



Diploma Programme subject in which this extended essay is registered: Sports Exercise and Health Science
(For an extended essay in the area of languages, state the language and whether it is group 1 or group 2.)

Title of the extended essay: To what extent is football helmet technology effective regarding concussions and head protection today compared to original helmets?

Candidate's declaration

This declaration must be signed by the candidate; otherwise a grade may not be issued.

The extended essay I am submitting is my own work (apart from guidance allowed by the International Baccalaureate).

I have acknowledged each use of the words, graphics or ideas of another person, whether written, oral or visual.

I am aware that the word limit for all extended essays is 4000 words and that examiners are not required to read beyond this limit.

This is the final version of my extended essay.

Supervisor's report and declaration

The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.

Name of supervisor (CAPITAL letters)

Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.

He began the process well, creating an outline that was detailed and structured. He seemed to have a sincere interest in his topic and an understanding of how to formulate his thesis. His initial draft was essentially a descriptive essay, lacking resources or any elements of compare and contrast. Throughout the writing process, he struggled with the development of his thesis and answering his research question. His essay remained one-dimensional, describing helmet technology throughout the twentieth century. He inputted his research late, which affected the flow of his paper. While I believe he learned the proper steps of how to write a research paper, he did not seem concerned with drafting and revising his work. He was more satisfied with completion than anything else.

This declaration must be signed by the supervisor; otherwise a grade may not be issued.

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

I spent hours with the candidate discussing the progress of the extended essay.

Assessment form (for examiner use only)

| Criteria | Achievement level | | | | | |
|-------------------------------|-------------------|---------|------------|---------|------------|--|
| | Examiner 1 | maximum | Examiner 2 | maximum | Examiner 3 | |
| A research question | 1 | 2 | | 2 | | |
| B introduction | 1 | 2 | | 2 | | |
| C investigation | 1 | 4 | | 4 | | |
| D knowledge and understanding | 2 | 4 | | 4 | | |
| E reasoned argument | 0 | 4 | | 4 | | |
| F analysis and evaluation | 0 | 4 | | 4 | | |
| G use of subject language | 1 | 4 | | 4 | | |
| H conclusion | 0 | 2 | | 2 | | |
| I formal presentation | 2 | 4 | | 4 | | |
| J abstract | 0 | 2 | | 2 | | |
| K holistic judgment | 1 | 4 | | 4 | | |
| Total out of 36 | 9 | | | | | |

**To what extent is football helmet technology effective
regarding concussions and head protection today compared to
original helmets?**

Candidate Number:

Word Count: 3855



Abstract

This paper focuses on the development of football helmets starting from the origin to the modern day innovations. The paper seeks to answer to what extent football helmet technology is effective regarding concussions and head protection today compared to original helmets. To answer the question the paper first briefly explains what concussions are and how they are caused. Following this the original football helmets are looked at and the change from leather caps to polycarbonate helmets is broken down and why the change came about is looked at. The paper then changes focus to technology besides the helmets themselves including monitoring equipment such as HITS technology. The reasons for changes today are looked at with specific cases such as Junior Seau being investigated and the impact concussions are having today in the sport of football is finally outlined.

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Introduction

Concussions are serious issues in the world of sports especially in full contact and tackling sports. Contact sports such as American Football are notorious for serious head injuries. Fortunately science and technology is rapidly working on solutions for athletes in all levels of sports especially regarding mechanical ergogenic aids, specifically helmets. American football is one of the most affected sports by these innovations and concepts. Concussions are ever present in the sport of American Football due to the high speed and physical nature of the sport even with new rule changes for the athletes' safety and new technology being developed and altered nearly every year.

Concussions are head injuries which occur when the brain collides with the inside of the skull multiple times (Boriboon, Kia). Concussions are usually caused by an impact to the head such as a tackle or hitting the ground which causes an abrupt change in direction, although being shaken back and forth quite violently can cause a concussion. The cerebral fluid which surrounds the brain and serves as a barrier between the brain and the skull cannot stop the brain from touching the inside of the skull during a concussion resulting in an injury to the brain in most cases.

