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Review Article

A Review of the Incidence of Head Injuries in Football, Baseball, Ice Hockey, and Cycling

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Abstract: Head injuries in sports have merited greater attention from professionals, the media, and the general public in recent years. The purpose of this research was to conduct a review of articles that focus on the incidence of head injuries in football, baseball, ice hockey, and cycling. Twenty three studies were identified for inclusion because they contained quantitative data on the number or percentage of head injuries in those four sports. A table was created comparing the data by: sport, research design, level of play, and number of head injuries. Analysis of the data showed that the most studied sport was ice hockey, the most studied level of play was the professional level, and the most used study designs were case studies and emergency department surveillance. Some studies included implementation of prevention strategies to decrease the incidence of head injuries. The most common prevention strategies were rule changes and better equipment. Future studies will help determine the most successful prevention strategies that can be implemented in each sport to further reduce the incidence of head injury in sports.

Keywords: Head Injury, Concussion, Prevention, Football, Baseball, Ice Hockey, Cycling

1. Introduction

1.1. Significance of Concussions

Head injuries in sports are prevalent in recent news. There have been many lawsuits, both at the collegiate level and the professional level, related to how coaches, trainers, and administrative officials handle athlete head injuries. A class action lawsuit against the National College Athletic Association (NCAA) resulted in the establishment of a new program to assist college football players with medical monitoring and a new research program that focuses on the prevention, treatment, and effects of concussions [1]. In another lawsuit, retired National Football league (NFL) players received compensation from the league to assist with their ongoing medical costs and other losses. The players involved are suffering from dementia, depression, or Alzheimer's disease, and they believe their diseases were the result of repeated head injuries they suffered while playing football [2]. Other sports, such as baseball, ice hockey, and cycling carry a high risk of head injuries. This study seeks to explore similarities and differences among the incidence of head injuries in football, baseball, ice hockey, and cycling. This topic is important because even minor head injuries, if not treated properly, may result in traumatic brain injury (TBI), concussions, mental status changes sometimes death.

1.2. Football Head Injury Introduction

Football injuries to the head are common and usually result from head to head contact, hands to head contact, or head to ground contact. In a study that examined 328 football players from multiple colleges, 70.4% of players reported that they had symptoms of concussions, while only 23.4% reported they were aware that they had had a concussion. Of the players who reported they had symptoms of a concussion, 27.6% reported their symptoms lasting longer than a week, and 84.6% reported they had more than one concussion [3].

1.3. Baseball Head Injury Introduction

The most common head injuries in baseball occur during a

line drive hit, a pitch to the head, or a collision between a base runner and the catcher. In an emergency department surveillance study, baseball was found to have the highest proportion of head injuries relative to all injuries, when compared to ice hockey, soccer, and football. There were 1854 head injuries out of 5300 total injuries in the sport for youth ages 5 to 18 years old from 2004 to 2014 [4]. Concussion rates in U.S. high school and collegiate baseball players were recorded during the 2005-2006 school year, from 100 high schools and 160 colleges. There were 9 concussions reported in high school baseball and 12 reported in college baseball. A national estimate was created for high school baseball players and the number of concussions was estimated to be around 1991 in that school year. Most of these concussions were due to being hit by a pitch [5].

1.4. Ice Hockey Head Injury Introduction

Ice hockey is very physical and aggressive, making it a high-risk sport for injury, especially head injury. The most common injuries in ice hockey come from a stick to the face, check to the head, puck to the face, contact with the boards, and falls to the ice [6].

International Ice Hockey Federation Adult World Championship tournaments and the Olympic Winter Games from 2006 to 2013 were analyzed to see the frequency and type of injuries that occurred in these tournaments. Researchers found that out of 528 injuries, 39.8% were head injuries. Of those head injuries, 11.2% of the players returned to play the same game and 9.9% of head injuries were concussions and the player was not allowed to return to the same game [7].

