helmets were initially fitted properly by an equipment manager across all of our helmeted sports are represented in figure 4.4.

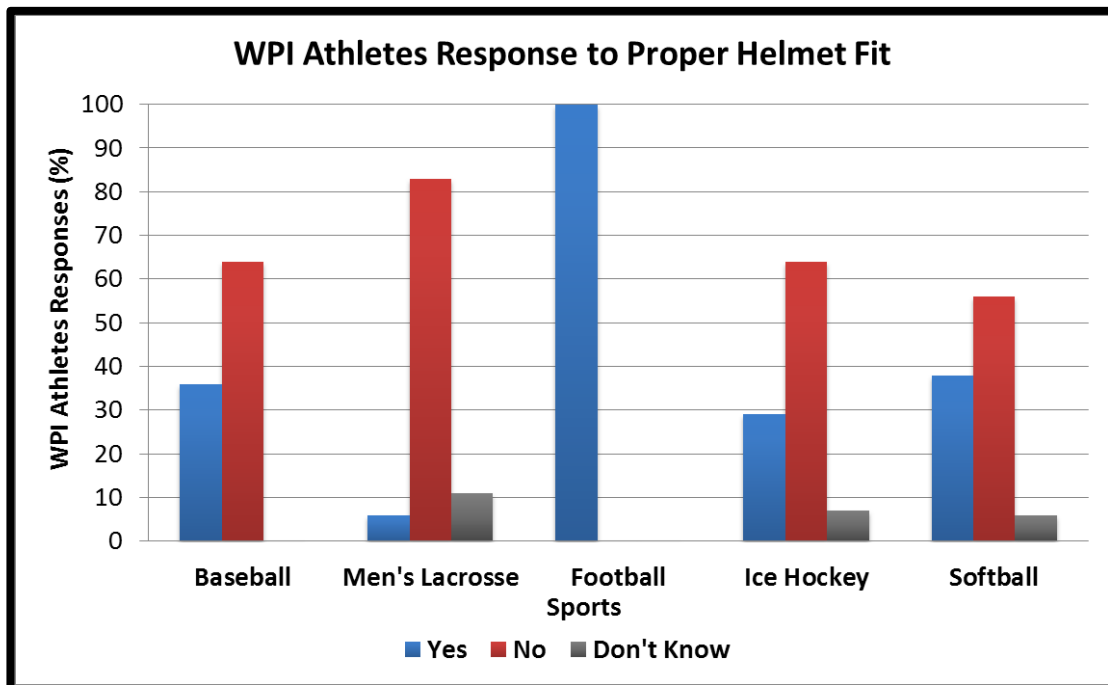


Figure 4.4: Proper Fit of Helmet among WPI Athletes - Source: Survey

Condition of helmets such as age and proper use are essential to the efficacy of their performance. WPI athletic teams' helmets were on average less than two years old. The only participants of a helmeted sport who reported their helmets were between three and six years old were those on the ice hockey team, a club sport whose helmets are individually owned. Since the school was not providing the helmets or overseeing their reconditioning or replacement, helmets may be maintained or renewed less frequently than those provided to varsity teams.

The only team in which more than half the players knew when their helmets were reconditioned or replaced was the football team. The players on the football team who knew when reconditioning took place, reported it occurring each year. Athletes from the men's lacrosse and softball teams also reported that they knew how often their helmets were reconditioned or replaced. However, the responses were inconsistent enough to show they did not have accurate information. These findings again show the extra emphasis placed on maintaining football helmets.

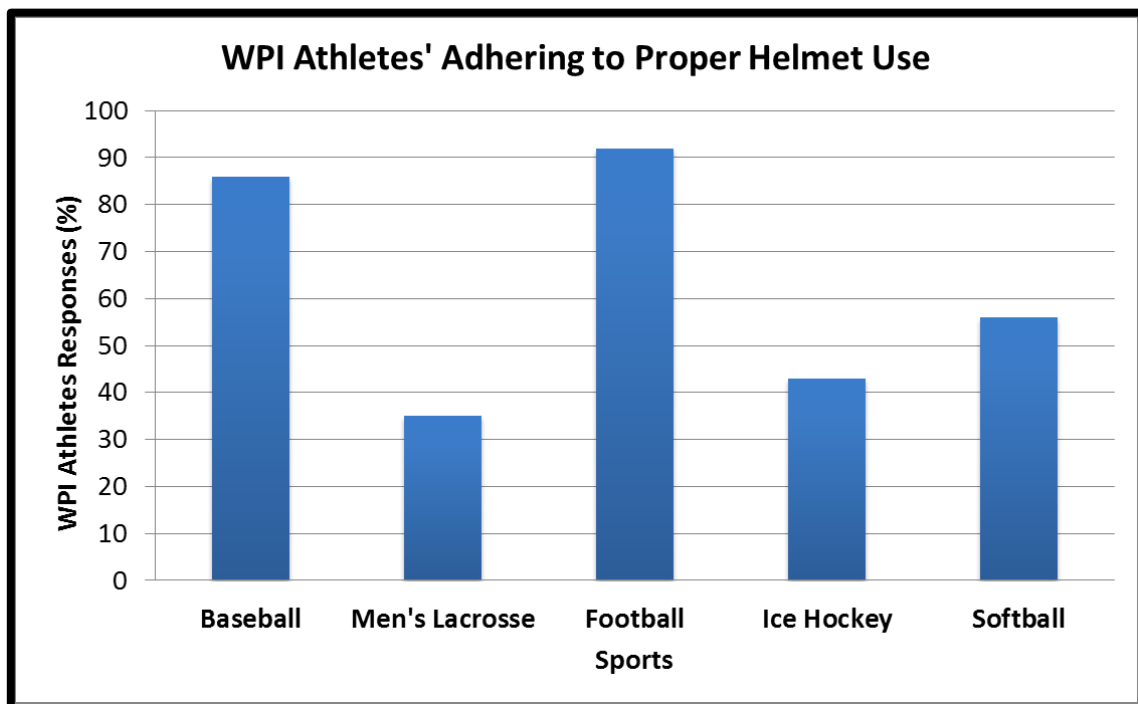


Figure 4.5: Proper Use of Helmets among WPI Athletes - Source: Survey

Proper use of helmets, such as ensuring that a helmet is positioned properly, is essential to ensuring that a helmet provides its full potential for protection. As shown in figure 4.5, above 80% of baseball and football players indicated that they adhere to proper helmet use by making sure their helmets are both positioned properly and inspected for damage prior to each use. In men’s lacrosse and ice hockey, however, only about 40% of the players reported such care. Proper use of helmets is important as it can increase their effectiveness and may lead to decreased concussion potential.

4.2.3: Educational Campaign Awareness

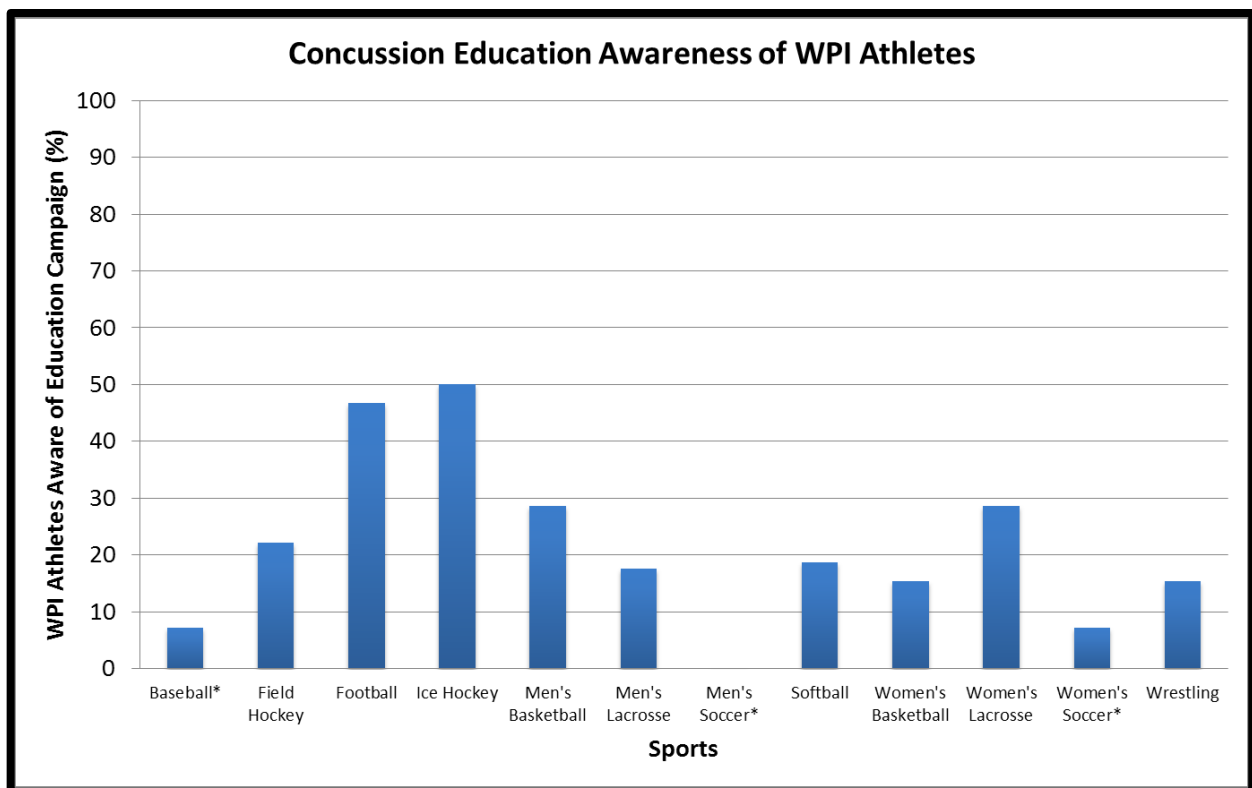


Figure 4.6: WPI Athletes' Awareness of Education Campaigns - Source: Survey

Throughout all the sports teams that were surveyed, we found an overall lack of knowledge of education programs. Programs such as the CDC’s “Heads Up” initiative attempted to educate athletes on concussion treatment and awareness. Each team’s reported awareness of concussion education programs is shown in figure 4.6. The team that demonstrated the greatest

awareness of concussion educational campaigns was the hockey team, followed closely by the football team with 50% and 47% of respondents, respectively, reporting that they were aware of campaigns such as “Heads Up”. This finding may be because players, parents, coaches, etc. within these two sports are more informed of the high rates of concussions within their sports.

