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Concussion Preventative Head-Gear in Contact Sports

by

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ABSTRACT

This thesis explores the concussion preventative head-gear used in four contact sports: football, baseball, soccer, and basketball. The most effective head-gear from each sport is presented along with the reasons behind their success. Football and baseball organizations have regulations set in place for players to be required to wear helmets, while soccer and basketball organizations do not require players to wear any sort of head-gear. This thesis presents the reasons why soccer and basketball organizations do not require players to wear head-gear, but it also shows the equipment that have been used by players in the past to prevent further head injuries.

This paper includes a personal anecdote as well as a recommendation for soccer organizations to require head-gear during competition and for basketball organizations to fund research into protective equipment specific to basketball players.

Thesis Supervisor: Maria Yang

Tile: Professor of Mechanical Engineering
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Chapter 1: Introduction

The aim of the research in the thesis is to understand the current methods of concussion prevention in contact sports and to offer a recommendation on how to encourage the implementation of these methods into sports that currently don’t use concussion preventative head-gear.

Recently, there has been an increase in awareness of the risks of long-term brain damage due to contact sports, as evidenced by numerous trends. Fewer and fewer youth and high school males are participating in football every year. Over 5,000 former players in the National Football League (NFL) have sued the NFL, claiming the NFL did not do as much as they should have to make sure their players were well informed of the dangers of concussions. A settlement was approved in 2015 by a federal judge that up to $5 million per player could be provided for serious medical conditions that were associated with repeated head injuries [11]. Large organizations, including the NFL, are now contributing huge amounts of money to fund research into better ways to protect players against head injuries. Equipment manufacturers are also searching for new material and designs that could be incorporated into these sports and give athletes the protection they need.

Head injuries can occur in almost every sport, but they are certainly more common in some than others. The sports where head injuries are more common include: football, baseball, softball, ice hockey, soccer, lacrosse, wrestling, and basketball. The majority of these sports require that head-gear is worn during competition. In 2017, the United States had a market of $350 million for protective sports equipment for football alone. For all protective sports equipment, the market was $1.9 billion and is projected to be $2.2 billion in 2022 [11]. Helmets are a huge portion of this market and each sport has a different design for their protective equipment. In the following
sections, I have chosen to research football, baseball, soccer, and basketball because they are all sports with a high number of concussions every year. Football and baseball have rules and regulations that require players to wear head-gear while soccer and basketball do not. What types of headgear are common in football and baseball and why do athletes choose to use these types? Should sports such as basketball and soccer adopt a more regulated form of headgear?

Chapter 2: Football

In the United States, American football is the sport associated with the highest number of traumatic brain injuries. This number is a bit skewed because it is also the sport with the highest number of participants. Football helmet designs have changed many times over the years, and each iteration creates a safer helmet for the players. In every football game, each player has a certain risk of suffering from a concussion. The amount of risk is based on that player’s position, the amount of time they play, their level of fatigue, the type of helmet they are using, the size and weight of their opponents, and even the style of play that their team uses. In fact, in the NFL, a player that is mostly involved in pass plays has a higher risk of concussions. There are also different risk factors based on a team’s style of play. For example, an offensive scheme where there is a large amount of short passing games with many crossing routes (also known as a West Coast offense) will have a higher risk of their players suffering from a concussion [19]. Another factor associated with concussions is the type of tackle a player uses. When a player leads with their helmet, they are putting themselves and the player they are tackling at a higher risk of concussion. In fact, the NFL made a rule change in 2018 called the Use of Helmet rule. “The rule
states that it is a foul if a player lowers his head to initiate and make contact with his helmet against an opponent. This rule pertains to all players on the field, and to all areas of the field” [1].