Using emergency department surveillance, patients with injuries from hockey were analyzed from 1990-2006. Data was taken from the National Electronic Injury Surveillance System that surveyed 100 hospitals and emergency departments. Researchers found that 8228 patients went to the emergency department for ice hockey related injuries, with an estimated 302,368 ice hockey related injuries nationwide. From those injuries, 19.1% were sustained to the face, 16.4% were facial lacerations and 7% were concussions [6]. Another study that examined 42,029 ice hockey-related injuries, found that 27.2% were head injuries [4]. In a study conducted by the Center for Disease Control (CDC), 9% of ice hockey-related injuries were concussions [8]. A study published in the British Journal of Sports Medicine concluded that ice hockey has an incidence rate of 96 injuries per 1000 player hours. Of these injuries, 2-20% of them were concussions [9].

1.5. Cycling Head Injury Introduction

The biggest risk-factor for cycling is when a cyclist's head hits the pavement. Other risk factors are fans coming onto the road and causing an accident and collisions with cars. In 2016 a study examined emergency department visits to find the incidence of head injuries in cycling-related accidents. Out of 1.7 million emergency department visits, 16.7% were due to a cycling-related injury [10]. In a study done by the CDC, 26,212 concussions were reported from cycling-related events. Head injury made up 8.1% of all those cycling injuries [8].

2. Methods

The sports used for this systemic review were chosen from the AANS survey that examined hospitals across the U. S. to determine the top 20 sports that caused head injuries to participants [11]. Football and cycling were the top two sports leading to head injuries. Ice hockey and baseball were also in the top 20 and were chosen because of their popularity with spectators.

Online databases were searched for scientific studies on incidence of head injuries in the four sports. Inclusion criteria were articles that: were published in English; less than 20 years old; and articles that included quantitative data on the numbers of players and percentages of injuries. If studies examined multiple levels or multiple sports, they were included in all appropriate sections of the tables. This information is compiled in Table 1, Table 2, and Table 3.

3. Results

3.1. Tables of Data

This systemic review included 23 studies spanning the years of 2001 to 2017. Table 1 displays the head injury studies that included statistics on the number of head injuries examined. Those eight studies examined all four sports and all levels of play including a total of 1,780,009 head injuries.

Table 1. *Total Number of Head Injuries.*

Citation	Sport	Level of Play	Total Injuries	Type of Study
CDC 2011	Baseball	HS	121,309	ED Surveillance
McFaull et. al. 2016	Baseball	HS	5,300	ED Surveillance
CDC 2011	Cycling	HS	323,571	ED Surveillance
Deits et al. 2010	Cycling	Any	66,716	ED Surveillance
Gaw and Zonfrillo 2016	Cycling	Any	221,150	ED Surveillance
Gaw and Zonfrillo 2016	Cycling	Any	65,828	ED Surveillance
Kelly et. al. 2001	Cycling	Any	288,948	ED Surveillance
CDC 2011	Football	HS	351,562	ED Surveillance
McFaull et. al. 2016	Football	HS	22,264	ED Surveillance
Bakhos et. al. 2010	Hockey	Youth	7,662	ED Surveillance
Deits et. al. 2010	Hockey	Any	8228	ED Surveillance
Gaw and Zonfrillo 2016	Hockey	Any	7,341	ED Surveillance
Kelly et. al. 2001	Hockey	Any	288,948	ED Surveillance

Citation	Sport	Level of Play	Total Injuries	Type of Study
Simmons et al. 2017	Hockey	College	627	Descriptive
Tuominen et. al. 2015	Hockey	Pro	555	Case study

Fourteen studies included the incidence of head injury in their statistics as shown in Table 2.