The effects of a concussion can vary from a small headache at the moment of impact to very detrimental and noticeable symptoms. One symptom may be loss of consciousness if serious enough. The sufferer will experience this specific symptom and most other symptoms simultaneous to receiving the injury. Other signs can include confusion or becoming disoriented. This is diagnosed by asking simple questions to the patient such as his or her name or address. Dizziness or balance issues may occur at the same time as well, the person may not have the ability to walk themselves off the field of play or wherever else he or she received the injury. Headaches are easily provoked while suffering from a concussion, sound and light levels that are regularly tolerable may induce discomfort or pain leading to headaches as well. Concentrating becomes very difficult while suffering from a concussion and the sufferer may not be able to continue in regular studies or work. The final common symptom of a

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concussion is nausea and vomiting. Some people cannot cope with the extreme dizziness that can accompany concussions and therefore vomit (Boriboon, Kia).

Concussions in the game of American football have become very apparent and new research is being conducted at multiple different levels of football to reduce the frequency and severity of concussions. Original American football helmets were leather caps with a strap under the chin attaching it to the athlete's head. Multiple layers of leather were the original source of padding. These helmets were very ineffective in protecting the heads of the players and did little more than serve as a cushion for players. Helmet technology progressed very little for nearly half a century until a plastics company (Riddell) created a very simple but revolutionary helmet made of soft pliable plastic which covered the back and top of the head leaving the face exposed. 1939 marked a huge step in the progression of helmet technology in all applicable sports and even the military (Venables, Mark). In 1957 another big step was taken in the overall design, the facemask was introduced which disallowed helmets and other larger projectiles hitting the face directly. In 1973 air cushions were put into a helmet and this paved the way for different variations and improvements to the air cushion system that is still used today although in a much more sophisticated manner.

However these original helmets, even the plastic ones were doing very little for the reduction of concussions and head trauma. Athletes were still being affected by large hits and blows to the head. With advances being made in medical sciences regarding head safety, more and more concussions were being diagnosed and the issue of brain protection was coming to the forefront for athletes, coaches and trainers. As well multiple companies began producing plastic helmets come the 1940's which accelerated the rate in which new technology was being founded (Venables, Mark).

In the game of American football hits are inevitable and the head is just as likely to be struck as any other part of the body. In a survey conducted on high school football players in America in 2012, 32% of the athletes surveyed admitted to having a concussion that season and only 10% of those players were diagnosed with concussions at the time. These players who keep participating while concussed are

very vulnerable as it is much easier to receive repetitive injuries while the brain is still healing from a first concussion (Boriboon, Kia). Furthermore young athletes whose bodies are still developing are more susceptible to severe concussion and prolonged recovery times (Gilbert, Frederic).

The way the game itself is being played is also changing with new rules in place. Rule changes are attempting to eliminate large hits to exposed players. For example when receivers jump and open up their torso and head area they must be given time to advance with the ball before being struck in the head. As well all levels of football have removed any, and heavily penalize players who initiate, helmet to helmet contact. With rule changes being enforced the game is becoming much more progressive and is changing for the better regarding the players' safety.

With incredible advances occurring as rapidly as they are today and the last ten years especially regarding football helmets, technology is changing the way football is being played and the safety of players. Football helmet technology is becoming very effective in lowering severity and numbers of concussions and protecting the head in general by using new materials, new feedback systems and new designs within football helmets but football helmets are not concussion proof and nor can they be right now while still being functional.

Section 1

Football players have been running into severe issues regarding head injuries and concussions since the creation of the sport in 1876 at the Massasoit Convention (The Peoples History). The sport was originally played in the absence of any type of helmet; however in 1893 one very enthusiastic athlete who loved the game changed this forever. Joseph Reeves risked the possibility of becoming brain dead if he sustained another impact to his head but he asked his shoemaker to create a crude leather helmet which he believed would solve his problems (Blakley, Louis). Thus the first football helmet was created and many other players soon followed Reeves' example, slightly refining the leather bonnet through until the 1940's. Slowly more and more padding was added to the leather caps moving it away from what resembled a flimsy flying cap into a sturdy but not perfect helmet.

The original leather helmets did little for the athletes regarding large impacts which lead to concussions and various other head injuries. Nevertheless it did remove certain symptoms of the game including cauliflower ears. Cauliflower ears, which are swollen ears resembling cauliflower, occur when the ear is directly hit resulting in a block up of fluids within the ear. The helmets also helped prevent small cuts and bruises to the sides, top and back of the head which were a part of the sport. However the helmets did not protect any portion of the face which was left vulnerable due to the bonnet style of the helmets. Yet the helmets did remove direct head on head impacts which were the largest cause for head injuries.

