Prevention Strategies of Traumatic Brain Injury in Football Players

Zachary Hall[1§], Gary Baxter[2], Neil X. Dong[3], and Shih-Feng Chou[1†]

[1]Department of Mechanical Engineering
The University of Texas at Tyler
3900 University Blvd., Tyler, TX, 75799, USA
[2]Project Rose Research Institute for Sports Science
1814 Roseland Blvd #100, Tyler, TX, 75701, USA
[3]Department of Health and Kinesiology
The University of Texas at Tyler
3900 University Blvd., Tyler, TX, 75799, USA

[§]Presenting author: zhall2@patriots.uttyler.edu
[†]Corresponding author: schou@uttyler.edu

Abstract

In this project, we study the effects of the impact angle during a helmet-to-helmet collision on stress distribution and deacceleration values of the brain tissue in efforts to reduce brain injuries for football players. The overall goal is to provide sufficient information to improve the design of helmet technology. In addition, our study will be able to inform the athletes to avoid a helmet-to-helmet collision, such that, they can be trained to shift their heads in the horizontal direction to create a "glancing blow" effect. It is suggested that by avoiding a helmet-to-helmet collision, both rotational acceleration and stress can be reduced leading to a lower probability of receiving concussions and subsequent brain injuries [1].

1. Introduction

It's noted that athletes have a much higher risk of sustaining concussions and brain injuries. In addition, after receiving concussive injuries, they are at a much higher risk for other non-neurological injuries [1]. According to a study, athletes who had prior concussion history were 2.5-fold higher in the likelihood to injure their lower extremities or ligaments as compared to their non-injured teammates [1]. Furthermore, athletes injured by concussions are a public health concern and a burden to healthcare [1]. For professional athletes, especially those in a contact sport like football, they spend a large portion of their lives on the playing field in situations where physical injury is highly likely. As such, it is crucial that they have the best protection possible [1].

For many years, the National Football League (NFL) reported minimal evidence that helmet-to-helmet hits during professional football games resulted in brain trauma. However, in the recent years, NFL has made great efforts and spent millions of dollars in research and development to improve professional players' health either by improving the design of the helmets or by providing training package to players to reduce the possibility of a concussion [2].

A concussion is a type of mild traumatic brain injury resulting from a sudden impact or a change in the direction of motion causes the brain to cease normal functionality. While there are numerous causes for concussions, falls, car accidents, etc., physical impact sports are responsible for a large proportion of them [3]. With football being a highly physically sport, concussion are common place and lead to lasting brain deficiencies, such as headaches, anxiety, and depression. It's important to develop technology to prevent concussions and their side effects in athletes.

In essence, this work aims to study the effects of collision angle on stress distribution and deacceleration values of the brain tissue to provide important information to football players on chance of receiving concussion during a helmet-to-helmet collision. Our hypothesis is that a "glancing blow" produces significantly higher stress distribution and deacceleration on brain tissues than the one that is shifted horizontally by an angle. Our study will enable the players to learn the importance of avoiding head-on helmet-to-helmet collision by shifting their head in the horizontal direction, which will significantly reduce the chance of receiving a concussion.

2. Methods

In order to perform the test without sacrificing players' health, we build a computer automated design (CAD) model of a skull wearing a NFL regulation helmet followed by using the particular CAD model with a dynamic simulation software to emulate a collision. For this, we use a modeling software program called SimScale (Fig. 2 – Fig. 4).

Earlier it was stated that there are two things that play a key role in a head impact resulting in a concussion, stress distribution and deacceleration [1]. These two values can be directly measured using SimScale, as a data field shown in a gradient color model and point data, across an adjustable data collection period. (Fig. 1 and Fig. 5)

The impact period is defined inside of SimScale by first setting the total time for which the data is to be collected over, and then setting the interval for how often the data is to be collected during the time period to obtain a certain number of data points [4]. That number is calculated by dividing the total time period by the collection interval time.

After the data collection scheme was set, the next step was to determine by how much to shift the skull and which direction best to shift it. It was noted that if the skull was shifted too far towards the edge of the wall that skull would begin to rotate instead of creating a “glancing blow”.

As such, locations were defined on the impact materials along the center line of the skull to the edge of the impact materials which then were used to produce a “middle point”. Using the non-adjusted model as a control, numerous simulations were run with varying data collection intervals to see if a pattern emerged and if that pattern lends itself to the hypothesis.