Table 2. *Incidence of Concussion.*

Citation	Sport	Level of Play	Incidence of Concussion	Type of Study
CDC 2011	Baseball	HS	7.90%	ED Surveillance
McFaull et. al. 2016	Baseball	HS	35.00%	ED Surveillance
CDC 2011	Cycling	HS	8.10%	ED Surveillance
Deits et al. 2010	Cycling	Any	67.60%	ED Surveillance
Gaw and Zonfrillo 2016	Cycling	Any	25.10%	ED Surveillance
Gaw and Zonfrillo 2016	Cycling	Any	7.50%	ED Surveillance
Kelly et. al. 2001	Cycling	Any	13%	ED Surveillance
Weislo 2011	Cycling	Pro	1.50%	Case Study
CDC 2011	Football	HS	7.20%	ED Surveillance
Delaney et. al. 2002	Football	College	70.40%	Survey
McFaull et. al. 2016	Football	HS	16.30%	ED Surveillance
Meeuwissee et. al. 2000	Football	College	6.10%	Case Study
Bakhos et. al. 2010	Hockey	Youth	3.80%	ED Surveillance
CDC 2011	Hockey	HS	9.70%	ED Surveillance
Deits et. al. 2010	Hockey	Any	7.00%	ED Surveillance
Gaw and Zonfrillo 2016	Hockey	Any	1.20%	ED Surveillance
Kelly et. al. 2001	Hockey	Any	21%	ED Surveillance
McFaull et. al. 2016	Hockey	HS	27.20%	ED Surveillance
Tuominen et. al. 2015	Hockey	Pro	3.80%	Case study
Kerr et al 2017	Baseball men	College	.25%	descriptive
Kerr et al 2017	Football men	College	2.42%	descriptive
Kerr et al 2017	Hockey men	College	1.62%	descriptive
Kerr et al 2017	Hockey women	College	1.21%	descriptive
Krolikowski et al 2016	Hockey	Youth	1.85%	descriptive
Krolikowski et al 2016	Hockey	Youth	2.48%	descriptive
Krolikowski et al 2016	Hockey	Youth	4.12%	descriptive
Krolikowski et al 2016	Hockey	Youth	7.91%	descriptive
Michael et al 2017	cycling	youth	25.8%	ED surveillance
Michael et al 2017	cycling	youth	15.8%	ED surveillance
Simmons et al 2017	Hockey	College (men)	56.3	descriptive
Simmons et al 2017	Hockey	College (men)	42.5	descriptive
Simmons et al 2017	Hockey	College (women)	58.1	descriptive
Simmons et al 2017	Hockey	College (women)	68.2	descriptive

Seven studies organized their data around the number of participants, comparing those with head injuries to those without head injuries. Table 3 displays that data with a total of 116,251 participants.

Table 3. *Total Number of Participants.*

Author/year	Sport	Level of Play	Participants	Type of Study
Weislo 2011	Cycling	Pro	198	Case Study
Delaney et. al. 2002	Football	College	328	Survey
CDC 2011	Hockey	HS	45,450	ED Surveillance
McFaull et. al. 2016	Hockey	HS	42,029	ED Surveillance
Kerr et al 2017	Baseball men	College	1757	descriptive
Kerr et al 2017	Football men	College	9718	descriptive
Kerr et al 2017	Ice hockey men	College	3689	descriptive
Kerr et al 2017	Ice hockey women	College	1301	descriptive
Krolikowski et al 2016	Hockey	Youth	1479	descriptive
Krolikowski et al 2016	Hockey	Youth	1479	descriptive
Krolikowski et al 2016	Hockey	Youth	620	descriptive
Krolikowski et al 2016	Hockey	Youth	620	descriptive
Michael et al 2017	cycling	youth	516	ED surveillance
Michael et al 2017	cycling	youth	516	ED surveillance

3.2. Graphs

The next step was to analyze the data by: sport, level of play and type of study.

Figure 1 shows the number of studies for the four sports in this systemic review. Ice hockey was the most studied (n=14),

followed by football (n=12), cycling (n=8) and finally baseball (n=7). If studies examined multiple sports, they were included with each sport examined.

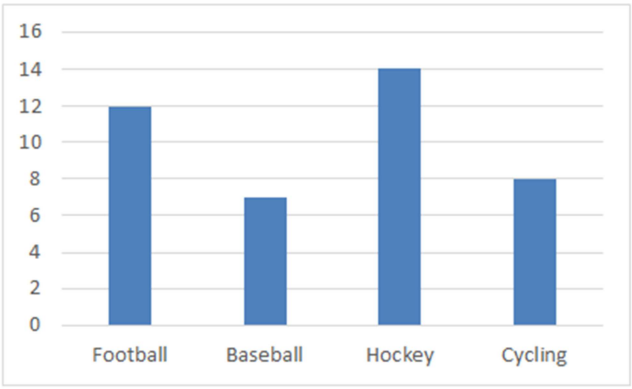

Figure 1. *Number of Studies by Sport.*

Figure 2 shows the number of studies for each level of play. The professional level was the most studied (n=9), followed by youth (n=7), college (n=6), and high school (n=3). There were 4 studies that looked at all ages.

