Ankle Injury Prevention

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1.) Introduction

1.1) Objective:

Our team wants to help basketball players of all levels prevent ankle injuries by monitoring ankle stress throughout a basketball game. After collecting ankle stress data, we can analyze the data and show players time instances where they put their ankle under extraneous stress, how stable their ankle behaves on landings (bad landings is the number one cause of ankle sprain) and whether their ankle stress patterns are similar to the patterns of a low injury-risk player or to the patterns of a high injury-risk player. We will measure ankle stress through the design of a shoe outfitted with the appropriate sensors. By measuring ankle stress, we can even design a metric "Ankle Stability" that informs professional players of the reliability of their ankles given their movement mechanics. This measure will greatly help inform coaches in deciding how long to play a player in a game to maximize their output and minimize their injury-risk.

1.2) Background:

In basketball, the most common injury that occurs is the ankle sprain or ankle roll. This injury occurs when the ankle inverts or everts more than its normal range of motion, thereby tearing ligaments and causing swelling. A tally of all injuries has shown that 13% of injuries at the NBA [1] level and 40% of injuries at the high school level [2] are ankle injuries, making it the most common injury at both levels of play. To describe the motion of the ankle, we will use the following terms. The frontal plane describes the eversion and inversion of the ankle (twists inwards and outwards), while the sagittal plane describes the dorsiflexion and plantarflexion of the ankle (moves up and down) [3].

Today, basketball players have access to athletic shoes and ankle braces that may help to support ankle joints, however these do not provide any sort of feedback to the player. Our device goes a few steps further by collecting the ankle range of motion data, comparing that data to the player's normal range of motion, and then providing feedback as to how the player's ankle behaved during a game. Additionally, our solution will be easy to use and will not interfere with a player's performance. In the end, we expect this device to help prevent ankle injuries amongst basketball players by giving both the player and the coach a better understanding of possible ankle injury.

1.3) Physical Design:

The system will fit onto a basketball shoe. A pressure sensor will be fitted onto the bottom surface of the shoe, which will help detect when a player jumps and lands. The microcontroller, battery, and bluetooth components will be packaged and mounted onto the top of the shoe. We thought about placing this package into the sole of the shoe to abstract away the complexities of the design from the user, but we recognized the importance of the sole of the shoe for performance in basketball. Therefore, to preserve the integrity of the shoe, we decided to mount this package on top of the shoe. Flex sensors that help us collect ankle rotation data will be adhered to a soft sleeve that extends upwards from the heel of the shoe. This soft sleeve will adhere closely to the user's ankle, allowing the flex sensors to flex appropriately as the user rotates his ankle.

Figure 1: Physical Design

1.4) High-Level Requirements List:

- The device must be able to operate for the entirety of a basketball game (approx. 30 minutes) and weigh less than 100 grams in order to simulate natural movements and not inhibit the player's movement.
- The sensor module is able to detect a player's range of motion (ROM) in each plane and compare that data to the normal range of motion for each respective plane. Frontal plane

ROM: 23 degrees inversion through 12 degrees eversion; sagittal plane ROM: 10 to 20 degrees of dorsiflexion through 40 to 55 degrees plantar flexion. [4]

- The mobile app must be capable of interpreting the flex sensor and pressure sensor data in order to provide relevant and reliable feedback to the user.

2.) Design

2.1) Block Diagram:

The power unit will be able to supply power to the signal collection unit for at least 30 minutes in order to be able to function for the entirety of a basketball game. The physical components, the power unit and the signal collection unit will be designed to inhibit the movement of the player as much as possible. The signal collection, processing and user interface units will all be able to work together in order to interpret the data and provide relevant feedback to the user. Finally, the pressure and flex sensors of the signal collection unit will be designed to detect the physical angle of the user's ankle and the signal processing unit will be designed to interpret this data and compare it to data of the normal range of motion of the ankle.