Each year, the NFL evaluates which helmets best reduce head impact severity under laboratory conditions simulating concussion-causing impacts sustained by NFL players during games. In order to evaluate which brand of football helmet is the safest to use, there needed to be a mechanism in place to test all of these helmets the same way and to produce a metric that would allow players to make an educated decision on which helmet to use. One method that is used is the Summation of Tests for the Analysis of Risk (STAR) equation. This equation computes one metric from 24 drop tests. This method correlates all of the head impacts a player will experience throughout one season into four impact locations at six different drop heights. In the STAR equation below, \( L \) represents the impact location, \( H \) represents the drop height (60, 48, 36, 24, 12 in., and lowest), \( E \) represents the head impact exposure as a function of \( H \) and \( L \), and \( R \) represents the injury risk as a function of \( a \), which is the peak resultant head acceleration from each specific height and impact location [17].

\[
STAR = \sum_{L=1}^{4} \sum_{H=1}^{6} E(L, H) \cdot R(a)
\] (1)

Head impact exposure is defined as the amount of impacts that a single player will sustain over an entire season. The STAR equation estimates this number to be 1000 impacts in one season. Each impact tested was placed into one of four categories based on the elevation and azimuth angles as defined in the figure below.
The four categories included: top of the helmet, front of the helmet, rear of the helmet, and side of the helmet. The angles necessary for each category are shown in Table 1.

**TABLE 1. Definition of impact location categories based on azimuth and elevation angles [17].**

<table>
<thead>
<tr>
<th>Azimuth Angle</th>
<th>Elevation Angle</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;65°</td>
<td>N/A</td>
<td>Top of helmet</td>
</tr>
<tr>
<td>Between 45° and -45°</td>
<td>&lt;65°</td>
<td>Front of helmet</td>
</tr>
<tr>
<td>Between 135° and -135°</td>
<td>&lt;65°</td>
<td>Rear of helmet</td>
</tr>
<tr>
<td>All other angles</td>
<td>All other angles</td>
<td>Side of helmet</td>
</tr>
</tbody>
</table>
A traditional football helmet typically includes a hard outer shell along with an inner padding, such as the Riddell Revolution Speed Classic, which is in fact used by MIT Varsity Football. This design is fairly rigid and absorbs direct impact, but does not do much to absorb rotational/shear forces. The figure below gives a transparent view of the components in a Riddell Revolution Speed Classic [9].

![Riddell Revolution Speed Classic diagram](image)

**FIGURE 2.** Riddell Revolution Speed Classic consists of a hard, rigid outer shell and an inner padding. A - Liner; B - Bumper; C - Inflatable Liner; D - Front Pad; E - Frame Pad; F - FlexLiner; G - Liner Retainer Cap; H - Face Mask Mount; I - Face Mask Clip; J - Ratchet-Loc Housing [9].

Every year the NFL tests all the football helmets currently being used by their players along with new helmets that are available on the market. The VICIS ZERO1 has been the top-ranked helmet in the NFL performance testing for three years straight. Let’s look into why this helmet is so effective.
The ZERO1 consists of essentially four different layers. The outermost shell (LODE SHELL) is an impact absorbing shell that locally deforms, similar to a car bumper. The next layer (VICIS RFLX) consists of a columnar structure that reduces for both linear and rotational forces by moving uni-directionally. Underneath this columnar structure is another hard shell (ARCH SHELL) that is customizable to fit each player’s head size. The final layer (FORM LINER) is a liner made up of special foams and waterproof textiles that conforms to each individual player’s head shape. This inner most layer distributes the pressure evenly around the head. These layers are diagramed below in Figure 3 [2].

FIGURE 3. Diagram of layers/components inside the VICIS ZERO1 football helmet [2].
The NFL has required helmets for competition since 1943. Since then, more and more research has demonstrated the negative effects of repeated head trauma. Due to this research, NFL players are adopting new helmets every year that are proven to be safer. In 2018 the NFL prohibited 10 helmets that did not perform as well as the others and over 50% of players are willingly deciding to use helmets that perform better during the NFL performance tests [3]. Some players, on the other hand, are more reluctant to switch. Tom Brady, for example, uses a helmet model that is only allowed to be worn by players that wore that helmet during the 2017 season (new players are not allowed to wear it). As the world learns more about head injuries, the rules continue to change.

Chapter 3: Baseball

Helmets are heavily used in football and a huge part of the sport. When we think of football, we think of helmets. This is not the case for baseball. It wasn’t until 1970 that Major League Baseball strictly enforced all batters to wear a batting helmet. At this time, the batting helmet had no flaps protecting the ears. It wasn’t until 1983 that players were required to use a helmet with at least one ear flap. These flaps were designed to help to protect the side of a batter’s face from baseballs during pitches. For the next two decades, there wasn’t much progress at all with the batting helmet, until 2005 when the MLB finally tested a new batting helmet. This new helmet consisted of a molded crown, side vents, back vents, and larger ear holes. This type of helmet is similar to those used by players today [15].