4.2.4: Perceived Risk

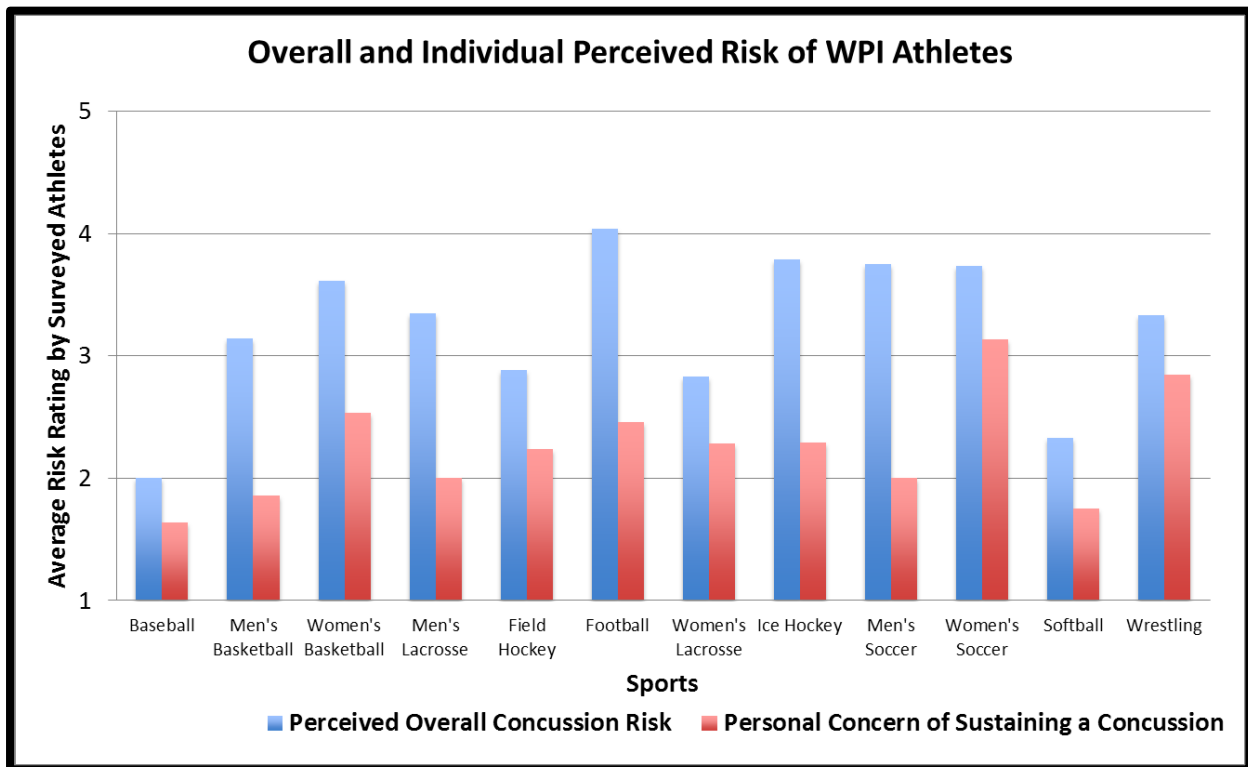


Figure 4.7: Comparison of WPI Athletes' Perception of Personal and Overall Risk - Source: Survey

One of the goals of our surveys was to ask each team’s players to estimate the potential for concussion in their sport. It is our opinion that if players believe their sport has a low potential for concussion, they may be less likely to follow suggestions for proper play or use helmets or other head protection correctly. In our surveys the athletes were asked to rank on a scale of 1 to 5—one representing no risk and five representing high-risk—of how concerned they were of personally sustaining a concussion while playing their sport and what they perceived the overall potential for concussion in their sport to be. Our survey results indicated that across all of

our sports, athletes perceived their own personal risk of sustaining a concussion to be less than that of their sport overall. The athletes' responses to these questions are shown in figure 4.7. The sports with the greatest gap appear to be football and ice hockey. We suspect this gap to be the result of historic attitudes about being injured in those sports.

Athletes were asked if there were any particular play situations which they perceived to produce more concussions, such as heading the ball in soccer or spearing in football. They were asked the same about positions in their sport; e.g., for the goalie in soccer or the catcher in baseball. Specific positions that respondents could select as the most dangerous can be found with the compiled survey questions in Appendix B. Some high-risk positions and situations are indicated in table 4.3 and are described in more detail within the sport-specific sections.

Sport	Position or Situation	Most Significant Response	Second-most Significant Response
Baseball	Situation	Hit by Pitch	Collisions in the Field or on the Base Path
	Position	Catcher	-
Basketball	Situation	Falling on Floor from Taking a Charge	-
	Position	-	-
Men's Lacrosse	Situation	Hit to the Head, Physical Contact	-
	Position	-	-
Field Hockey	Situation	Colliding with Another Player	Defense, When the Ball is Shot
	Position	-	-
Football	Situation	Helmet to Helmet Hits	Tackles
	Position	Running Backs/Linebackers	-
Women's Lacrosse	Situation	Stick Contact to Head	-
	Position	-	-
Ice Hockey	Situation	Hit Into Boards	Falls on Ice
	Position	-	-
Soccer	Situation	Head to Head Contact on Headers	-
	Position	Defenders	Goalie
Softball	Situation	Base Path Collision	-
	Position	Catcher	-
Wrestling	Situation	Head Hitting the Mat on Takedowns	-
	Position	-	-

Table 4.3: High-risk Positions and Situations by Sport - Source: Survey Traumatic Brain Injuries in Youth Sports

4.3: Concussion Potential Rating per Sport

The number of brain injuries occurring per cause in each sport, divided by the number of participating athletes from the NFHS’s data, was used to determine each cause’s weighting in the calculation of sports’ concussion potential. Each cause’s occurrence frequency rating in each sport was determined through questioning WPI athletes on particular situations present in their sports that correlate to our four physical causes, such as “How often is a batter hit by a pitch” relating to projectiles. Their responses ranged from 0 (never), to 6 (every play/at bat). The responses were then averaged to obtain the frequency ratings used in equation 3.1, and are shown in table 4.4 for each sport and cause.

Sport	Falls Rating	Projectiles Rating	Contact Rating	Stationary Rating
Football	5.88	3.53	5.88	0.92
Basketball	4.05	3.15	5.92	1.96
Soccer	4.20	4.77	5.44	1.52
Baseball	4.29	1.79	0.84	1.50
Softball	4.75	1.89	3.06	0.44
Wrestling	3.85	0.00	4.00	0.00
Boy's Lacrosse	4.29	2.94	4.53	1.59
Girl's Lacrosse	3.71	3.29	4.07	2.29
Field Hockey	2.78	1.89	3.06	0.44
Ice Hockey	4.07	1.93	3.64	5.29

Table 4.4: Frequency Ratings by Cause for Each Sport - Source: Survey

Situations involving contact and falls appeared frequently across the majority of our sports. They occur an average of “a few times every possession” in basketball, football, and slightly less often in soccer. Projectile situations generally occur less often than contact or falls, and the most infrequent situations overall were those involving stationary objects. An exception to this trend is shown in ice hockey, where player contact with the boards greatly increased the frequency of the stationary objects cause.

Using best practices for risk assessment as determined in section 2.5, we developed a system for identifying comparative concussion potential among our ten sports through equation 3.1, as shown in table 4.5.

<u>Ranking for Concussion Potential</u>	<u>Sport</u>
1	Ice Hockey
2	Football
3	Soccer
4	Basketball
5	Boy's Lacrosse
6	Wrestling
7	Girl's Lacrosse
8	Baseball
9	Softball
10	Field Hockey

Table 4.5: Ranking of Sports by Concussion Potential - Source: NEISS,

A more effective assessment may have been performed with more extensive data on youth athlete exposure in addition to more accurate situational occurrence information. The overall concussion potential for each sport was comprised of the summation of each cause's frequency ratings and the weighting values we determined for each cause in each sport. The weighting values were calculated by dividing the number of concussions in the sport (NEISS) by the number of participants in that sport (NFHS), then multiplying the resultant by the percentage of cause occurrence. The calculated scores for concussion potential of our top five sports as well as each cause's contribution to this evaluation is shown in figure 4.8. It was surprising that ice hockey presented the greatest potential for concussions as football currently receives the greatest amount of attention regarding these injuries and related incidents.

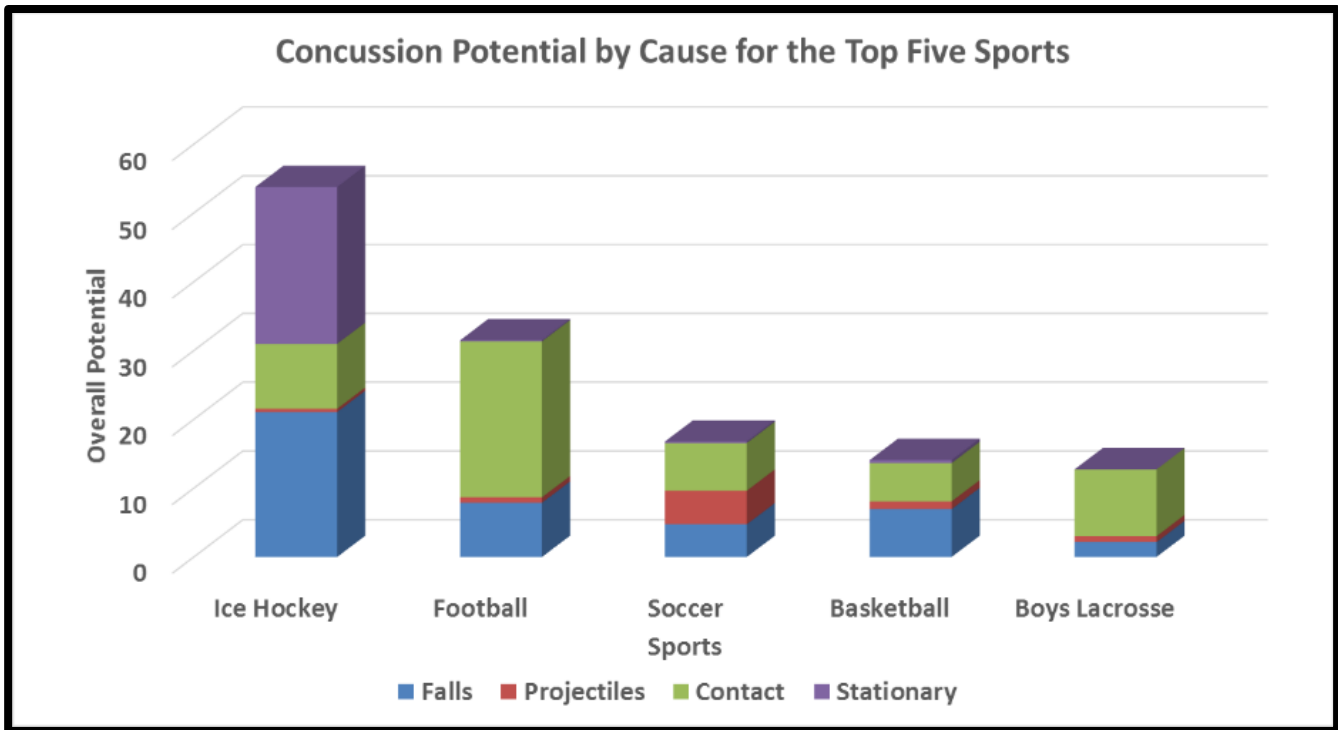


Figure 4.8: Concussion Potential by Cause for the Top Five Sports - Source: NEISS, NFHS, & Survey

An alternative way to analyze our data was to omit the situational frequency ratings from our overall evaluation. Much like our previous method, this approach would have been more accurate given complete exposure data for youth sports. The final ratio, a quotient of percent participation and percent concussion occurrence per sport, produced comparative values similar to our concussion potential. Table 4.6 shows both the rankings identified through this method (in descending order), as well as their ratios of concussion potential per cause. Evaluation through this approach disregarded the frequency of particular situations that occur during play but allowed us to draw explicitly defensible conclusions. An example of such a conclusion is that the comparative concussion potential presented from contact in football is about three times that presented in soccer.