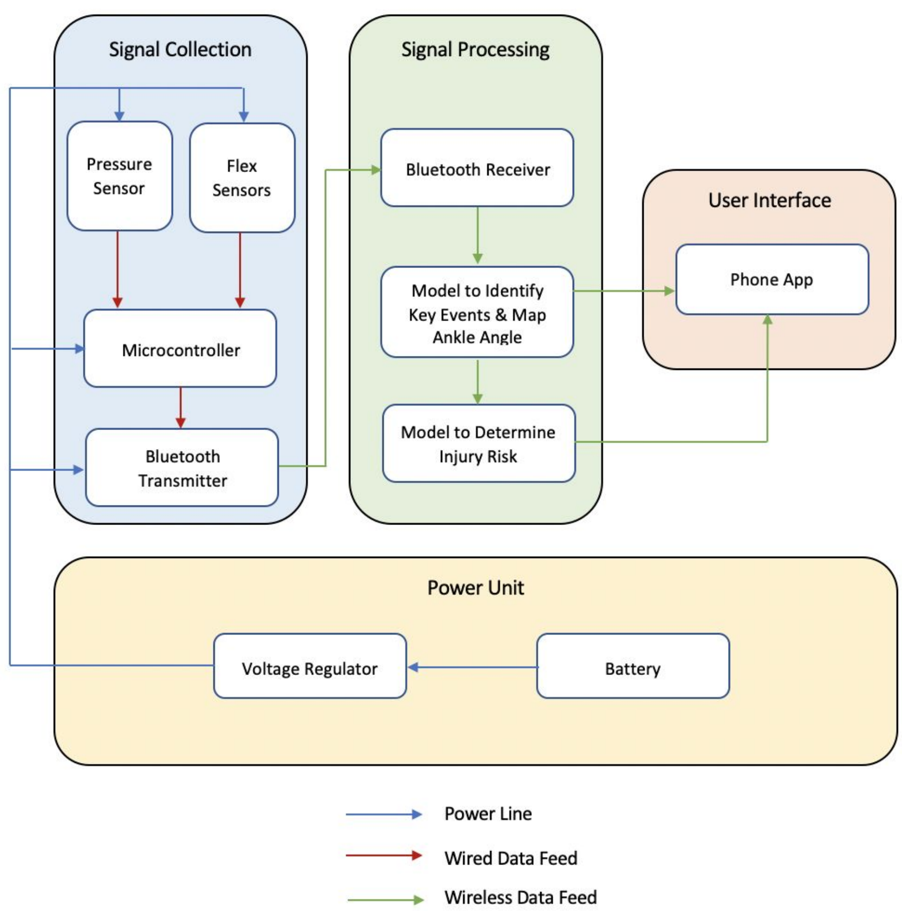

Figure 2: Block Diagram

2.2) Functional Overview and Block Requirements:

2.2.1) Power Unit:

This system provides power for the Signal Collection module.

Battery:

We will use rechargeable batteries to power the microcontroller, bluetooth transmitter, flex sensors, and pressure sensor. They will be connected to a voltage regulator, and the voltage will be properly regulated. The batteries will have to supply at least the operating voltage of the microcontroller. The batteries will be charged using an A/C adapter plugged into an outlet.

- Requirement 1: The battery must be able to power the flex sensors, pressure sensor, and bluetooth transmitter.
- Requirement 2: The battery should be able to do so for at least 30 minutes.

Voltage Regulator:

The voltage regulator will be used to provide the correct operating voltage to the flex and pressure sensors. This setup allows us to have a localized power unit, which we can regulate before powering the various blocks.

- Requirement 1: The voltage regulator must be able to distribute a lower voltage to all flex sensors and the pressure sensor.

2.2.2) Signal Collection:

This system collects data from the user and transmits it to the Signal Processing module.

Microcontroller:

Our microcontroller will be used mainly for data collection and transmission purposes. It will take in the raw data from the flex and pressure sensors and then utilize the bluetooth module to transmit the data to the mobile app platform.

- Requirement 1: Must be able to collect data from the flex and pressure sensors at a rate of at least 2-5 Hz.
- Requirement 2: Must be able to properly send data to the bluetooth transmitter.

Bluetooth Transmitter:

The bluetooth transmitter will communicate with the microcontroller using a UART connection. It will send data collected from the sensors through the microcontroller at a fixed frequency to the bluetooth receiver.

- Requirement 1: Must be able to pass data from the sensors to the bluetooth receiver.

Flex Sensors:

The 4 flex sensors will be used to collect data on the angle of the user's ankle. The sensors will use the resistance of the sensor in order to attain a value for normal angle position as well as values for abnormal positions. This data will then be passed to the microcontroller.

- Requirement 1: Must not drastically change resistance values with use.
- Requirement 2: Must reliably give data that is different for both normal ROM and ROM that causes injury.

Pressure Sensor:

The pressure sensor will be used to collect data on which section of the ankle and foot the user is applying pressure on. It will also be used to determine when the user is jumping and landing. The sensor will be able to attain the value for the normal amount of pressure placed on each section by the user and compare that to any abnormal amount of pressure in a certain area. The data will then be passed to the microcontroller.