3. Results and Discussion

3.1 Results

These helmet collision simulations were performed on SimScale, where data showed the stresses and deacceleration values in region of primary motor cortex in the brain (Fig. 1). In addition, simulation results were made to compare stress and deacceleration results between head-to-head collision (in axis) and a 20° tilt of the skull (i.e., 5 cm lateral displacement for a 6-foot football player) (Fig. 6). Results from minimum von Mises stress suggested a significant decrease from 84 kPa to 27 kPa if the football player could avoid the head-to-head collision as a result of the tilt. The much-lowered stress spreading over a longer time scale during impact indicated a decrease in energy absorbed by the helmet and brain during collision.

Furthermore, head-to-head collision produced +3.5 and -3.2 m/s^2 deacceleration value within 0.01 ms, which could potentially result in significant brain damage (Fig. 7). In comparison, if a football player was able to tilt the head for 20°, the deacceleration value was 40-fold lower. Overall, our preliminary data suggested that concussion could be avoided if the football players were better trained and can tilt their head to avoid head-to-head collision.

3.2 Discussion

While these results proved the initial hypothesis, it’s worth noting that the next step is to further increase the amount of data taken over the collision interval time in SimScale, so that this may be used in further research. As such, the data interval was increased to have 150 data points, which also produced a similar significant decrease in von Mises stress in the skull, from to, which further agreed with our initial hypothesis. These are important steps in preventing an NFL athlete from receiving a concussion.

4. Summary

According to the established methods and the results (approximately 50 simulations), shifting the skull from the middle point toward outer edge of the impact materials reduced stress distribution and deacceleration in brain tissues (Fig. 6 - 7). Our results suggest that by providing a better training package, athletes may be able to protect themselves from concussion if a proper self-defensing technique (i.e., tilting heads) is employed.

Acknowledgement

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References

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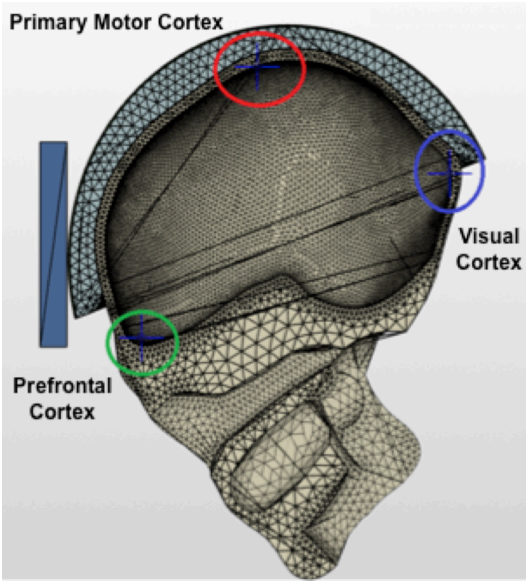

Figure 1. Location in the skull for data collection.

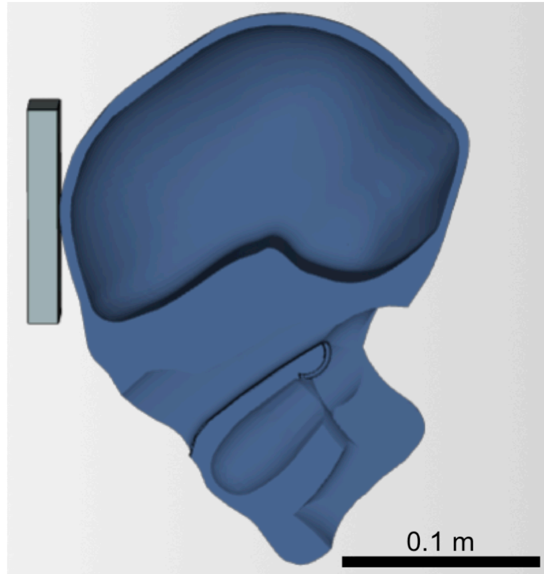

Figure 2. Simscale model.

