Ankle Injury Prevention

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Abstract

We designed a biomechanical athletic sock that any basketball player can easily slip on. With this sock, athletes can monitor their ankle stress throughout a basketball game and receive feedback through an user interface. The ankle angle tracking, jump and landing detection, injury risk assessment, and stress measurements are executed by the communication between the power unit, signal collection unit, signal processing unit, and the user interface. With such a device, we hope to make players more aware of the stress their ankles undergo and adjust their playing time accordingly to minimize injury risk. All further design considerations, challenges, tests, and results are documented in this report.

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1. Introduction

1.1 Problem and Solution Overview

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 level [1] and 40% of injuries at the high school level [2] are ankle injuries, making it the most common injury at both levels of play.

Our team's goal is to help basketball players of all levels prevent ankle injuries by monitoring ankle stress throughout a basketball game. The more stress a player's ankle undergoes, the more fatigued the muscles are, making it more susceptible to injury. After collecting ankle stress data, we analyze the data and show players time instances where they put their ankle under extraneous stress.

We will measure ankle stress through the design of a sock 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 provide valuable information for coaches to decide players' game time to maximize their output and minimize their injury-risk.

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 (ROM) 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 among basketball players by giving both the player and the coach a better understanding of possible ankle injury.

1.2 Visual Aid

First, there is a need to establish some anatomical terminology for us to quantify ankle motion. An ankle's range of motion happens in three planes: frontal plane, sagittal plane and transverse plane, as shown in Figure 1 [3].

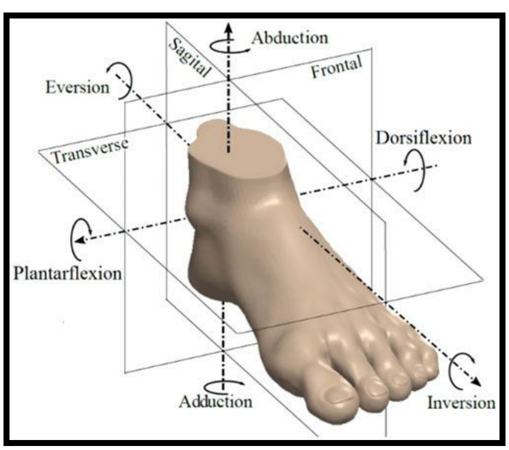

Figure 1: Visual Representation of Ankle Planes

The frontal plane describes the motion of pushing your toes downwards or upwards. The sagittal plane describes the motion of pointing the left or right edges of your foot towards the ground. For this project, we omit examining the transverse plane as few injuries are the result of hyper-extending the ankle in this plane. Table 1 shows the normal ranges of motion for the frontal and sagittal planes [4].

Table 1: Normal Ranges of Motion for Frontal and Sagittal Plane

Normal ROM		
Frontal Plane	**Inversion**	23°
	Eversion	12°
Sagittal Plane	**Dorsiflexion**	10°-20°
	Plantar Flexion	40°-55°

1.3 High-Level Requirements List

- The device must be able to collect and stream data without data drop for a 30 minute period.
- The sensor module is able to detect a player's range of motion (ROM) in each plane and the signal processing module is able to compare that data to the player's 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 user interface should display informative metrics that tell players how much stress their ankles are experiencing during games and whether the stress they experience could pose any injury risk.

2. Design

2.1 Overview

Our product has hardware components and software modules that work together to provide the user with a solution to monitor ankle stress. In Figure 2 we depict how hardware and software work together in our block diagram.