	Overall	Falls	Projectiles	Contact	Stationary
Ice Hockey	2.77	1.16	0.06	0.58	0.97
Football	1.55	0.37	0.06	1.07	0.05
Soccer	0.92	0.29	0.27	0.33	0.04
Basketball	0.89	0.47	0.10	0.26	0.06
Baseball	0.70	0.06	0.41	0.20	0.02
Boys Lacrosse	0.69	0.12	0.07	0.50	0.00
Wrestling	0.62	0.44	0.00	0.16	0.02
Softball	0.46	0.04	0.34	0.08	0.00
Field Hockey	0.34	0.04	0.09	0.20	0.01
Girls Lacrosse	0.31	0.05	0.05	0.17	0.04

Table 4.6: Ratios between Participation and Concussion Occurrence - Source: NFHS and NEISS

4.4: Baseball Findings

We found that baseball presented a relatively low potential for concussion, placing eighth among our ten sports in table 4.5. As shown in figure 4.9 projectiles contributed significantly to the concussion occurrences in baseball (59%). Concussions due to projectiles include baseballs striking players in the head or face from pitches, fly balls, and line drive hits. These dangers are expected and are well known among athletes. However, there was an unexpectedly large presence of contact related concussions (29% of the total concussions for baseball). Players being hit with bats along with fielders' collisions with base runners comprised most of these injuries. The surprisingly frequent occurrence of bat-induced concussions was mostly a product of players' lack of attention while others were "warming up" to hit, resulting in being accidentally struck with a bat.

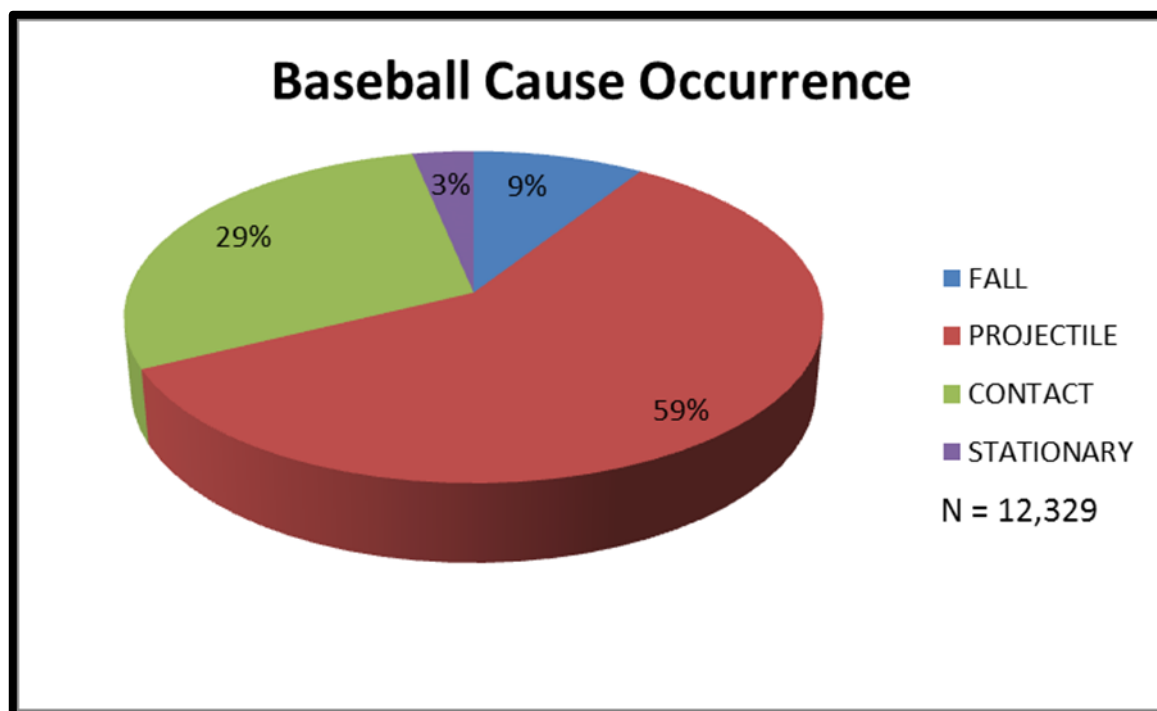


Figure 4.9: Baseball Concussion Cause Occurrence - Source: NEISS

When analyzing the preventative methods' effects on concussions within baseball, our most significant finding was that baseball players were generally unaware of the large number of concussion occurrences within their sport or their personal potential of sustaining a concussion. Our survey results determined that, on average, players believed baseball presented a low risk for concussions—corresponding to a 2 on our 5-point scale—and players' personal concern of sustaining a concussion was even lower—corresponding to a 1.64 on our 5-point scale. Figure 4.7 compares players' concern of sustaining a concussion compared to their perception of the general risk in baseball. This finding is concerning as baseball presented the fourth highest concussion occurrence among our sports. These finding indicates that there are a substantial number of concussions sustained each year in baseball that are not reflected in the perceptions of its athletes.

4.5: Basketball Findings

After gathering data, survey results, and participation statistics, basketball was established as the sport with the fourth highest potential for concussions, following ice hockey, football, and soccer. Contrary to initial predictions, the number of concussions in basketball was greater than all other sports except for football. Falls where players struck their heads on the floor contributed nearly half (53%) of all observed concussions as shown in figure 4.10.

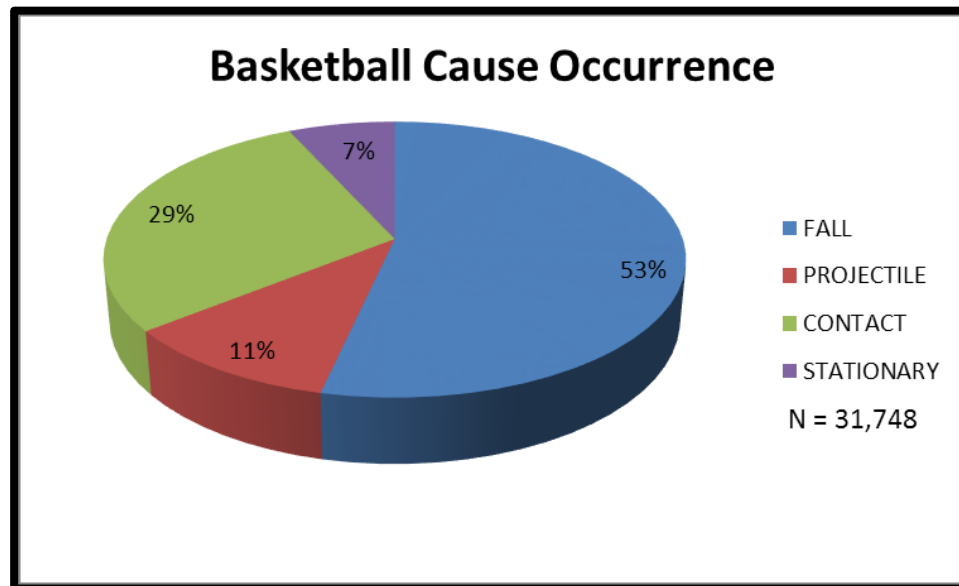


Figure 4.10: Basketball Concussion Cause Occurrence - Source: NEISS

Our survey responses reinforced that falls are a fairly common occurrence happening on average “a few times per quarter”. Specific situations that contributed heavily to this cause were players taking charges and players going up for a rebound as identified in the following comments presented in NEISS case reports:

- “15 [year old female] went to take a charge & fell on back of head during basketball game”
- “12 [year old male] was playing basketball, went up for rebound, & fell to floor, hitting back of head”

Although our results show that the most dangerous part of basketball is falling to the floor, whether due to contact or simply tripping, diving or slipping, it is important to take into account that this situation is a risk well known to the sport.

A more promising method of concussion reduction may be through a preventative method such as an education program. While many programs such as “Heads Up” show promise in reducing concussions, more than 70% of the athletes were unaware of the program and the material it discussed as shown in figure 4.6. Another possible method of limiting concussions is the use of currently optional equipment such as concussion headbands, pending proof of their effectiveness. While no players involved in our survey reported using these headbands, there are basketball players currently making use of them (“HALO,” 2014).

4.6: Boy’s Lacrosse Findings

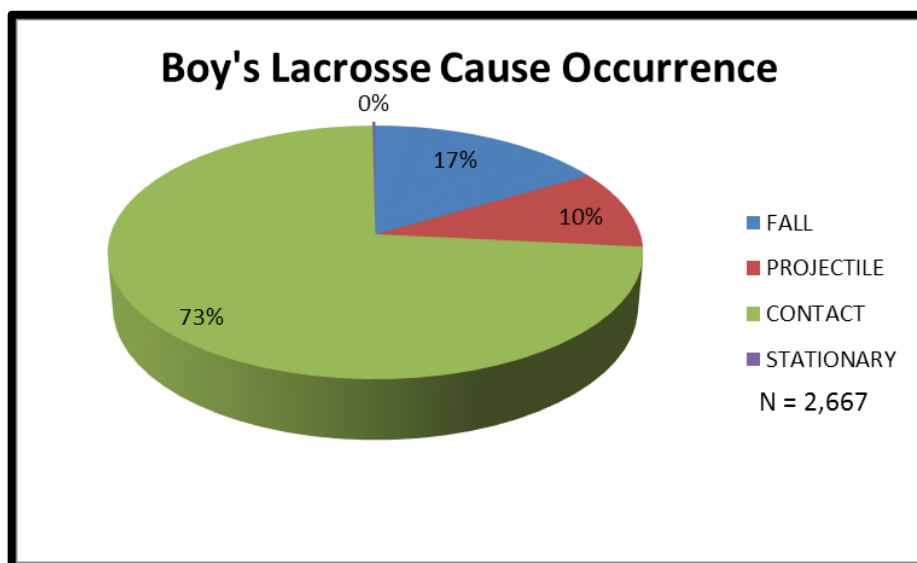


Figure 4.11: Boy's Lacrosse Concussion Cause Occurrence - Source: NEISS

Analysis of boy’s lacrosse found that it ranked fifth among our sports in concussion potential. Concussion occurrence in boy's lacrosse was dominated by the cause category of contact, making up more than 70% of concussions within the sport as shown in figure 4.11. This category was comprised of situations that arose from overly aggressive play, such as head-to-

head or stick-to-head contact. Contact presents the greatest potential for concussion by far with falls representing the next highest cause of concussions, accounting for a mere 17% of concussions.