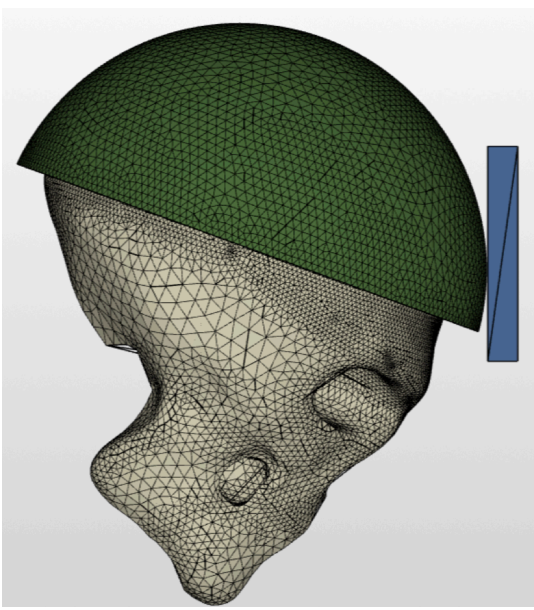
Figure 3. Helmeted skull mesh.

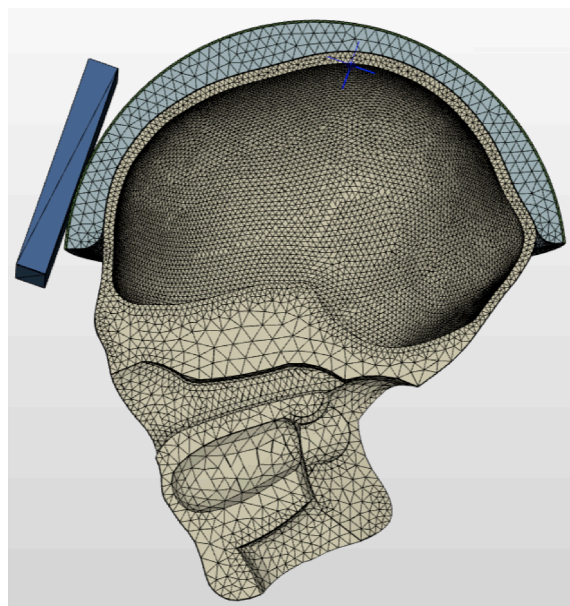
Figure 4. Helmeted skull mesh.

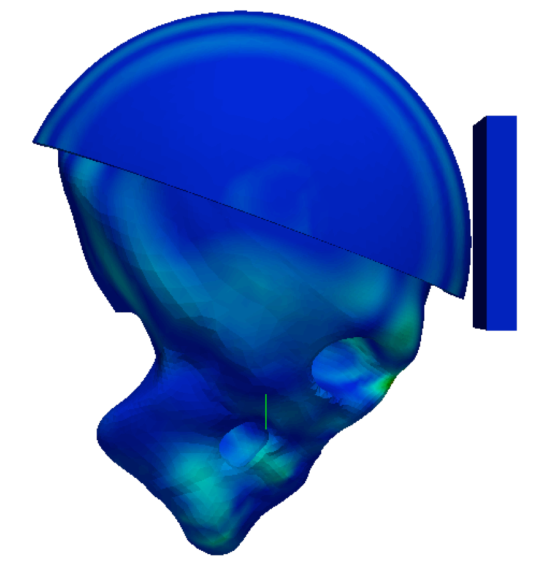

Figure 5. Deacceleration gradient field during impact.

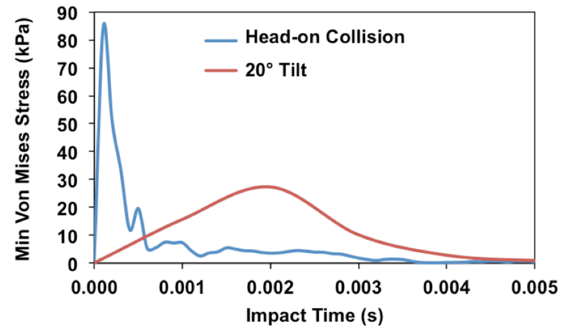

Figure 6. von Mises stress at the primary motor cortex during impact comparing head-on collision and collision after tilting.

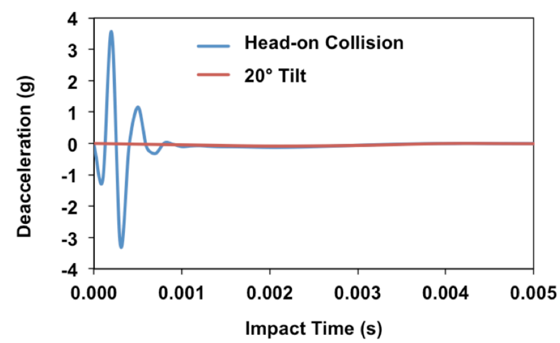

Figure 7. Deacceleration value during impact at the primary motor cortec comparing head-on collision and collision after tilting.