Soon after helmets were made mandatory in play in the 1930's Riddell created a plastic helmet which again changed helmets forever. These helmets were much stronger, lighter and lasted longer than the previous leather helmets but these helmets had one major flaw considering they were being used in a contact sport, if hit hard enough the brittle plastic would shatter leaving the helmet utterly useless to athletes. The helmets most important benefit was that they started to receive the majority of the impact players withstood. The helmets consisted of an inner module which encased the players' head but did not

directly touch the rest of the outer plastic shell. This meant that the helmet now took most of any impact rather than it being focused on players' skulls which the leather helmets were still doing (iSport).

The facemask was another revolutionary step towards players' safety in the game of football. With the introduction of the facemask, which first appeared as a cross shape piece of plastic across the front of a leather helmet in the 1920's, the fronts of athletes' heads were now protected. This also helped in a much more significant manner to preventing concussions because concussions can easily occur if the bottom of a player's jaw is struck forcefully and the longer facemasks prevented direct contact to the chin and jaw area (Football Fever). After Riddell invented the first plastic helmet they also invented a more professionally designed facemask, rather than merely taping plastic to the leather caps Riddell allowed facemasks to be removed and replaced. However these facemasks were still fabricated from plastic and did break in big impacts similar to the helmets they were attached to (Football Fever).

After the large step of plastic within the football helmet revolution it kept evolving more and more, different aspects became even more vital as research being performed dictated the causes of severe injuries and helmet producers could change and adapt their products to the new research. In the 1940's little changed to the plastic helmet of Riddell which disallowed the players' heads to come into direct contact with the outer shell. Come 1950's, after WWII, the football helmet started to change once again. In 1957 the premier tubular facemask was created and used on football helmets. This new rubber coated plastic facemask did not smash quite as easily. This was after previous facemasks had been banned for shattering on impact and impairing players' vision when the shards of plastic were sent array.

In 1973 football helmets took another large leap towards what they are today. An air fitted football helmet finally met new industry tests to become a marketable helmet. The bladders in the helmet could be inflated and deflated to fit the players' heads more effectively. The proper fit ensured the outer shell did not come too close to the skulls of the players rendering the helmet ineffective. As well the helmets could be tightened to the exact fit so the players' heads could not shift back and forth freely

within the helmet which could worsen injuries if they occurred. In 2002 the air cushion and bladder technology was further developed which allowed even more space between the head and the outer shell.

The need for change was quite obvious to the officials and the players involved with football in the last decade with a big push for player safety and concussion prevention. One big case of concussion symptoms and the effects of professional football is Junior Seau. Junior Seau was a linebacker in the National Football League for a long career of 20 seasons from 1990 to his retirement in 2009. He did not leave the sport until he was 40 years old, much older than the average for the NFL which is only 28. The sport takes a heavy toll on the whole body including the head forcing most people to play less than 10 years professionally. Junior Seau was one of many players who received multiple concussions throughout his career. Unfortunately he suffered from depression very soon after leaving the NFL and took his own life in 2012, three years after his retirement (Gbajabiamila, Akbar). He shot himself in the chest similar to Dave Duerson who donated his brain to research in a suicide note. Both players' brains were studied and both were diagnosed with chronic traumatic encephalopathy, a degenerative brain disease which atrophies integral functioning parts of the brain including the medial temporal lobe, thalamus, brain stem and more (McKee, Ann). Chronic traumatic encephalopathy is common in boxers with early cases recorded in the 1920's and in football players both sets of athletes are in constant danger of being repetitively struck in the head which is the cause of chronic traumatic encephalopathy (McKee, Ann).

There are many other cases similar to Junior Seau and Dave Duerson and this has caused the NFL and many other leagues to change many aspects of the game including the helmets. The NFL was sued in 2013 by the families of those who were believed to be victims to multiple concussions and retired players who are still alive for a total of \$765 million part of which is designated to funding concussion research as well as compensation for those suffering with severe concussion symptoms. The NFL has also modeled rule changes for other leagues including college and high school sports. High school leagues now even have mandatory baseline tests for athletes before the season starts and the athletes must pass the test again before being able to play again.



