Concussion Detection System

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1 Introduction

Concussions seriously affect athletes with injuries sustaining a lifetime. Despite these long lasting injuries, concussions still occur frequently. In one year, there are 1.7 to 3.0 million concussions recorded in sports. A majority of these concussions occur in sports with athletes wearing helmets, such as football, hockey, and lacrosse. These sports are commonly played as students. As a result, student athletes are more prone to concussions with traumatic brain injuries than any other athlete. Even more worryingly, an estimated 5 in 10 concussions go unreported. Because coaches, trainers, and doctors do not have numerical data to diagnose a concussion when it happens, serious injuries are often overlooked, allowing athletes to continue to play. For example, Tua Tagovailoa suffered two serious head injuries in a row. The public saw Tagovailoa possibly seriously injure himself as he was stumbling off the field with the first concussion. Yet, a week later Tagovailoa was cleared to play again and was hit in the head again. Instead of stumbling, he started clenching his hands in response to a most likely brain stem injury that could have been prevented with definitive data on his head injury status the first time. Tagovailoa is one example of the serious injuries that can occur from concussions.

2 Problem Description

Though there are several ways to aid the concussion epidemic, a major help would be a way to detect a concussion when it occurs. The question is if there is this need for a concussion-detector, why has it not been created already? There are several factors that need to be considered: size, weight, durability, receivers, transmitters, material, and more. It is only in recent years with the development of technology that a marketable concussion-sensor is possible. There are new companies like NoMo that are developing innovative electroencephalography (EEG) headbands that can detect the brain’s physiological response to a hit. However, NoMo is being sponsored by the military and professional sports. This means that the technology embedded into the headband could be more costly. If the technology is more costly, then it becomes inaccessible to more of the population. A majority of high-impact sports are played in high schools, which are already severely underfunded. A high-technology concussion-detector would be unfeasible for these high schools to purchase. Therefore, our goal is to create a low-cost concussion-detector for student athletes.

3 Proposed Solution

In general, the concussion-detector should be able to gather data, receive data, and determine if a player has been hit in such a way that may cause a concussion. In order to do this, we will break down the project into three parts and five functions with various requirements.

3A. Three Parts

1. Sensor

The sensor itself is crucial to the proposed solution as it will collect the data to determine when a concussion occurred. The sensors mentioned will be an accelerometer and a pressure sensor. The exact requirements for the sensor are listed:

I. Sensing Properties
   A. Determine the neutral position of the head
   B. Measure a change of position of the head
   C. Identify the origin of the change of position of the head

II. Physical Properties
   A. Lightweight
   B. Thin
   C. Heat-repellent
   D. Sweat-resistant/somewhat water resistant for certain applications
   E. Durable

2. Application

The application will receive the data that the sensor collects and alert the user when a potential concussion has occurred. The back end should be all the programming to detect a concussion, while the front end is the user interface. The following properties are needed for the application:

I. Back End
   A. Receive the live data collected from the sensor
   B. Store the data into a programmable format
   C. Create functions that can:
      1. Detect when there is a large change of the position of the head in the data
      2. Store potential large changes in the data and add the data together to account for potential accumulation of hits

II. Front End
   A. Show if the application is receiving live data or not
   B. Display the live organized data
   C. Notify when a large change of position of the head has occurred
   D. Alert when a potential concussion has occurred

3. Design

The design of the concussion-detection system will be such that it can be placed inside a helmet since most concussions occur in helmet-required sports. This means that the detection system:

I. Fit in various types of helmets such as hockey, football, boxing, and lacrosse
II. Not move when the user is playing their sport
III. Not pose any additional risk to the user or in any way compromise the integrity of the helmet they are already wearing
IV. Stay comfortable for the user by being breathable, sweat-resistance, and minimize heat trapping
V. Function in various environments where the sports are played such as outdoor and indoor locations

3B. Five Functions

The 5 main functions connect the 3 main parts–sensor, application, and design–to create a functioning concussion-detection system. The 5 main functions are:

I. Detecting when a helmet or head has been hit: This will be the main function for the sensor. The sensor should be able to detect a change of position of the head. Through reading scholarly articles and various experimentation, a set change will be designated as a concussion-possibility threshold.
II. Recognizing where the hit made contact with the helmet or head: This is the secondary function for the sensor. The sensor will most likely be composed of various sensors. Therefore, a specific sensor should be able to flag itself if it feels the most pressure from a hit compared to others.
III. Receiving live data from the sensors: This is the most important part for the application. The application will receive live data from the sensors most likely through bluetooth or wifi. If no data is received from the sensors, then there is no chance to detect a possible concussion.
IV. Differentiating between a regular hit and a concussion hit: This is the secondary function for the application. Through programming and the concussion-possibility threshold, an alert can be created when the change of position of a head hits an extreme, or is moved in a way that has been known to cause concussions. This will all be in the back end portion of the application.
V. Alerting when a concussion hit has occurred: The alert is the third most important function for the application. The alert is the easiest and fastest method to alert the user for when a potential concussion hit has occurred. This would allow the user to pull the athlete out immediately and check up on them.