The contact-related incidences we have identified, while illegal as per the rules of the sport, are still inherent due to the intensity of play. In an attempt to decrease the risk presented in this sport, all players are required to wear helmets. However, our survey responses demonstrated lack of a standard replacement policy in addition to the absence of guidelines for inspection prior to use. If helmets are not held to a standard that is equivalent to the need for protection within the sport, then their usefulness is severely limited. Additionally, we found that boy's lacrosse players are generally unaware of concussion education materials such as the "Heads Up" campaign as shown in figure 4.6.

4.7: Field Hockey Findings

The potential for concussions presented by field hockey was the lowest of all sports in our analysis. This sport was one of two in our study that represented less than 1,000 concussions over our five-year data. While a limited number of concussions occurred in the sport, contact was the greatest contributor, representing two-thirds of all concussions. A large portion of these occurrences were produced by collisions between players, specifically those resulting in head contact. Players leading with their heads while bending over and running with the ball was the most common situation which led to concussions, but that form of play is inherent the sport.

Concussions may be reduced in this sport by addressing the potential of projectile-related injury, which is responsible for roughly 30% of the concussions in field hockey, as shown in figure 4.12. A recurring situation regarding projectiles was penalty corners. During this on-field situation there are twice as many offensive players as there are defensive ones. The defensive players line up in the goal and charge out to guard the offensive players when the ball is put into

play. The offensive players are close enough to the goal that they can shoot the ball almost immediately after receiving it, increasing the risk of defensive players being hit by an offensive player's shot ("Penalty," 2014).

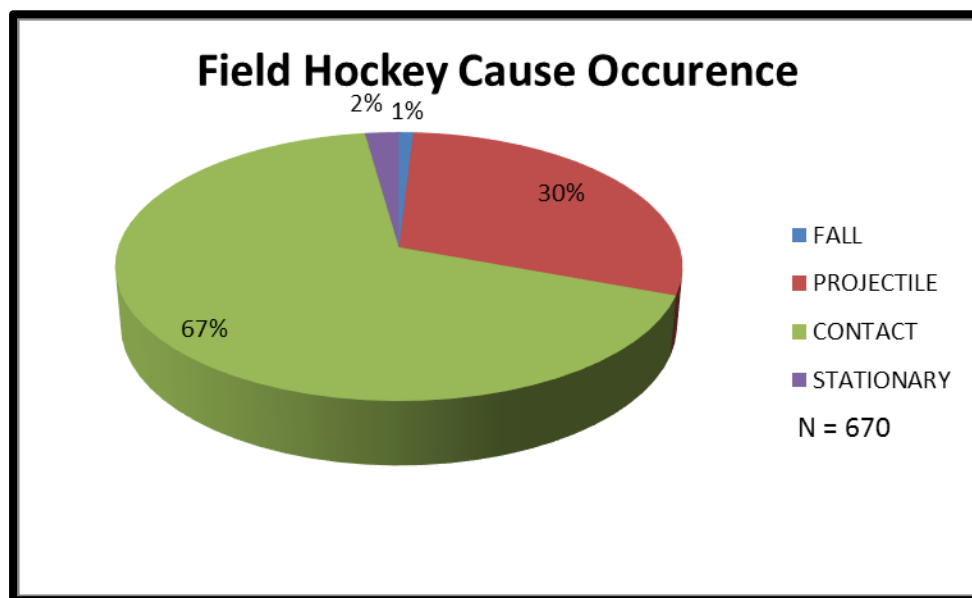


Figure 4.12: Field Hockey Concussion Cause Occurrence - Source: NEISS

Head protection is available and used by some during penalty corners. While the effectiveness of such products, like face masks, has not been definitively established, their use may be beneficial to reduce the prevalence of projectile-related concussions. Additionally, protective headgear may also reduce the potential of injuries presented through contact, such as player collisions that occur when two players are going for a ball. If found to be effective, such headgear could prove much more beneficial than the current required protective equipment of mouth guards and goggles.

4.8: Football Findings

Football, as determined through our analysis, presented the second greatest potential for concussions for youth athletes, as shown in table 4.5. This finding contradicted our initial assumptions regarding football as the public's attention and research's focus on the sport gave

the impression that it posed the greatest concussion potential among all sports. We found that nearly 70% of all concussions from football were from contact to the head, shown in figure 4.13, reinforcing previous work citing head-to-head contact as the leading contributor to risk of sustaining concussions. This problem is already widely recognized and work is currently being done to address it, such as the testing of helmets to evaluate their effectiveness by researchers and engineers at Virginia Tech ("Virginia," 2013).

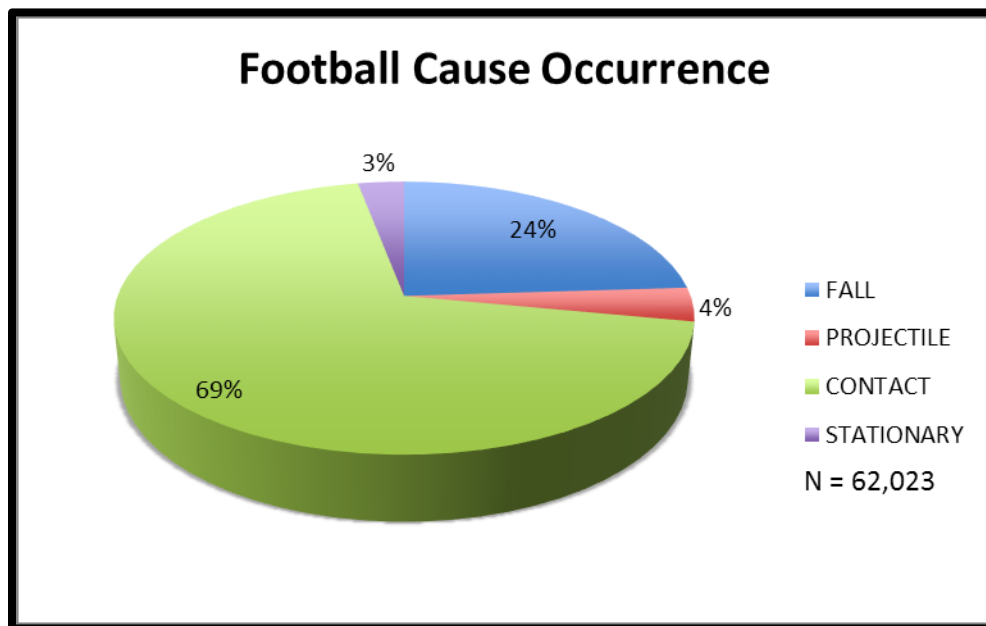


Figure 4.13: Football Concussion Cause Occurrence - Source: NEISS

In the case of concussions in football, some preventative methods may prove to have potential for the reduction of concussions. The preventative method which shows the most promise is emphasizing proper play to the athletes. Our surveys indicated that although the athletes were aware of how to correctly tackle or block, they sometimes used their head due to the physical advantage their helmets presented in stopping or obstructing their opponent. Furthermore, the idea of proper play should be stressed more within gameplay situations, as over 60% of survey respondents indicated that they observed concussions more in games than in scheduled or other types of practice as shown in figure 4.3. From these results, it is clear that the

unpredictability of game situations present a more dangerous environment than the predefined, predictable practice situations.

4.9: Girl's Lacrosse Findings

Accounting for less than one percent of the total concussion reports we collected, girl's lacrosse exhibited the third lowest potential for concussion in our study, as shown in table 4.5. However, the number of reported concussions was surprising for a “non-contact” sport, considering contact was the leading cause of concussion, accounting for about 55% of the total injuries, as shown in figure 4.14, and 61% of the sport's calculated potential for concussion evaluated through equation 3.1.

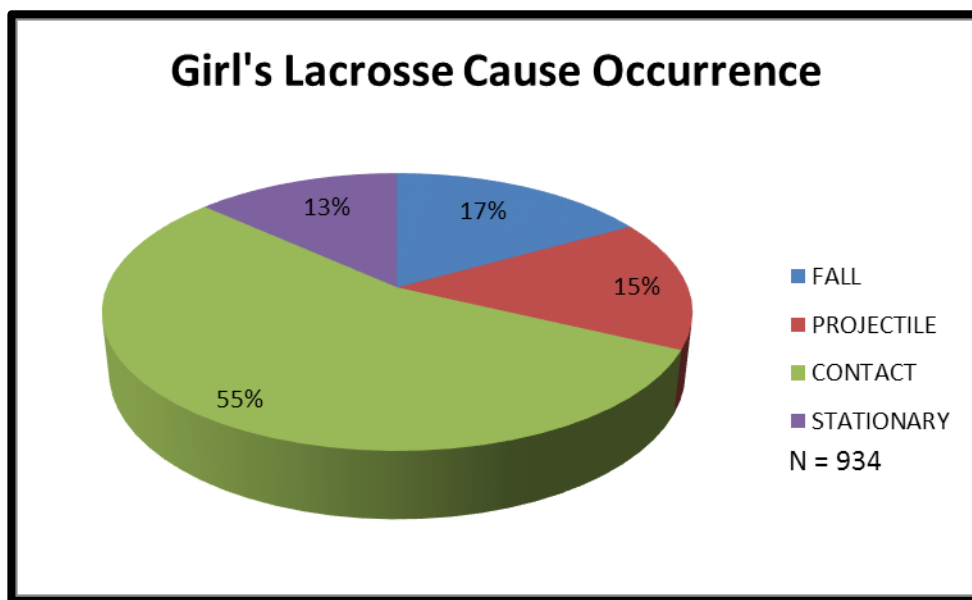


Figure 4.14: Girl's Lacrosse Concussion Cause Occurrence - Source: NEISS

Because contact is the leading cause of concussions, proper play to reduce illegal contact presented the greatest potential for reduction in concussions. Most contact induced concussions were due to stick-to-head contact, accounting for 68% of contact cases, with player-on-player collisions representing the remainder. Girl's lacrosse only allows stick-to-stick contact, however our athletes reported that high stick checking and player contact were a major reason for

concussions ("Stick," 2014). Evidently failure to adequately implement proper play techniques and enforce the rules of play have been identified as major contributors to concussion occurrence.

Protection also presented potential in reducing concussions in girl's lacrosse as players are required to wear mouth guards and goggles, but neither of these has been proven to protect against concussions (McCrary, 2001). No player who responded to our survey reported wearing any head protection (such as concussion headbands or helmets) other than the previously described required pieces, leaving them without protection against sustaining a concussion.

4.10: Ice hockey Findings

Ice Hockey, despite presenting the third lowest number of concussions among our ten sports as shown in table 4.1, was determined to present the highest potential for concussion in our study as shown in table 4.5. The NFHS data indicated that ice hockey had the fewest participants of the analyzed sports (36,500) and when related to the number of concussion occurrences obtained through the NEISS database it produced the highest participant-concussion ratio. Falls to the ice accounted for the most concussion occurrences followed closely by contacting a stationary object as shown in figure 4.15. However, when calculating the concussion potential of ice hockey, falls were determined to have a lower associated risk than head contact with a stationary object such as the boards or a goal post. The stationary object category represented about 35% of the concussion potential associated with ice hockey as determined by equation 3.1. This high cause occurrence is because players are hit into the boards "almost every play" whereas falling to the ice occurs closer to "a few times per period" as reported by our survey respondents.