Section 2

Within the last ten years the technology in football helmets has developed faster than at any other time in their short history. Rapid changes in materials and design are creating much safer helmets than ever before. Vin Ferrara, a quarterback at Harvard graduating in 1996, recently came across an ingenious new way to protect the head of football players in 2007. He saw a simple squeeze bottle in his medicine cabinet and realized how well it dispersed the energy of an impact by deflating a bit when struck (Schwarz, Alan). With help from neurologist Dr. Robert Cantu he received legitimate reassurance that his idea may work before taking it to engineers to develop a helmet out of the squeeze bottle. The helmet was released for sale in 2008 and featured a polycarbonate shell lined with 18 small black discs which slightly deflated when struck to release the energy away from the helmet and the head (Schwarz, Alan). The three dimensional liner in this helmet relies on the small structures to reduce the impact rather than the traditional rigid foam liners which relied on material density to protect the skull and brain (Post, Andrew). It passed all pre market tests which dictated that it cannot exceed 1200 on the severity index because that is when the skull can start to fracture. Ferrara's design averaged 340 severity index units which was lower than any other helmet on the market at the time. Ferrara's design scored in the 200's in several key testing areas and concussions occur at 300 severity index units or higher meaning his design met industry standards and received certification to sell (Schwarz, Alan). This changed the way football helmets were designed once again and new helmets today are based off of the same technology moving away from the rigid foam which had been used nearly since plastic was introduced in 1939. The air cushions last much longer and are much more effective at directing energy away from the head than the rigid foam.

Another factor pushing the technology of football helmets is the competition between leading helmet manufacturers. There are four major brands which are all looking for new ways to protect the head, Riddell, Adams, Schutt and Xenith. In 2007 84% of NFL players were wearing Riddell helmets before Xenith made their air cushioned helmet. Now the competition to perfect this technology and develop new ideas is being led by Xenith and Riddell. Adams, Schutt and Xenith focus more on younger

athletes in high school programs that cannot afford to purchase team sets of high end helmets but whose parents are interested in their specific child's safety.

However competitive the technology race may be the companies are still not able to create a completely concussion proof helmet today. The materials that are being used cannot enable helmets to be completely rid of concussions while still being functional. Dr. Timothy Gay says that it may be possible to create a concussion proof helmet however the helmet would have to be wrapped in fifteen inches of foam rubber on the outside (Wilson, Mark). In one opinion on concussion proof helmets, Barry Jordan M.D. M.P.H., simply stated that there is no way to remove concussions from contact sports because a helmet does not and will not stop the rapid acceleration or deceleration of the head but does aid in more serious head traumas such as crushed skulls. In his opinion football equipment has not helped to improve players' safety in any significant way.

Technology apart from the helmets themselves can be extremely helpful in diagnosing concussions and keeping track of the players' heads in games and practices. In helmet sensors developed by Simbex called HITS (Head Impact Telemetry System) does exactly this. HITS relays information straight from the field to the sidelines in real time so each hit can be analyzed by technicians and doctors during the game. This allows doctors to pull players off the field if a hit is deemed too violent or if a concussion may have occurred. HITS uses six accelerometers placed in a U-shaped pad that fits into helmets, along with a radio transmitter that sends the information to the sidelines. The accelerometers pinpoint the g's experienced in the hit and exactly where the hit happened on the helmet and the information is presented on graphs on computers on the sidelines (Venables, Mark). In 2003 HITS was used for the first time in the NFL at the same time the helmets were being used in Virginia Tech University to record data there. While using only 8 helmets throughout the whole team 3,212 impacts were recorded in the course of just one season (Noden, Merrell).

Diagnosing concussions is an important aspect of developing the helmet technology and athletes need to be involved in this part of prevention for advances to be made. Multiple guidelines are available

to trainers and coaches in regards to return to play after a concussion. Two examples of such guidelines are the American Academy of Neurology and the Prague return to play guidelines. The AAN guidelines use a grade system of the concussion (either I, II or III) and are accompanied by appropriate timelines of return to play according to specific systems. The newer Prague system does not grade the concussions in the same way but rather bases its return times on symptom resolution. If the concussed person can pass certain criteria asymptomatic then they are deemed to go to the next stage continuing on for five stages (walking, light jogging, jogging, running, playing) until they can compete again (Yard, Ellen).

A large study by Ellen Yard and Dawn Comstock from 2005 to 2008 looked into the compliance of these guidelines from high school athletes in the USA. The data from the study is shown below and is graded using the AAN guidelines. These numbers are averages per 100,000 exposures (Yard, Ellen). In the 2007-2008 column criteria in which they were using changed in that they asked the trainers involved to report all concussion no matter how long the affects lasted. Previously the concussion had to have an affect lasting at least one day or longer.