4 Demonstrated Features

At the end of this project, the concussion-detection system should have all the following parts and features working:

I. Sensor Features
   A. Detect a neutral position of the head
   B. Measure the change of position of the head during a potential hit
   C. Identify changes of pressure to the head during a potential hit
   D. Transmit position of head to application

II. Application Features
   A. Store data provided by the acceleration and pressure sensors
   B. Organize the data into programmable formats
   C. Distinguish between a potential concussion hit and a regular hit from the organized acceleration and pressure data
   D. Add regular hits together to account for potential concussions from consecutive hits
   E. Display a functional and easy-to-use interface for users to see the live-data from the sensors on their phones
   F. Alert the user on their phone when a possible concussion has occurred

III. Design Features
   A. Create a light-weight, durable, sweat-resistant, and heat-repellent device that houses the acceleration and pressure sensors
   B. Fabricate the device such that it fits in various helmet types and sizes

With these 12 features, our concussion-detection helmet should be able to identify a potential concussion when a hit occurs.

5 Available Technologies

There will likely be several technologies that will be necessary to complete your project and multiple choices were highlighted to showcase flexibility:

1. Wireless Communication: Available on ESP32 - Free
2. Application: Available to build online - Free
3. Circuit Board - $50
4. Accelerometers
   a. IIS2D Series 3.6 V Ultra-Low-Power 3-axis Digital Magnetic Sensor - LGA-12 - $2.62/unit
   b. LIS2MDL Series 3.6V 50 Hz High Performance 3-Axis Digital Magnetic Sensor-LGA-12 - $1.81/unit
5. Pressure Sensors
   a. Digi-key 101020031 Grove Piezo Vibration Sensor - $6.50/unit
   b. Piezo Vibration Sensor - $5.50/unit
6. Headbands

   a. Acozycoo HeadBands - $11.99/5 units
   b. BEACE SweatBands - $16.95/3 units
7. Helmets
   a. Hockey Helmet - $49.99
   b. Football Helmet - $150.00
   c. Boxing Helmet - $17.99
   d. Rugby Helmet - $39.99

6 Engineering Content

The team should have significant struggles in designing, building and hopefully not destroying the product. One important aspect is designing the board to accommodate all the parts required to allow working, real time feedback.

To create such a technology we will need to first create and design a board to accommodate a minimum of 10 pressure sensors to go around the head. The wires and design must all be separate and distinct so we can tell where the impact occurred. There must also be a minimum of 4 accelerometers around the head that detect the speed and direction of the head after a hit. We must differentiate between a quick and safe motion of a head turn and an actual hit or whip that could cause a concussion. Creating an algorithm to decide whether or not a serious concussion worthy hit occurred will take significant research and fine tuning. Also, with the added protection of a helmet, some hits are not as serious as others so that must be factored in. Further we will have to find a way to protect the device such as the board design during a play so that the device neither hurts the player nor is destroyed during play. The device will have to have a protective cover that may have to be 3D printed or created from other materials.

Another challenging component of this project is its connectivity to a wifi application that displays the results of the hit. This application needs to update in live time to inform the players and sports staff immediately of a potential concussion. Time is of the essence with concussions, so it is very important that this component of the project works as intended. Another important component of the project will be testing. We will need to perform very extensive tests on our product to see if it performs as intended. The existence of multiple different sensors on our product requires more extensive testing than other groups. The physical placement of the sensors on the product will need to be tested to determine which location is best and many different types and placements of hits will be tested. We anticipate that the testing will be conducted on different helmets and in different environments applicable to each sport as well to give a clearer and more accurate picture of the hits that can occur during different types of gameplay and while wearing different helmets. It is imperative that the device works in different environments and temperatures as well.

7 Conclusions

To battle this serious epidemic of head injuries, a concussion sensor on a helmet or head apparatus could likely report head injuries when they occur or help reduce future head injuries. The goal is to create a sensor that can provide live feedback, through an app, about the hits taken by the head. With live feedback, it would be easier for coaches, trainers, and doctors to diagnose concussions, as well as when the concussion happened. On top of this, the data collected can help determine whether a player is cleared to continue playing, reducing the possibility of secondary concussions occurring. With that being said, there are several factors that need to be taken into account in the development of the sensor: multiple data points, size, weight, and durability. It is also important to make sure that wearing the sensors will not pose any additional risk of injury to the athlete or in any way compromise the integrity of the helmet they already wear. Despite these factors, it is highly plausible that a sensor that reports head injuries when they occur can be developed using the iterative design process and at a low-cost. Hopefully, our low-cost product can be implemented in youth sports programs across the country, increasing concussion awareness.