As of today, players are required to wear some type of protective helmet while batting and running the bases. The National Association Leagues require the helmet to be a double ear-flap helmet while the Major League players are only required to wear a single-ear flap helmet, but they
can wear a double ear-flap helmet if they prefer. Even base coaches are required to wear helmets as well as bat/ball boys and girls [20]. Although these rules are set in place for their protection, there have been lots of people advocating against these new rules.

Some baseball players refuse to wear a helmet that is too bulky, even if it is safer. The right fielder for the Mets, Jeff Francoeur, responded to seeing a safer helmet by saying “I could care less what they say, I’m not wearing it. There’s got to be a way to have a more protective helmet without all that padding... We’re going to look like a bunch of clowns out there.” He is not alone. Many major league players believe these newer helmets are too bulky, heavy, and geeky-looking. The ideal situation is to have “a helmet that’s comfortable and that doesn’t look bad,” said Athletics infielder Nomar Garciaparra [3]. Even in 2007, after a 35-year-old first base coach was hit by a batted ball and died, a number of coaches were still objecting to the new rule that base coaches had to wear helmets. They were willing to risk their health as long as they didn’t have to wear an uncomfortable helmet during games.

In recent years there has been a new trend of wearing helmets with a C-Flap. This extended flap increases the area of protection even further than the ear-flap as you can see in Figure 4. Even though this accessory is not very attractive to look at, there are a number of All Star players that wear the C-Flap as a preventative measure as opposed to a rehab procedure following an injury [5]. This is a very healthy trend for baseball. Not only are players understanding the risks associated with the sport, but they are willing to sacrifice how they look in order to protect themselves. This is a trend that is not happening in a number of sports such as basketball which I will discuss later on.
FIGURE 4. The left image is a single ear-flap helmet. The right image is a double ear-flap helmet with a C-Flap attached to the left ear-flap [5].

In 2013, Rawlings released their S100 Pro Comp batting helmet which then became the Official Batting Helmet of Major League Baseball and still is to this day. The reason the MLB made this helmet the standard was due to the glaring advantages it had over the helmets previously used. It is constructed using aerospace-grade carbon fiber composite and is able to protect the player from ball strikes up to 100 miles per hour. Compared to the previous MLB standard helmet, the S100 Pro Comp is 300% stiffer and 130 times stronger. At the same time, it is also lighter and smaller than previous iterations of the S100 and reduces the energy felt by a 100 miles per hour pitch by 75% [4].

With improvements in technology, it is only a matter of time before an even newer batting helmet becomes available for Major League players. Fortunately, there has been a push from the MLB along with some of their top players to prioritize safety over comfort and aesthetics, which can’t be said for every sport.
Chapter 4: Soccer

Now we will be discussing sports where concussion preventative head-gear is not required, even though they are sports with high rates of head injuries. In fact, Table 2 shows the average annual estimates of emergency department visits from 2010 through 2016 for nonfatal traumatic brain injuries related to contact sports among persons aged less than 18 years old [18].

<table>
<thead>
<tr>
<th>Activity</th>
<th>Overall</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>53,657</td>
<td>52,088</td>
<td>1,570</td>
</tr>
<tr>
<td>Basketball</td>
<td>29,675</td>
<td>19,057</td>
<td>10,617</td>
</tr>
<tr>
<td>Soccer</td>
<td>23,847</td>
<td>12,177</td>
<td>11,670</td>
</tr>
<tr>
<td>Hockey</td>
<td>8,110</td>
<td>6,697</td>
<td>1,412</td>
</tr>
<tr>
<td>Combative Sports</td>
<td>6,798</td>
<td>6,371</td>
<td>426</td>
</tr>
<tr>
<td>Miscellaneous contact ball games</td>
<td>4,877</td>
<td>3,392</td>
<td>1,485</td>
</tr>
</tbody>
</table>

Behind football, the next two sports with the most nonfatal traumatic brain injuries are basketball and soccer, yet neither of these sports require concussion preventative head-gear. In the last decade, a minority of soccer players have started to use protective head-gear in the United States. The United States Soccer Federation, National Collegiate Athletic Association (NCAA), and National Federation of State High School Associations all permit the use of protective head-
gear, but the U.S. Soccer Federation does not endorse head-gear on the other hand. Some believe that large organizations that are slow to permit the use of headgear, like the U.S. Soccer Federation, are doing so because of the stigma that soccer is a safe alternative to football. They believe that more youth athletes are turning to soccer rather than football due to the belief that football is safer, and incorporating head-gear would taint that image [6].