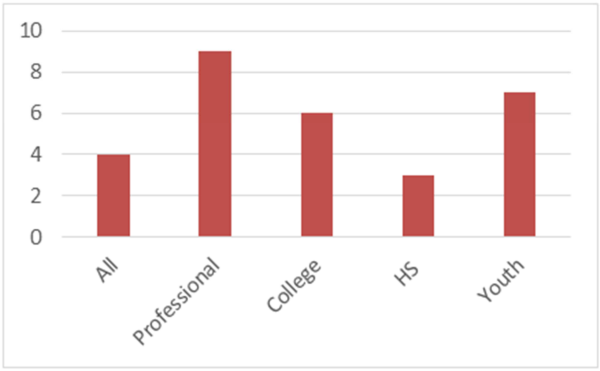

Figure 2. *Level of Play.*

Figure 3 shows the types of studies used to examine head injuries in the four sports. Emergency department studies (n=7) and case studies (n=7) were the most common method used. Descriptive studies (n=5) and surveys (n=3) were also used to examine head injuries.

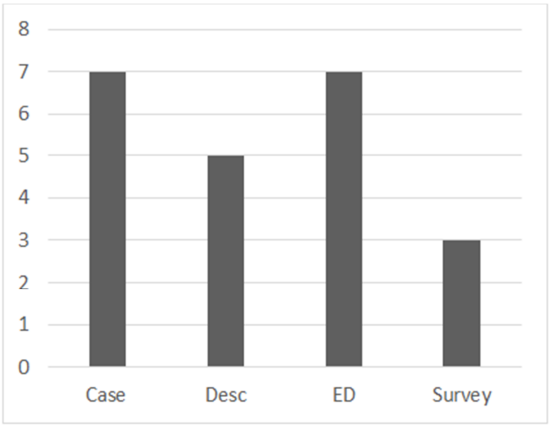

Figure 3. *Types of Studies.*

From all 23 studies, calculations included an overall average incidence of head injuries and the standard error for each average sorted by sport and displayed them in Figure 4. The average incidence of head injuries in football was 24.66% with a standard error of +/- 9.81%. The average incidence of head injuries in cycling was 21.00% with a standard error of +/- 7.36%. The average incidence of head injuries in ice hockey was 12.017.82% with a standard error of +/- 5.34%. Finally, the average incidence of head injuries in baseball was 10.96% with a standard error of 8.20%.

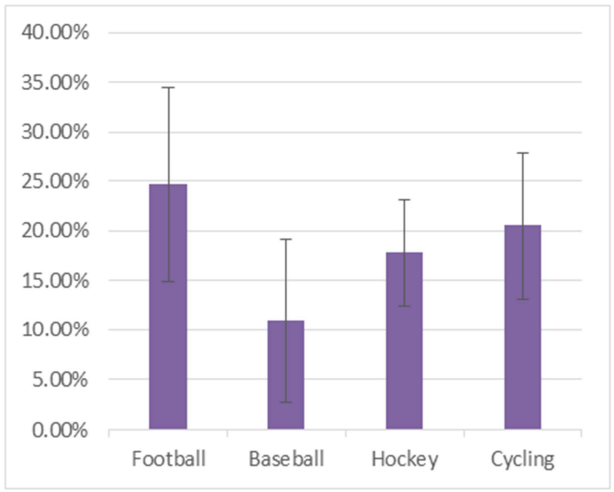

Figure 4. *Incidence of Head Injury by Sport.*

4. Discussion

The incidence of head injuries varies by sport and by level of play but in all cases the incidence could potentially be reduced with the implementation of prevention strategies. Many studies reported encouraging results using one or more prevention strategy.