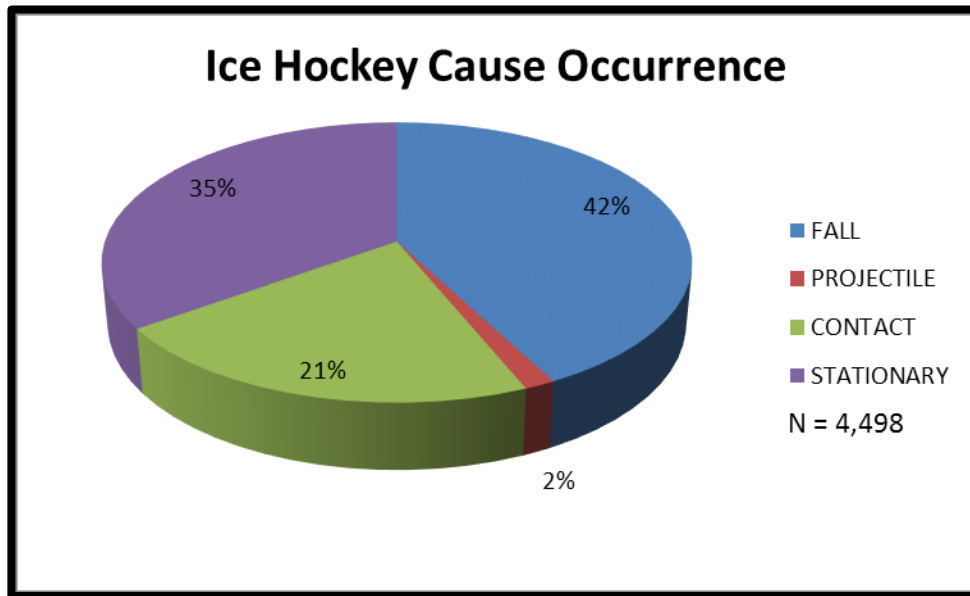


Figure 4.15: Ice Hockey Concussion Cause Occurrence - Source: NEISS

Other high-risk situations in hockey for sustaining concussions include player collisions and sticks hitting player's heads. These plays occur with a similar frequency as being checked into the boards, as at least one of the two is reported to occur almost every play, however, these situations account for a significantly lower percentage of concussions (21%), as shown in figure 4.15. These top three causes are typically associated with aggressive play, which is likely a reason that male athletes in hockey experience a far greater percentage of the reported concussions than females (94%, compared to 6%). In women's ice hockey, the rules of play are the same as men's, except that women are not allowed to check thus leading to less aggressive ("Rules," 2014).

In our evaluation of concussion potential and prevention in ice hockey, effectiveness of protective equipment presented the greatest opportunity for a reduction in concussions. As previously stated, most concussions in hockey occur from head contact with the ice from a fall, or from collisions with the boards. This finding reveals an obvious need for an effective helmet. Through our surveys, 64% of WPI ice hockey players indicated that their helmets were not fitted by an equipment manager, as shown in figure 4.4. Additionally, 57% did not inspect their

helmets for cracks or dents before every use to ensure their helmets would be most effective, as shown in figure 4.5. These two findings hint that players do not take proper use or maintenance of their helmets seriously enough, decreasing their effectiveness. All hockey players wear helmets in established youth leagues, however the amount of concussions sustained while playing hockey is still very high, showing potential for improvement regarding their effectiveness.

4.11: Soccer Findings

After evaluating concussion potential among our sports, soccer ranked third, as shown in table 4.5. The leading cause for concussions in soccer was contact, accounting for 36% of the total concussions shown in figure 4.16. Head-to-head contact when going up for headers and elbow-to-head contact during gameplay represented the largest amount of contact-related concussions.

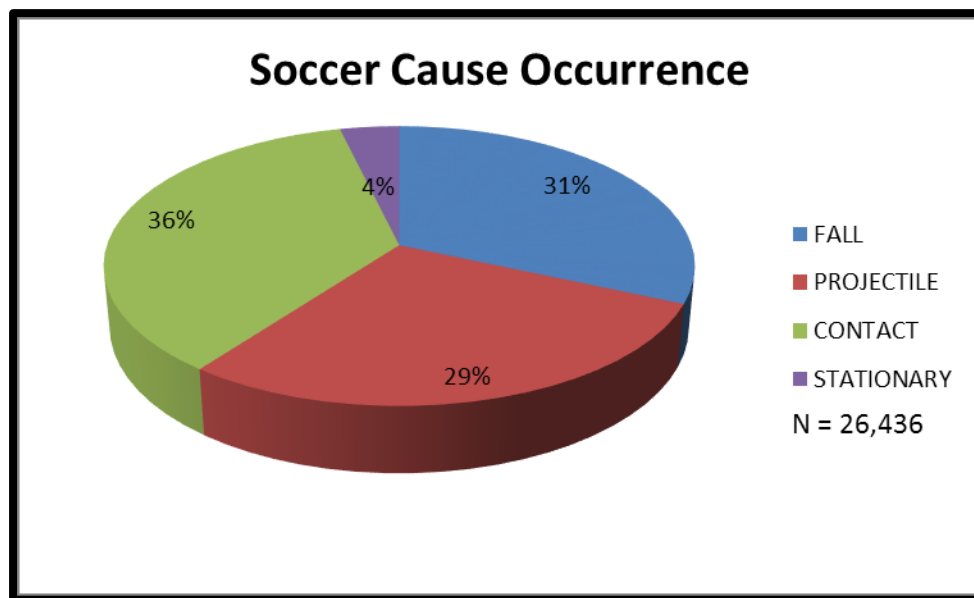


Figure 4.16: Soccer Concussion Cause Occurrence – Source: NEISS

Female athletes were found to experience a slightly greater proportion of the concussions in soccer than males as 66% of the reported soccer concussions were from females. Additionally, female players made up 61% of the entire projectile related injury reports. In our surveys, three

girls' soccer players reported that they wore concussion headbands. Our survey results also showed that the women's soccer team perceived that their personal risk of getting a concussion while playing soccer was a 3.13 on a scale from 1 to 5, while the men's soccer team rated their personal risk of getting a concussion a 2 on that same scale as shown in figure 4.7. Female athletes perceived that soccer presented a higher risk for concussion, possibly due to female soccer players having an evidently higher rate of concussions.

In soccer, proper play and protection present potential for a reduction in concussions. From our surveys, the question, "Which situation presented the greatest occurrence of concussions?" revealed overwhelmingly that "going up for a header" was the highest risk situation. Players could reduce the occurrence of this source of concussions by making sure they have enough space between them and another player before going up for the header. Protective equipment also showed potential for reducing concussions in soccer. The effectiveness of concussion headbands at reducing rates of concussions has not adequately been proven, but studies show that these headbands may provide some protection against concussions (Delany, 2008).

4.12: Softball Findings

Softball ranked second to last in our ranking of ten sports based on physical potential for concussions, shown in table 4.5. The relatively small number of concussions shown in table 4.1 were mostly due to projectiles which caused 73% of concussions in softball (figure 4.17). Fly balls, ground balls or line drives were identified through our surveys as happening "almost every inning" and resulted in a high frequency rating for projectiles. Another situation that was prevalent was the ball being thrown or pitched and hitting a base runner or batter in the head.

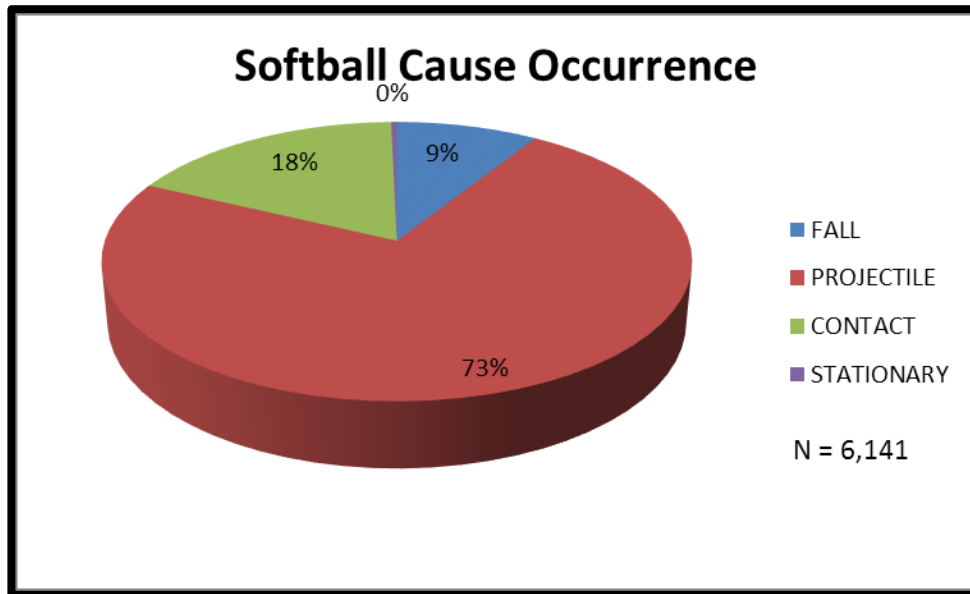


Figure 4.17: Softball Concussion Cause Occurrence - Source: NEISS

The use of effective protective equipment presented potential for a reduction in concussions. Softball is played on a smaller field than baseball, therefore fielders are closer to the batter and have to react more quickly to avoid being hit. The popularity of wearing face masks in the field is already on the rise in youth softball and high school programs which may lead to fewer concussions due to projectiles (Reynolds, 2011).

Proper play also shows potential for reducing the number of concussions. Projectiles were followed in percent cause occurrence by contact and falls shown in figure 4.17. Sliding or diving into bases happens frequently in softball, as 56% of surveyed softball players reported that this event occurs "a few times every half inning" as shown in table 4.4. Responses to high-risk positions or situations in the survey also indicated that a collision at the plate presented a high potential for sustaining concussions, as shown table 4.3. Teaching youth players how to properly slide and dive, as well as teaching how to legally defend the base or plate, may lead to a reduced number of concussions caused by this situation.