The most common form of head-gear used by soccer players is a protective headband that is placed around the forehead and the back of the head. The purpose of these headbands is to absorb the impacts that occur during collision with the ground and other players. There are some doctors that argue against the use of head-gear. One reason is that the head-gear makes the player’s head heavier. Most soccer concussions are caused by an acceleration/deceleration of the head or a rotational change. A heavier head is believed by some to increase the risk of these types of injuries. Another reason is a false sense of security while wearing head-gear, there is potential for players to act more recklessly due to the fact that they are wearing protective equipment [6].

Until recently, there has not been much evidence on how effective these headbands are at preventing head injuries. One study from 2003 in which four headbands were tested and the resultant peak acceleration of the head was measured at three different speeds and two different ball pressures concluded that the headgear used “showed little ability to attenuate impact during simulated soccer heading. However, statistically significant decreases are present at the highest speeds and pressures tested, suggesting that headbands may play a role in decreasing impact for more forceful blows” [16]. Another study from 2003 showed that three headbands “were effective at reducing the peak impact force by approximately 12.5%” [12].

In 2018, the first ever independent ratings to evaluate the performance of protective headgear for soccer players was released by the Virginia Tech Helmet Lab. The lab grades the safety
equipment using the STAR method described previously. 22 types of protective head-gear were tested and the results show that protective equipment can reduce risk significantly. An impact simulator was used to mimic two players' heads colliding in a match, the typical way that concussions will occur during a soccer match or practice, at three different speeds and two different impact locations. Of the 22 headbands tested, Storelli's ExoShield was able to reduce injury risk by up to 84% during the impacts tested [7]. The testing setup used by the Virginia Tech Helmet Lab is shown in Figure 5 [8].

FIGURE 5. Head-to-head impactor includes two head and neck assemblies on sliding masses. An addition sliding platform is located behind the striking head to propel the sliding torso mass and prevent neck extension during acceleration down to rail. The striking headform is attached to a cable and pulley system that accelerates the torso mass by as set of connected falling weights [8].

With this new evidence that head-gear can help reduce the risks of head injuries in soccer, it is something that should definitely be promoted and encouraged to our youth. Contact sports need to change in order to protect the players, even if that means adjusting the rules and regulations to require players to wear equipment they haven't worn in the past.
Chapter 5: Basketball

Basketball has been a passion of mine throughout my entire life. I have been playing the sport ever since I could walk and I have been playing for MIT’s Varsity Basketball team for the last four years. With almost thirty thousand annual emergency department visits for nonfatal traumatic brain injuries related to basketball, why aren’t basketball players required to wear some sort of protective head-gear?

Basketball has never been a sport that requires a helmet. Even though it is one of the sports with the highest number of concussions, rules have yet to be changed with regards to protective equipment for the head. The most common head injury that occurs during a basketball competition is from player-to-player. The only common equipment worn by players is the mouth guard, which isn’t worn for concussion prevention. The mouth guards are worn to protect the teeth of players and there is yet to be evidence of mouth guards helping to prevent concussions, even though this is a common misconception [13].

In all my research, I have only found two instances where basketball players have worn protective headgear. The first instance was in 2010 when John Peckinpaugh, a forward for the Indiana University – Purdue University Fort Wayne (IPFW), started wearing a boxing helmet during practices and games. The only reason he wore the helmet was because his coach and team doctor told him it was the only way he would be allowed to play. Peckinpaugh had four concussions in a little over a month during his sophomore season and even considered quitting basketball altogether out of fear of long-term side effects if he were to sustain another concussion. Even though Peckinpaugh suffered these concussions, he doesn’t think that basketball players should be wearing helmets of this sort. He believes he just got unlucky. He also commented that
the helmet made him extremely hot, his peripheral vision was limited, and it itched a lot. These reasons could have played a role in why he wouldn’t suggest players wearing it as a preventative even before having a concussion [14].