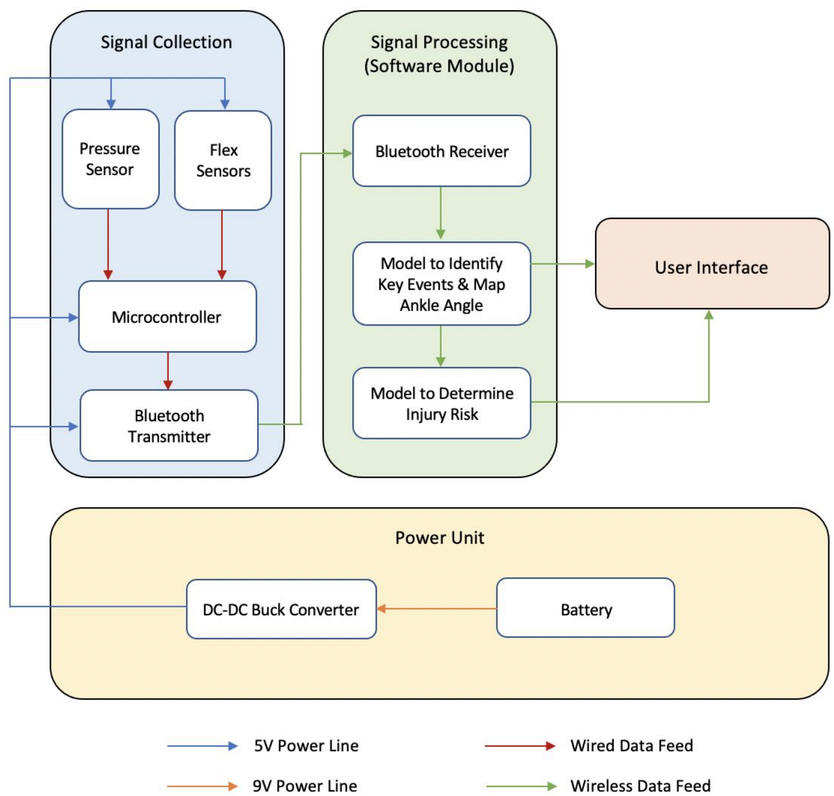

Figure 2: Functional Block Diagram of Ankle Injury Prevention Device

Hardware components are responsible for powering our sensors and sending the data to our software via Bluetooth. Software components are responsible for processing the data and displaying feedback onto the User Interface.

2.2 Physical Design

From the beginning to end of our project, our physical design went through some changes. Initially, we wanted to create an actual basketball shoe that a player would have to purchase in order to utilize our risk assessment technology. However, this design required us to place a relatively large box on the tip of the shoe, which after more consideration we believe would have interfered with the player's performance more than we'd like. Therefore, after speaking with the machine shop, we decided to equip a sock with the proper sensors and attach the box containing the battery and pcb to a velcro strap that could be attached to the player's leg. Figure 3 presents the final assembly of our design.

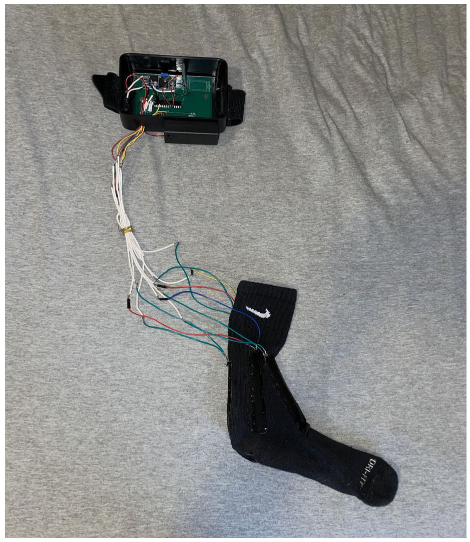

Figure 3: Final Physical Assembly

2.3 Power Unit

The power unit consists of a 9V rechargeable battery and a 9V to 5V DC-DC buck step-down converter. The 5V power is responsible for driving the four flex sensors, the pressure sensor, the microcontroller, and the Bluetooth transmitter.

2.3.1 Battery

Although rechargeable batteries have a higher initial cost, we went with a 9V rechargeable battery due to its high performance and efficiency in comparison to regular batteries. We decided that this will best ensure the functionality of the design during a full basketball period.

2.3.2 DC-DC Buck Converter

After analyzing the operating conditions for each of our electrical components, it was evident that we would need to step down the voltage to 5V. Originally, we planned on using a linear regulator to step down the voltage, however, after evaluating the effect of its low efficiency on the rest of our design, we decided to implement a high efficiency buck converter module instead.

2.4 Signal Collection

This unit collects data from the user and transmits it to the signal processing unit. It consists of a microcontroller which receives data from the flex sensors [5] and pressure sensor, and passes this data off using the Bluetooth transmitter.

2.4.1 Microcontroller

In order to simplify the hardware on the device, we decided to ensure that the majority of the data processing was done on the software side of things. Because of this, we solely needed our microcontroller to be able to stream the maximum and minimum possible voltage values outputted by the sensors and send them to the software. We also wanted to make sure it would be able to do this for 30 minutes, the length of the battery, without dropping any of the data.

2.4.2 Bluetooth Transmitter

Since we had already decided on the microcontroller we were going to be using, it was important we had a Bluetooth module which was easily compatible with the microcontroller. It was also imperative that the range of the module was 30 feet, in order to ensure the device would work across the entire width of the basketball court, so the computer running the software can easily be placed on the sideline of the court.

2.4.3 Flex Sensors

The most critical aspect of our design was to accurately extract a user's ankle position from the data collected by the flex sensors. To do so, we placed four flex sensors onto our athletic sock with one on the inside of the ankle, one on the outside, one on the front, and one on the back.

After understanding the behavior of flex sensors, we decided that the minimum number of sensors needed to capture directions of motion in both the sagittal and frontal planes would be four. Flex sensors change resistance in a linear manner that can be modeled only when they are bent in a certain direction. Hence, we needed two flex sensors for each plane to capture both directions of motion. Furthermore, we decided against using more flex sensors due to cost and scope constraints. Since each flex sensor is governed by its own unique equation, adding additional sensors would equate to much more testing and verification. Additionally, the sensors were easily the most expensive part of the design, so adding more would greatly raise the costs.