4.13: Wrestling Findings

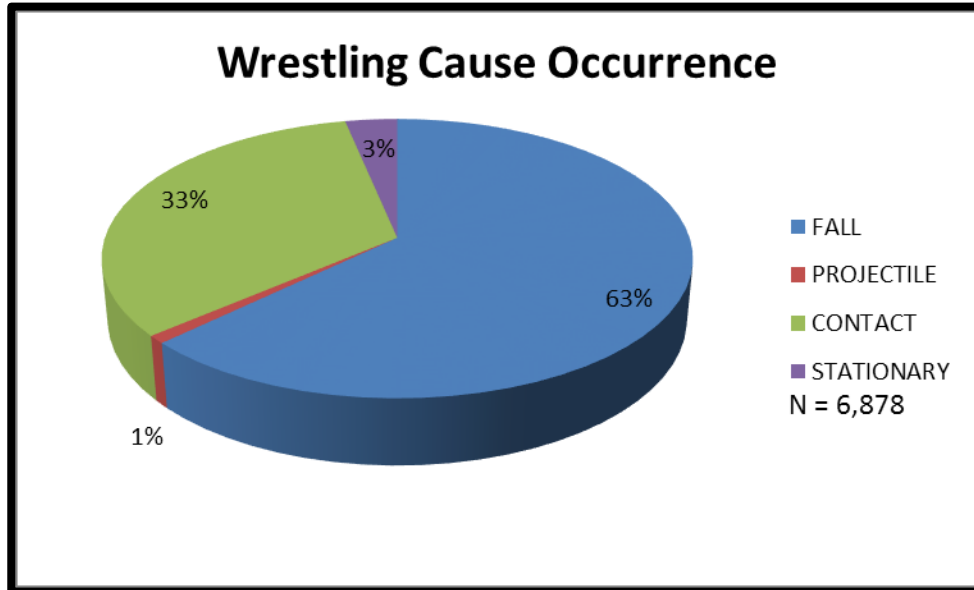


Figure 4.18: Wrestling Concussion Cause Occurrence - Source: NEISS

Wrestling was sixth on our physical concussion potential ranking as shown in table 4.5. Wrestlers' heads hitting against the mat, mostly caused by participants being thrown, dropped, or slammed, comprised the “falls” cause category and 63% of all concussions shown in figure 4.18. Participant responses to our surveys indicated that player’s heads were brought into contact with the mat “many times per match”. Examples of this situation in the comments section of a couple injury reports were:

- *"13 [year old male] at wrestling match, slammed down by opponent, hit forehead,"*
- *"12 [year old male] was wrestling and was dropped on head."*

Competitors being hit by knees, elbows, or other body parts comprised the next largest cause of concussions, contact, which represents 33% of total concussions as shown in figure 4.18.

Protective equipment presents potential for a reduction in concussions as wrestlers already wear headgear that is designed to protect athlete’s ears from damage, not against head injuries. Just over two thirds of wrestlers we surveyed confirmed that this headgear did not

protect against concussions, as shown in Appendix C. Which is a problem because the majority of concussions in wrestling came from players being hit into the mat and may be addressed through more protective headgear.

Chapter 5: Conclusions and Recommendations

Based on our findings from the previous chapter, we provide a set of recommendations intended to partially address the problem of concussions in youth sports. As varying levels of research and action have been carried out to reduce these injuries, our project was undertaken as a new approach to evaluate data holistically across sports in a way that would lead us to recognize patterns and trends of concussion occurrence. The following recommendations address a multitude of findings, some of the most significant include: education, proper play, protective equipment, and situational occurrences within sports.

5.1: Concussion Reporting Protocol

We recommend the Commission improve the collection of relevant details of injuries reported at NEISS hospitals.

Much of our work to address TBI and concussions in youth sports made heavy use of NEISS case reports as identified in figure 4.1. The reports, filled out by qualified physicians, portrayed many useful pieces of information such as gender, age, diagnosis, and case weight, as described in section 3.1. However, our project made extensive use of the “Comments” sections of the reports. This area allowed the physicians freedom to identify the situation responsible for their patients injury. The detail of this section varied on its usefulness as juxtaposed in the following examples:

- Helpful report: “9 [year old male] [patient] was in lacrosse game when ball was thrown[,] hit to forehead[,] was wearing a helmet. [Diagnosis concussion]”
- Not helpful report: “player hit head while playing soccer,”

The second report failed to provide an identifiable cause. Furthermore, the lack of detail in the latter report was present across approximately 23% of the total concussion reports (shown in

Appendix C) and led to the exclusion of such reports from our assessment, possibly biasing our results.

If more specific situations for the causes of concussions (examples shown in section 4.2) were known, the NEISS reporting system could be adjusted to be much more effective for researchers. Additional information regarding venue of the injury (game, practice, etc.) and protective equipment, such as “was it used?” and “what brand?” would also be helpful for the CPSC.

5.2: Method for Assessing Sport’s Risk

We recommend the Commission work to create a consistent method for assessing the risks within youth sports.

The main goal of our project was to assess the potential of sustaining a concussion in select sports. Through an experimental approach to analyze physical causes (as defined in 3.3) we established concussion occurrence breakdowns by cause. Our novel approach was a function of sport-by-sport concussion occurrence, high school participation data, and situational frequency ratings (as defined in 3.3). Due to time and financial limitations some of our data collection methods were less than ideal for developing concrete conclusions. For example, we used high school participation as a surrogate for accurate exposure rates of youth athletes, thus limiting the validity of our approach. Additionally, more precise information obtained through recommendation 5.1 and an increased sample sizes for a survey of participants in youths sports could have bolstered the validity of our results. The inclusion of these factors in a longer and more comprehensive study could produce an accurate standard evaluation method for concussion potential or the potential of any general injury within sports. Such a method would provide better background information on which to effect change.

5.3: Research Hockey Safety

We recommend that the Commission further study opportunities to prevent concussions in ice hockey.

Ice hockey led all of our sports in concussion potential, as well as ratio of concussion occurrence to participation, as shown in tables 4.5 and 4.6 respectively. This result can be attributed to the non-proportional relationship between participation and number of concussions compared to our other sports, shown in table 4.1. These results indicate a significant need for the reduction of concussions sustained in this sport.

One potential approach incorporates helmets and their protective effectiveness. Through our surveys, athletes indicated a lack of care and attention to the proper use and fit of helmets, shown in figures 4.4 and 4.5 respectively. While not relating to actual play, misuse of helmets, including proper positioning and inspection prior to use, can lead to an increased risk for concussions (“Which,” 2010). However, even if hockey helmets are used correctly, their effectiveness at protecting the user from concussions is minimal (██████████¹, personal communication, December 10, 2014). Further research into the effects of proper use, fit, and the actual protection provided by helmets is advised to the CPSC and shows potential for a reduction in concussion occurrence.

Another approach to reducing concussions in this high impact and velocity sport is through education on proper play and high-risk situations presented to athletes. Collisions with stationary objects (aka “the boards”) and contact with other players contribute to more than half of the potential for concussions determined through equation 3.1. Both of these situations have been identified as happening at least “a few times per shift” by WPI athletes, shown in table 4.4. While athletes are aware of these situations, which produce almost two-thirds of total concussions in hockey, our research showed that the players perceived hockey to have a lower

risk than 70% of our sports as indicated in figure 4.7. Effective communication of the risks of prevalent situations and possibly how to avoid them shows potential for a reduction in concussions for this sport.

5.4: Public Awareness

We recommend that the Commission, perhaps in collaboration with other agencies or groups, conduct further research into public awareness of high-risk situations and overall concussion risk present in individual sports.

Our surveys indicated a lack of awareness of both educational programs (no more than 50% in any of the sports) and risk presented in their sports, shown in figures 4.6 and 4.7 respectively. The risk awareness determined in each sport also showed that players generally perceived their personal risk of sustaining a concussion to be lower than the risk in their sport. As there is not yet enough data to confirm these problems among the entire population of athletes, we recommend that the Commission conduct research into the public's awareness of information regarding concussions; such as the potential for concussions in specific sports (shown in table 4.5) and how to properly fit and use helmets, shown as needing improvement respectively in figures 4.4 and 4.5. The results of the research into public awareness can inform the CPSC, and other involved organizations, of gaps in the public's knowledge regarding concussions that may be addressed in future educational campaigns.

The need for further research into venues (games, practices, etc.), positions, and situations (which demonstrated higher perceptions of occurrence of concussions) is indicated in our data. Some of the situations players believed to produce higher risks of concussions are already illegal during play, such as collisions in girl's lacrosse and charges in basketball. We therefore recommend that the CPSC, in conjunction with other organizations such as youth sport administrative bodies, perform an investigation into the effectiveness of instruction or alternative

methods of education intended to reduce the frequency with which players engage in improper play as well as the effect that such a reduction might actually have on concussion occurrence.

5.5: Helmet lifespan

We recommend that the Commission, in collaboration with ASTM and other SDO’s, study the effects of age on helmet performance.

The inconsistency of helmet replacement and reconditioning practices (see Appendix C, indicates the need for research into the effects of helmet lifespan on their performance. Helmets that are old or not properly reconditioned are likely to be less effective in absorbing concussion-causing impacts (“Rawlings,” 2012). We advise further research by the CPSC or other concerned organizations to determine the effects of age on helmets. If research reveals that the extended lifespan of helmets significantly reduces their protection, we recommend standards for replacement or reconditioning, similar to those in football, be created in other sports.

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¹The identity of the interviewee redacted throughout this document has been withheld pending resolution of a possible conflict of interest.

Appendix A: Return to Play Management

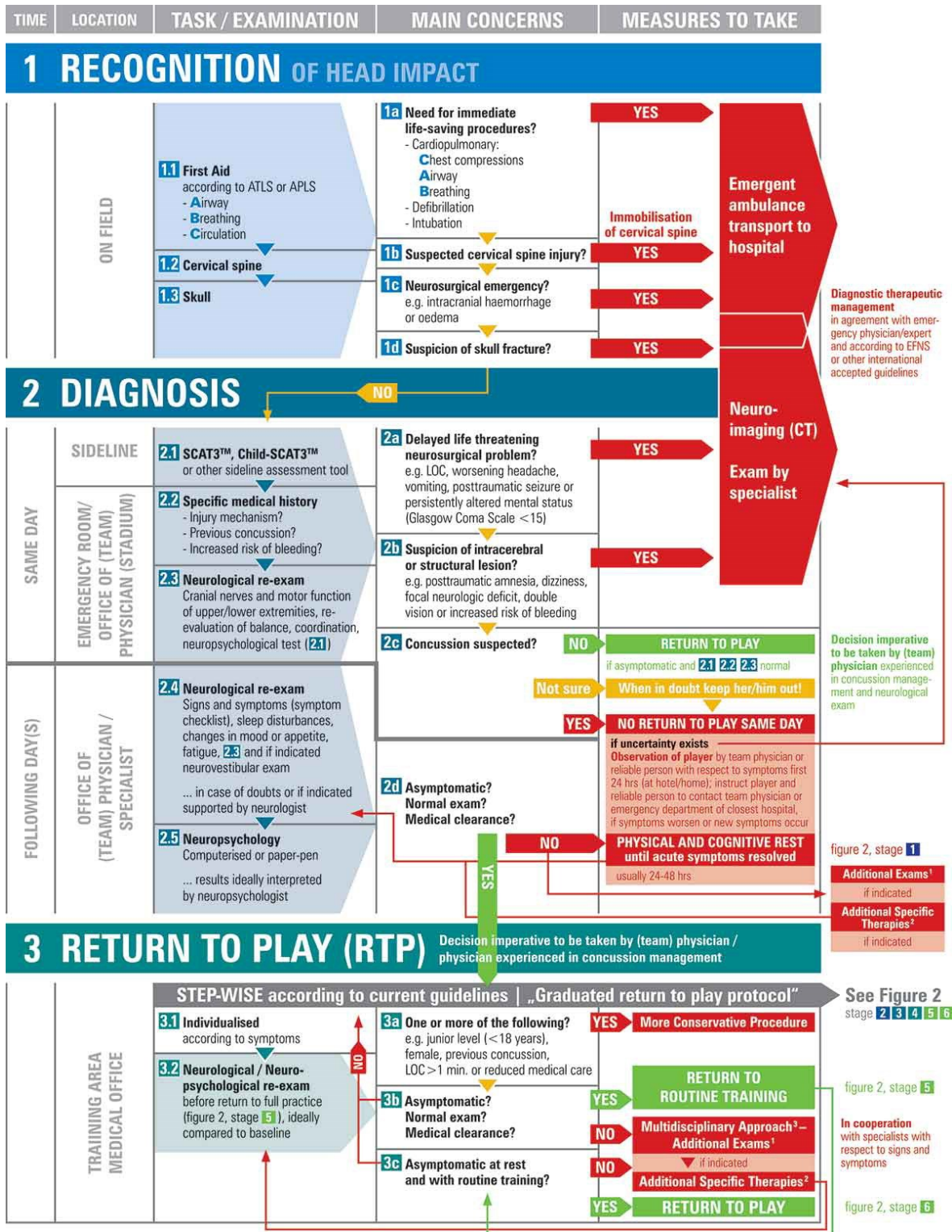


Figure 1: An example of return-to-play procedure following an athlete sustaining a concussion – Source: (Feddermann-Demont, Straumann, & Dvořák, 2014)