4.1. Sports Equipment Changes

A major category of injury prevention is improvements in sports equipment. Since 1976, improvements in helmets have reduced serious head injury by 84% [9]. Helmets were once were made of soft material that covered a player's head. Currently, helmets have a hard outer shell with padding on the inside that has contact with the head, and also a face guard. Youth hockey provides an example of a successful implementation strategy. One study reported that players without faceguards suffered head injuries at a rate of 12.2 per 1000 player-hours while hockey players with full faceguards had an incidence of head injuries of 2.9 per 1000 player-hours [12]. A baseball study that examined safety balls and faceguards in youth baseball, and found a 28% reduction in head injuries when using a softer ball at the youth levels of baseball. They also found there was a 35% reduced risk of head injury when using a faceguard [13]. An emergency room surveillance study examined data from children under the age of 15 who were injured in bicycle accidents. They examined 516 patients and found that those

wearing helmets had a 15.8% risk of head injury versus a 25.8% risk of head injury for children who were not wearing helmets [14]. All of these studies are strong evidence to support better equipment.

4.2. Rule and Regulation Changes

The other major prevention strategy is rule changes and regulations. In all four sports, rule changes and regulations have resulted in fewer head injuries. In 2011, Major League Baseball (MLB) established a new concussion protocol, "the seven-day disabled list", that all teams are required to follow. If a player is diagnosed with a concussion, that player is ineligible to play for a minimum of seven days and must be medically reevaluated the player is cleared to play again. This new agreement between the MLB and the Major League Baseball Players Association also states that all players and umpires must do a neurological baseline test prior to the season that could be used to help diagnose a concussion [15].

The NHL is changing rules to better protect players, and handing out fines and suspensions, in efforts to avoid head injuries, while keeping integrity of the game. Ice hockey players are now required to use helmets while playing the sport. Along with the helmets, at the junior level, players are required to have fill face guards, which have reduced the rate of concussion from 12.2 to 2.9 concussions per 1000 player hours compared to helmets with no face guards [4]. In 2011 the NHL instituted stricter rules that limit the scenarios whereby hits to the head can be deemed legal. That rule change stabilized the number of players suffering from concussions in the following season, stopping a trend of increasing numbers of concussions that had been occurring in previous seasons [16]. Also, in 2010, the NHL started a new concussion protocol which identified exact steps each player who has been diagnosed with a concussion must go through in order to be cleared to play again [17].

Not all rule changes result in fewer injuries. In 2011 Hockey Canada implemented a "zero tolerance for head contact" rule for youth hockey. The study included 2099 Pee Wee and Bantam ice hockey players but found an increase in the incidence of game related concussions following the head contact rule change. Researchers hypothesized that increased education and awareness of the dangers of head injuries after the rule change may have contributed to the higher incidence of reported concussions [18].

In Canada, provinces and territories have different legislation regarding the use of helmets while cycling. In a study looking at hospital admissions for cycling related injuries between 1994 and 2004, provinces with legislation regarding helmet usage saw a decline of 54% of young people admitted for cycling injuries while provinces without legislation, saw a decrease of only 33.1%. In provinces with legislation, head injury rates decreased by 26% in adults while head injury rates remained constant in adults in provinces without legislation on helmet usage [19].

4.3. Public Education and Awareness

In all four of these sports, there is a need to educate the public about the seriousness of head injury. A survey of 6,937 people, many of whom are athletes, parents of athletes, coaches, trainers, or medical professionals, tested their knowledge of the symptoms of TBIs. Most respondents listed physical characteristics such as headaches and dizziness, as well as cognitive impairment like confusion. The least listed symptom of concussions were ones relating to mental health, such as irritability and anxiety [20]. There is a the lack of understanding among athletes parents, coaches, and some medical professionals on the signs and symptoms of TBIs. Education about TBIs will make people more aware of how dangerous TBIs can become. This is one of the simplest and most effective ways to prevent head injuries.

5. Conclusions

This study showed that the incidence of head injuries is high for all levels of play in football, hockey, baseball and cycling. Future studies on head injury will lead to better prevention strategies to further reduce the incidence of head injuries

It is important to keep in mind the seriousness of head injury. When a concussion is suspected, the athlete should be removed from play and be required to rest, follow a predetermined concussion protocol, and be reexamined before returning to play. The data presented in this review underscores the need for more public education, implementation of prevention strategies, and better management of sport-related head injuries.

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