- Requirement 1: Must reliably give data that is different for both normal ROM and ROM that causes injury.

2.2.3) Signal Processing:

This system receives data from the Signal Collection module and processes it, sending the processed data to the User Interface. The bluetooth received mentioned here is the bluetooth receiver of the user's phone and the two models are both run on the phone.

Bluetooth Receiver:

The bluetooth receiver will receive data from the bluetooth transmitter and will then share that data with the model to determine injury risk. The bluetooth receiver will be at a location which optimizes the communication radius of the bluetooth module.

- Requirement 1: Must be able to receive data from the bluetooth transmitter and share that data with the model to determine injury risk.

Model to Identify Key Events & Map Ankle Angle:

This is the software module where we establish basic digital understanding of how the ankle is being used in the real-world. We implement identifying key events in basketball (jump, land, push-off) through analyzing the pressure sensor raw data. We also need to understand the ankle by mapping its real-world position into angle measures through analyzing the flex sensors raw data.

- Requirement 1: Achieve an accuracy of 90% of recognizing key events (jump, land, push-off) through testing

- Requirement 2: Achieve an accuracy of 90% of mapping ankle angle into digital measurements. This can be verified by performing measurements in real life and comparing them to digital measurements.

Model to Determine Injury Risk:

This is the software module where we implement our logic to determine ankle injury risk. There are two metrics that we really care about:

- Ankle stability index: how stable the player's ankle behaves during high risk events (jump, land, push-off). This index can be standardized using indices from multiple players, helping the player understand if their ankle is under abnormal stress during basketball games.
- Ankle injury risk: given a player's ankle stability index, how likely is a player to injure themselves in the future. This can be calculated using a bayesian method, whereby the likelihood of a player getting injured in the future is estimated by how likely similar players were injured in the past using historical data.

To determine if this model is successful:

- Requirement 1: Communicate with at least 5 different basketball players and determine if the index measure aligns with their experience
- Requirement 2: Verify the bayesian model using a determined threshold for the posterior value and historical data. Achieve at least 70% accuracy.

2.2.4) User Interface:

This system receives processed data from the Signal Processing unit and displays this data to the user.

Phone App:

A user-friendly phone app will show the player core statistics such as:

- Number of jumps and landings
- Ankle stability during jump
- Ankle stability during landing
- Number of push-offs
- Ankle stability during push-off

To determine if this app is successful:

- Requirement 1: Display statistics in an interactive manner such that the player is able to quickly understand the statistics

2.3) Risk Analysis:

The sensor module poses the greatest risk to successful completion of our project. The entire functionality of this device is dependent on the assumption that the pressure and flex sensors will collect accurate readings during a basketball game. If these readings are inaccurate, there will be a cascading effect throughout the system. The computations done on the raw sensor data will be inaccurate, which in turn will cause the feedback at the user interface to also be inaccurate. In addition, since our computations involve a comparison of the player's normal range of motion and the player's range of motion during a game, if the sensors do not properly read the player's normal range to begin with, then all further calculations will be incorrect as well.

In order to best avoid this risk, we plan to complete multiple requirement verifications on both the flex sensors and the pressure sensor. We also must ensure that all sensors function as expected before implementing them into our design. For example, we must have a baseline understanding of the flex sensor resistance given a specific angle (i.e. 50 ohms corresponds to a 45 degree angle).

3.) Ethics and Safety

It is important that we assess the possible ethical and safety issues relevant to our project. First, we will consider the possible safety hazards involved. This goes along with satisfying the ACM General Ethical Principle 1.2 "Avoid Harm" [5]. Since this device will be used in close contact with a person's ankle, the possibility of device failure is a potential hazard. In the case of a short circuit, our rechargeable batteries would explode, releasing shrapnel and acid. Additionally, a short circuit could be accidentally created if our waterproofing solution were to fail, allowing too much moisture into the circuit. Therefore, it is of grave importance that we are sure to properly waterproof the design.

Next, we will consider the possible ethical issues involved. Our project collects and processes potential Protected Health Information (PHI), which means that we must ensure the confidentiality, integrity, and availability of electronic PHI per The Health Insurance Portability and Accountability Act (HIPAA) [6]. Additionally, according to the IEEE Code of Ethics, we must be honest and realistic in stating claims based on available data [7]. Therefore, it is important that we do not make any false claims, but rather provide reliable feedback and recommend speaking with a doctor for any medical diagnosis.

4.) References

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