| | 2005-2007 | | | | 2007-2008 | | | | Overall | | | |
|------------|-----------|---------|----------|-----------|-----------|---------|----------|-----------|---------|---------|----------|-----------|
| | Total | Grade I | Grade II | Grade III | Total | Grade I | Grade II | Grade III | Total | Grade I | Grade II | Grade III |
| Football | 22.7 | 1.32 | 19.8 | 0.82 | 24.1 | 2.07 | 19.8 | 1.59 | 23.2 | 1.6 | 19.8 | 1.1 |
| Soccer | 25.8 | 1.49 | 22.5 | 0.81 | 28.2 | 2.52 | 22.7 | 2.09 | 26.7 | 1.87 | 22.6 | 1.28 |
| Baseball | 47.2 | 2.79 | 42 | 0.75 | 52.7 | 4.19 | 43.3 | 3.32 | 49.3 | 3.32 | 42.5 | 1.73 |
| Ice Hockey | 21 | 0.3 | 18.3 | 0.9 | 19.2 | 1.97 | 15.8 | 1.48 | 20.4 | 0.93 | 17.4 | 1.12 |
| Netball | 7.09 | 0.47 | 6.38 | 0 | 8.41 | 1.6 | 6 | 0.4 | 7.58 | 0.89 | 6.24 | 0.15 |
| Swimming | 16.4 | 1.55 | 12.4 | 1.86 | 14.5 | 1.11 | 10.6 | 2.79 | 15.7 | 1.39 | 11.8 | 2.19 |
| Softball | 4.09 | 0.29 | 2.92 | 0.88 | 2.15 | 0.54 | 1.07 | 0.54 | 3.41 | 0.38 | 2.27 | 0.76 |
| Wrestling | 16.6 | 1 | 14.5 | 0.84 | 15.9 | 1.16 | 14 | 0.58 | 16.4 | 1.06 | 14.3 | 0.74 |
| Other | 28.9 | 1.31 | 2.63 | 0.99 | 26.5 | 1.73 | 24.2 | 0.58 | 28 | 1.46 | 25.5 | 0.84 |
| Netball | 21.3 | 1.4 | 18.5 | 1.12 | 18.1 | 0.5 | 16.6 | 0.5 | 16.6 | 1.08 | 14.7 | 0.74 |
| Baseball | 6.07 | 0 | 5 | 0.71 | 10 | 1.18 | 8.24 | 0.59 | 7.56 | 0.44 | 6.23 | 0.67 |
| Softball | 7.07 | 1.18 | 5.5 | 0.39 | 6.9 | 1.38 | 4.83 | 0.69 | 7.01 | 1.25 | 5.26 | 0.5 |



These numbers show the extent to which football players are at risk to concussions when compared to any other sport, 49.3 per 100,000 the next closest being girls' soccer, 28 per 100,000. Football is nearly double all the other sports showing the importance of the development and treatment of concussions. Even with modern helmets, this recent study still demonstrates the numerous brain injuries that may occur and each athlete is subject to multiple exposures especially in a contact sport such as football.

These numbers are easy to manipulate though, this study could be compromised by trainers misdiagnosing concussions and athletes falsely reporting symptoms if they feel that it is not a serious issue or they are too competitive, wanting to get back into the game much sooner than recommended inflicting worse damage. This may shed light onto the issue of concussion occurrences but is subject to inaccuracy due to the human element present in the data collection.



Conclusion

In general the technology of football helmets is rapidly developing especially within the last ten years. The advancements in materials being used have advanced the design and effectiveness of football helmets in an incredible way. New designs are incomparable to what was being used 100 years ago when football helmets were still in their infancy as a piece of sporting equipment. From leather bonnets to polycarbonate battering rams every aspect of the helmet has come a long way to what it is today. The leather helmets slowly developed from caps to harder padded hats until the breakthrough came in 1939. After plastic was introduced to helmet designs in 1939 evolution of the helmet sped up. Soon came the facemask in 1957 changing the look of the helmet to what it is today, however many drastic changes were still to come. For example air cushions were put into helmets in 1973 for the first time which changed the way people thought of helmets forever, diverging from dense, rigid foams to many more possibilities now. This air cushion notion was used in a much different manner in 2007 which made a much bigger impact on the way helmets are being designed today. The small deflating discs are the most effective means of dispersing unwanted energy away from players and prolonging impacts avoiding sudden sharp impacts which are more likely to cause head injuries that is known today.

All these different methods of protecting the head of football athletes have changed how affective football helmets actually are. The rapid developing technology has created helmets that are great at lessening and preventing concussions, however this technology is not quite developed yet. There are still greater things to come in the football helmet evolution but today there is no helmet that can definitively eliminate concussions in every possible instance. Therefore, football helmet technology is effective regarding concussions and head protection today to a great extent.

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