The second instance was in 2012 when the Louisville Men’s Basketball athletic trainer, Fred Hina, suggested three of the Louisville players that had multiple concussions wear MMA sparring helmets during practices. The purpose was to limit risk and cut down on possibility of another concussion happening again. All three players were given the option of wearing the helmet or not and they all decided to wear it, even though they knew they looked funny. This helmet still allows the players to have full vision of the court, unlike the boxing helmet used by Peckinpaugh [10].

Both these instances had players wearing head-gear only after they had already suffered a concussion. If we could have players wearing the head-gear even before they suffer their first concussion, this will reduce the risks of long-term damage tremendously.

In my time playing basketball at MIT, I have suffered from two concussions, with the most recent one occurring during my senior year. While on defense, I took a charge and my head bounced against the ground, followed by a player from the other team landing on the side of my head. This concussion left me unconscious and unresponsive. While unconscious, I had a seizure on the court and was rushed to the hospital. The game was ended early. Following this incident, I contemplated whether or not it was worth it to continue to play basketball. After speaking with a neurologist, I decided I would continue playing basketball, but I would wear a protective headband during practices. The headband I chose was the Unequal Halo 2 and a photo of me wearing this headband is seen in Figure 6. This headband was the second best rated headband in the Virginia Tech Helmet Lab’s Soccer headband test [7]. I wore the headband for a few practices, but eventually stopped wearing it due to the reactions I got from my teammates as well as the
discomfort I felt while wearing it. Unfortunately, I was not willing to wear this headband due to social factors and discomfort. I was lucky enough not to sustain another concussion for the rest of the season, but I am just one of many players that have probably faced the same challenges following a concussion.

FIGURE 6. Photo of Adam Jurko (author) wearing the Unequal Halo 2 headband after suffering from two concussions in the span of 14 months.
Chapter 6: Conclusions and Future Work

The research found in this thesis supports the idea that some sports are using the appropriate head-gear for that respective sport, while other sports could reduce risk by requiring players to wear some form of protective equipment.

Football and Baseball are sports that are continuously researching how to improve their protective equipment. This trend is creating a safer environment for their players and increasing awareness. A possible plan of action that could further reduce the risk of injury is to look into changing the way the games of football and baseball are played and adjusting the rules to promote even more player safety. This is a difficult path due to the resistance to change from many promoters of these sports, but it will lead to more safety for the players.

Soccer is becoming more accepting of players wearing head-gear, but this acceptance is mostly at the youth level. The next step in concussion prevention is for professional soccer players to start wearing the head-gear as well. Professional players wearing this equipment will increase awareness worldwide and knock down some of the social and cultural barriers associated with wearing protective equipment on your head during soccer matches. Following this increase in awareness and acceptance, large organizations should make head-gear mandatory during competitions and practices.

Basketball is a sport that should start funding research into head-gear similar to that used in soccer to prevent concussions due to player-on-player collisions. In Chapter 5 I discussed some of the issues that are involved with wearing head-gear during basketball games and practices. In order for an equipment manufacturer to be able to design a form of head-gear for basketball players, they will need to address a few key issues. The first issue is the protection of the athlete’s head. Athletes
will believe that there is no point in wearing head-gear if there isn’t enough protection that goes along with wearing the head-gear. There needs to be clear evidence that this head-gear will reduce their risk. The second issue to address is the loss of eyesight while wearing the head-gear. This issue can be minimized by designing equipment similar to that seen in Figure 6, where there is no loss of peripheral vision at all. Comfort is the next design component, but the importance of comfort decreases as the reduction of risk increases. This means that players are willing to wear less comfortable equipment as long as they trust it to protect them. The comfort of the equipment should still be well-designed, but it is not a key component. The final issue the manufacturer would need to address would be the social aspect of wearing protective equipment. This can be solved by gaining the support of large organizations such as the National Basketball Association (NBA). If the NBA were to fund research programs and promote the equipment with the support of some of their top players, the youth would be more willing to protect their heads by putting on a headband.

If a manufacturer is able to create a form of equipment that addresses all these injuries, I believe that head-gear could become a part of the game of basketball, just as it has become part of so many other sports. Currently, I believe there are far too many concussions occurring in this sport for there to be no regulations in place to prevent these types of injuries.
References