Appendix B: Survey Questions

To determine the frequency of physical situations that cause concussions as well as to understand the preventative methods of sports that contribute to concussion risk, surveys were sent out to twelve WPI athletic teams (soccer and basketball were split into men's and women's). Below are the questions included in those surveys.

Baseball Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times every 2-3 innings	A few times every half inning	Almost every play / every play
Batter hit by pitch	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player hit by line drive or fly ball	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player gets hit by bat	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player collisions on the base paths or in the field	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players run into the fence or other stationary object	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player slides or dives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. When you received your helmet was it fitted correctly by an equipment manager?

- Yes
- No
- Don't know

4. Do you make sure your helmet fits tightly enough and is positioned properly on your head before every use?

- Yes
- No
- Don't know

5. How old is your helmet?

(Drop down options here included: "0-2 years", "3-6 years", "7-9 years", and "10+ years").

6. Do you know how often team helmets are reconditioned or replaced?

- Yes
- No

If so, how often?

7. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: hit by pitch, base path collision)

8. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Pitcher", "Catcher", "Infielder", "Outfielder", "Batter", "Base Runner", "Other", and "No particular position").

Why?

9. Please select a rating to answer the questions below.

1 (no concern / no risk) 2 (low risk) 3 (neutral / somewhat low risk) 4 (somewhat high-risk) 5 (very concerned / high-risk)

On a scale of 1-5 how concerned are you about getting a concussion while playing your sport?

On a scale of 1-5 how much of a concussion risk you think there is in your sport?

10. Are you aware of the CPSC's "9 Innings of Brain Safety in Baseball" program and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

Basketball Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times every quarter	A few times every possession	Almost every play / every play
Player falls onto the court	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players contact each other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players get hit with the basketball	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players run into the wall, hoop stanchion, or any other stationary objects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. Have you received any instruction on concussion safety?

- Yes
- No
- Don't know

4. Do you wear any optional protective equipment for your head?

- Yes
- No

If so, what is it?

5. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: falls, hit by basketball from pass)

6. Is there one particular position most likely to produce concussions?

(Drop down options here include: "Guards", "Forwards", "Centers", "Other", and "No particular position").

Why?

7. On a scale of 1-5 how concerned are you about getting a concussion while playing your sport?

(Drop down options here include: "1 (no concern)", "2", "3 (neutral)", "4", and "5 (very concerned)").

8. Rate on a scale of 1-5 how much of a concussion risk you think there is in your sport.

(Drop down options here include: "1 (no risk)", "2 (low risk)", "3 (somewhat low risk)", "4 (somewhat high-risk)", and "5 (high-risk)").

9. Are you aware of the CDC's "Heads Up" campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

(Basketball survey was duplicated and sent to both the women's basketball team and the men's basketball team)

Men's Lacrosse Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times per quarter	A few times every possession	Almost every play / every play
Players check each other high	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player falls on ground	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players collide with each other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players are hit by ball above waist	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players are hit by another player's stick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players collide with goals or other stationary objects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. When you received your helmet was it fitted correctly by an equipment manager?

- Yes
- No
- Don't know

4. Do you make sure your helmet fits properly and is not dented or cracked before every use?

- Yes
- No
- Don't know

5. How old is your helmet?

(Drop down options here included: "0-2 years", "3-6 years", "7-9 years", and "10+ years").

6. Do you know how often team helmets are reconditioned or replaced?

- Yes
- No

If so, how often?

7. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: hit by another player's stick)

8. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Defenseemen", "Midfielder", "Attackmen", "Goalie", "Other", and "No particular position").

Why?

9. Please select a rating to answer the questions below.

- | | | | | | |
|--|-----------------------------|--------------|---------------------------------------|---------------------------|--------------------------------------|
| | 1 (no concern /
no risk) | 2 (low risk) | 3 (neutral /
somewhat low
risk) | 4 (somewhat
high-risk) | 5 (very
concerned /
high-risk) |
|--|-----------------------------|--------------|---------------------------------------|---------------------------|--------------------------------------|

On a scale of 1-5
how concerned
are you about
getting a
concussion while
playing your
sport?

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|

On a scale of 1-5
how much of a

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|

1 (no concern / no risk) 2 (low risk) 3 (neutral / somewhat low risk) 4 (somewhat high-risk) 5 (very concerned / high-risk)

concussion risk
you think there is
in your sport?

10. Are you aware of the CDC's "Heads Up" campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

Field Hockey Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times per half	A few times every possession	Almost every play / every play
Player falls to the ground	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player gets hit by another player's stick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player gets hit with the ball above the waist	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player runs into the goal post/stationary object	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players contact one another	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. Have you received any instruction on concussion safety?

- Yes
- No
- Don't know

4. Do you wear any protective equipment for your head?

- Yes
- No

If so, what is it?

5. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: falling when fighting another player for the ball)

6. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Forwards", "Midfielders", "Fullbacks", "Goalie", "Other", and "No particular position").

Why?

7. On a scale of 1-5 how concerned are you about getting a concussion while playing your sport?

(Drop down options here included: "1 (no concern)", "2", "3 (neutral)", "4", and "5 (very concerned)").

8. Rate on a scale of 1-5 how much of a concussion risk you think there is in your sport.

(Drop down options here included: "1 (no risk)", "2 (low risk)", "3 (somewhat low risk)", "4 (somewhat high-risk)", and "5 (high-risk)").

9. Are you aware of the CDC's "Heads Up" campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

Football Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times every quarter	A few times per possession	Almost every play / every play
Players contact each other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players fall, dive or are tackled to the ground	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players are hit by the football	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players collide with goal post, benches, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. When you received your helmet was it fitted correctly by an equipment manager?

- Yes
- No
- Don't know

4. Do you make sure your helmet is tightly fitted and your chinstrap is secure before every use?

- Yes
- No
- Don't know

5. How old is your helmet?

(Drop down options here included: "0-2 years", "3-6 years", "7-9 years", and "10+ years").

6. Do you know how often team helmets are reconditioned or replaced?

- Yes
- No

If so, how often?

7. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: tackles, helmet to helmet contact)

8. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Quarterback", "Running backs", "Offensive linemen", "Receivers", "Defensive lineman", "Linebackers", "Defensive backs", "Other", and "No particular position").

Why?

9. Please select a rating to answer the questions below.

- | | | | | | |
|--|-----------------------------|--------------|---------------------------------------|---------------------------|--------------------------------------|
| | 1 (no concern /
no risk) | 2 (low risk) | 3 (neutral /
somewhat low
risk) | 4 (somewhat
high-risk) | 5 (very
concerned /
high-risk) |
|--|-----------------------------|--------------|---------------------------------------|---------------------------|--------------------------------------|

On a scale of 1-5
how concerned
are you about
getting a
concussion while
playing your
sport?

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|

On a scale of 1-5
how much of a
concussion risk
you think there is
in your sport?

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|

10. Are you aware of the CDC's "Heads Up" campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

Women's Lacrosse Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times per half	A few times every possession	Almost every play / every play
Player falls to the ground	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players contact each other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players are hit by the ball above the waist	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players are hit by another player's stick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player collides with goal or other stationary objects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. Have you received any instruction on concussion safety?

- Yes
- No
- Don't know

4. Do you wear any optional protective equipment for your head?

- Yes
- No

If so, what is it?

5. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: hit on head by lacrosse ball)

6. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Attack", "Defense", "Midfielder", "Goalkeeper", "Other", and "No particular position").

Why?

7. On a scale of 1-5 how concerned are you about getting a concussion while playing your sport?

(Drop down options here included: "1 (no concern)", "2", "3 (neutral)", "4", and "5 (very concerned)").

8. Rate on a scale of 1-5 how much of a concussion risk you think there is in your sport.

(Drop down options here included: "1 (no risk)", "2 (low risk)", "3 (somewhat low risk)", "4 (somewhat high-risk)", and "5 (high-risk)").

9. Are you aware of the CDC's "Heads Up" campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

Ice Hockey Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times every period	A few times every shift	Almost every play / every play
Player is checked into boards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player falls on ice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players collide with each other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player's helmets are hit by the puck	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player's helmets are hit by another player's stick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. When you received your helmet was it fitted correctly by an equipment manager?

- Yes
- No
- Don't know

4. Do you make sure your helmet fits properly and is not dented or cracked before every use?

- Yes
- No
- Don't know

5. How old is your helmet?

(Drop down options here included: "0-2 years", "3-6 years", "7-9 years", and "10+ years").

6. Do you know how often team helmets are reconditioned or replaced?

- Yes
- No

If so, how often?

7. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: hit into boards pursuing puck)

8. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Defensemen", "Wings", "Center", "Goal tender", "Other", and "No particular position").

Why?

9. Please select a rating to answer the questions below.

- | | | | | |
|-----------------------------|--------------|---------------------------------------|---------------------------|--------------------------------------|
| 1 (no concern /
no risk) | 2 (low risk) | 3 (neutral /
somewhat low
risk) | 4 (somewhat
high-risk) | 5 (very
concerned /
high-risk) |
|-----------------------------|--------------|---------------------------------------|---------------------------|--------------------------------------|

On a scale of 1-5
how concerned
are you about
getting a
concussion while
playing your
sport?

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|

On a scale of 1-5
how much of a
concussion risk
you think there is
in your sport?

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|

10. Are you aware of the CDC's "Heads Up" campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

Soccer Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times per half	A few times every possession	Almost every play / every play
Players head the ball	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players fall to the ground	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players contact each other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players slide or dive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players collide with goalpost or other stationary object	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. Have you received any instruction on concussion safety?

- Yes
- No
- Don't know

4. Do you wear any optional protective equipment for your head?

- Yes
- No

If so, what is it?

5. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s)? (Example: head to head contact with another player while trying to head ball)

6. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Goalie", "Defenders", "Midfielders", "Strikers", "Other", and "No particular position").

Why?

7. On a scale of 1-5 how concerned are you about getting a concussion while playing your sport?

(Drop down options here included: "1 (no concern)", "2", "3 (neutral)", "4", and "5 (very concerned)").

8. Rate on a scale of 1-5 how much of a concussion risk you think there is in your sport.

(Drop down options here included: "1 (no risk)", "2 (low risk)", "3 (somewhat low risk)", "4 (somewhat high-risk)", and "5 (high-risk)").

9. Are you aware of Sport’s Legacy Institute’s “Safer Soccer” initiative?

If you are aware of another concussion education campaign, please list it here.

(Soccer survey was duplicated and sent to both the women’s soccer team and the men’s soccer team)

Softball Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few games	A few times per game	A few times every 2-3 innings	A few times every half inning	Almost every play / every play
Batter hit by pitch	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player hit by line drive or fly ball	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player gets hit by bat	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player collisions on the base paths or in the field	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Players run into the fence or other stationary object	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Player slides or dives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Game
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. When you received your helmet was it fitted correctly by an equipment manager?

- Yes
- No
- Don't know

4. Do you make sure your helmet fits tightly and the chinstrap is on before every use?

- Yes
- No
- Don't know

5. How old is your helmet?

(Drop down options here included: "0-2 years", "3-6 years", "7-9 years", and "10+ years")

6. Do you know how often team helmets are reconditioned or replaced?

- Yes
- No

If so, how often?

7. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s)? (Example: hit by pitch, base path collision)

8. Is there one particular position most likely to produce concussions?

(Drop down options here included: "Pitcher", "Catcher", "Infielder", "Outfielder", "Batter", "Base runner", "Other", and "No particular position")

Why?

9. Please select a rating to answer the questions below.

1 (no concern / no risk) 2 (low risk) 3 (neutral / somewhat low risk) 4 (somewhat high-risk) 5 (very concerned / high-risk)

On a scale of 1-5 how concerned are you about getting a concussion while playing your sport?

On a scale of 1-5 how much of a concussion risk do you think there is in your sport?

10. Are you aware of the CDC’s “Heads Up” campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign, please list it here.

Wrestling Survey

1. How frequently do the following events occur in your sport?

	Never	A few times per season	Every few meets	A few times per meet	A few times per match	Many times per match	Constantly during a match
Athlete's head strikes the ground	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Athlete is hit in the head by opponent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. In what setting did the listed events occur most often?

- Meet
- Scheduled practice
- Other
- Don't know

If other, please specify where.

3. Have you received any instruction on concussion safety?

- Yes
- No
- Don't know

4. Do you think that your headwear adequately protects against concussions?

- Yes
- No

5. Is there one particular play situation most likely to produce concussions?

- Yes
- No
- Don't know

If yes, what situation(s). (Example: hit head on mat)

6. On a scale of 1-5 how concerned are you about getting a concussion while playing your sport?

(Drop down options here included: "1 (no concern)", "2", "3 (neutral)", "4", and "5 (very concerned)").

7. Rate on a scale of 1-5 how much of a concussion risk you think there is in your sport.

(Drop down options here included: "1 (no risk)", "2 (low risk)", "3 (somewhat low risk)", "4 (somewhat high-risk)", and "5 (high-risk)").

8. Are you aware of the CDC's "Heads Up" campaign and its efforts?

- Yes
- No

If you are aware of another concussion education campaign please list it here.

Appendix C: Supplementary Graphs

The graphs below are representations of wrestler’s awareness of the effectiveness of wrestling headgear (retrieved from Survey), the overall cause distribution for concussions (retrieved from NEISS), and the various ages of helmets within our sports (retrieved from Survey).

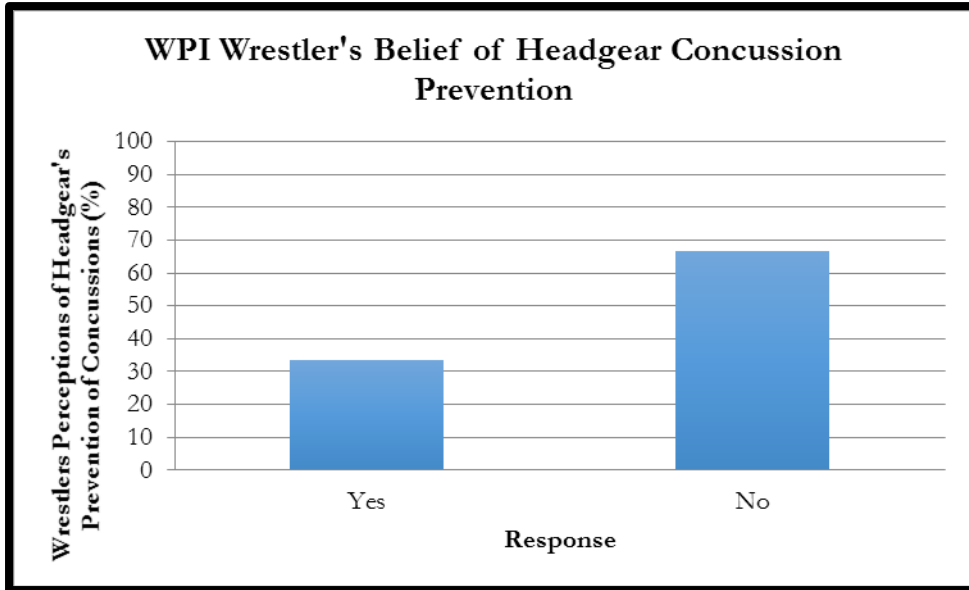


Figure 2: Wrestlers’ Perceptions of Concussion Prevention of Headgear – Source: Survey

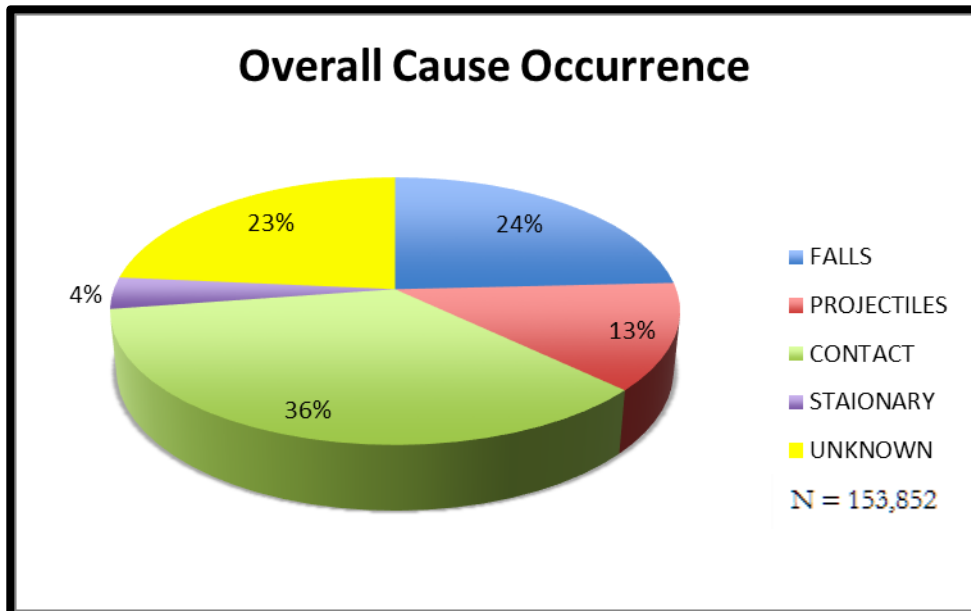


Figure 3: Physical Causes’ Distribution to Overall Concussion Rate – Source: NEISS

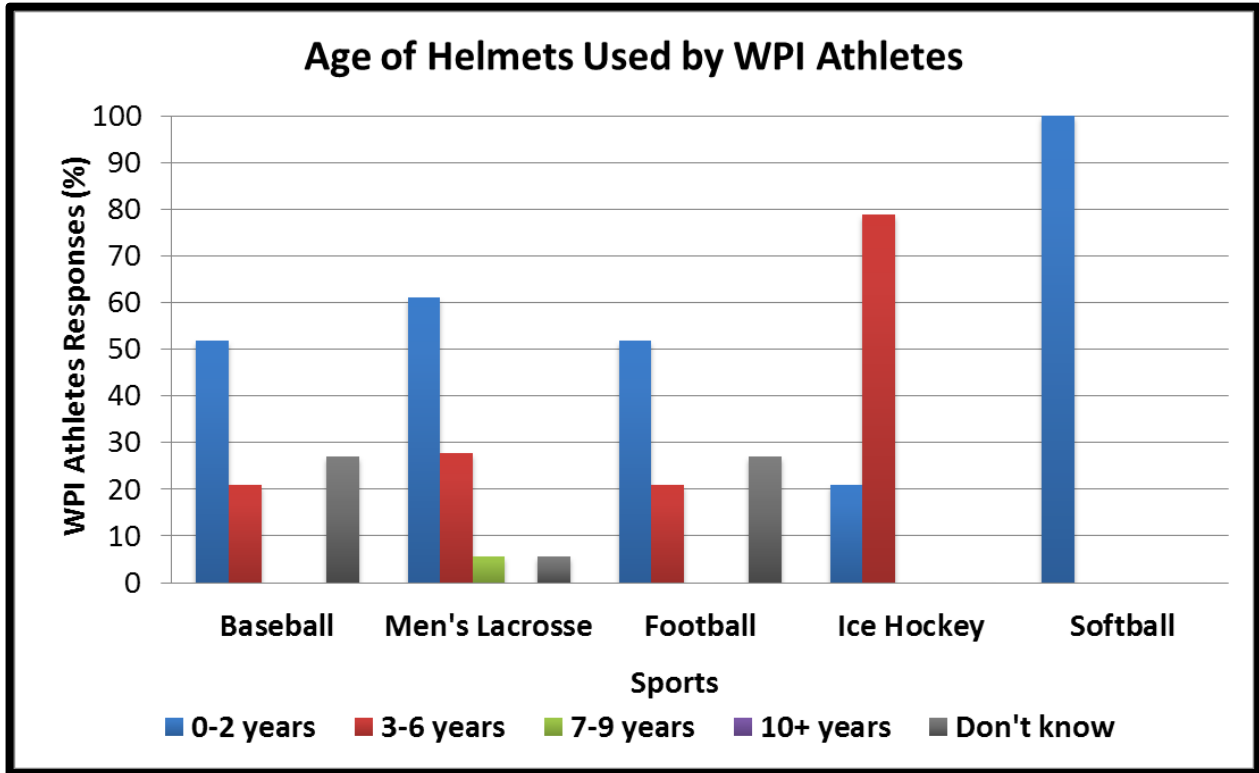


Figure 4: Helmets' Ages across Helmeted Sports Rate – Source: NEISS