Although we originally intended to model the flex sensors according to the mathematical relationship that we derived between the output voltage, bend angle, and the minimum and maximum resistances, we ended up creating a linear regression model for each flex sensor instead. This design choice was due to the fact that each flex sensor has up to 30% resistance tolerance, meaning that not every sensor would behave the same. Each sensor's equation followed the form of equation (1), where m represents the slope, and b represents the y-intercept. As an example, the relationship between the bend angle and output voltage of the flex sensor located on the inside of the ankle is represented by equation (2).

$$\theta = m * V_o + b \tag{1}$$

$$\theta = - 0.0093 * V_o + 3.9011 \tag{2}$$

It is made clear by these equations that the output voltage will decrease as the bend angle increases. This relationship proved to be critical in the signal processing analysis, as later explained.

2.4.4 Pressure Sensor

Since the pressure sensor that we decided to use in our design only measures up to 100 pounds of force, we were unable to use the pressure sensor to actually detect the amount of stress placed on the ankle during jumps and landings, but rather we simply used it to detect when the jumps and landings occur. Additionally, the pressure sensor has a small surface area which lead us to place it under the heel rather than the ball of the foot, since force is most concentrated in this location.

2.5 Signal Processing

The signal processing unit is responsible for receiving the sensor data from the microcontroller, processing that data to derive physical measurements such as angles, jumps, and landings to understand the user's ankle motion, and finally use those measurements to determine the user's risk of injury.

2.5.1 Bluetooth Data Receiver

The Bluetooth receiver module is responsible for reading all sensor data sent by the microcontroller. The microcontroller sends sensor readings at 10 Hz and our Bluetooth receiver module was designed to receive data at this rate with no drops.

Since in socket programming packets come in continuously and might contain incomplete messages, we use a buffer to record the data being streamed in. Whenever a complete message is sent, we read it and remove it from the buffer.

Since not all data being streamed is pertinent to analysis, we give the user ability to start and end recording data. By using these functions, the user will create a selection of data points to perform analysis on. This process is depicted in Figure 4.

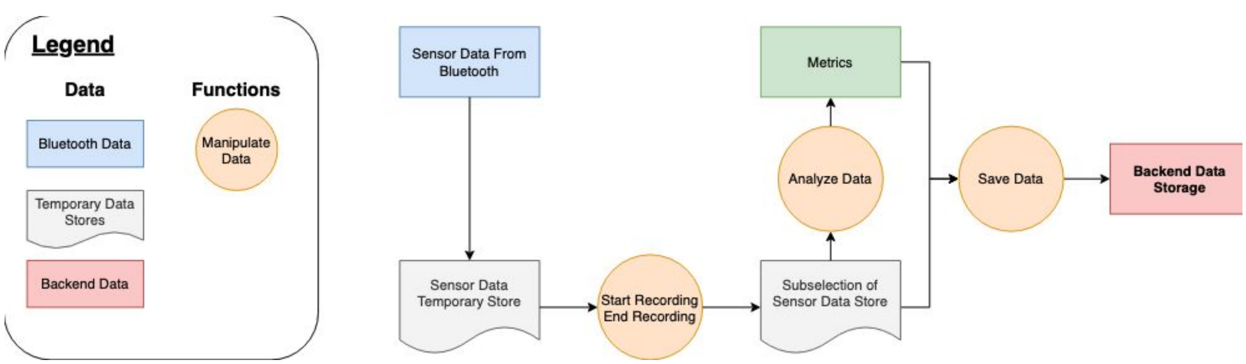

Figure 4: Software Data Flow

2.5.2 Map Ankle Angles and Identify Key Events

Now we know the correct selection of data to perform analysis on. With this module, we convert the raw data of voltage values into ankle angles as well as timestamps in which a player jumps and lands.

To convert flex sensor values into angles, we used each sensor's relative equation in the form of equation (1). Four equations are calculated for the four flex sensors we used through lab testing. On the software side, we just plug in these equations to get the angle of the flex sensor.

We always select the flex sensor that has a larger angle reading to model the motion of the ankle in that plane. We chose this logic because we know the flex sensor that is being bent in the opposite direction of its intended usage will output a larger voltage reading, corresponding to a smaller or even negative angle. Hence, selecting the larger angle of the two flex sensors ensures we always use the flex sensor that is being bent in the direction of intended usage, thereby correctly modeling ankle angle.

To find key events jump and landing, we simply observe when the pressure sensor spikes. We know that jumps and landings happen within one second of each other. Hence, we label the first spike as a jump and the second jump as a landing.

2.5.3 Determine Injury Risk

Having translated sensor values into more humanly readable measurements, we can now calculate metrics to measure injury risk. We wrote a single function to calculate all three metrics - total stress, average stress and angle variance. This function takes in parameters of start timestamps and end timestamps. When we want to understand how a player's metrics behave during jumps or landings, we just pass in a list of all start timestamps and end timestamps or jumps or landings. When we care about how the player's metrics behave overall, we just pass in timestamps of the start and end of the recording session. Figure 5 shows how we calculate the metrics under different contexts.

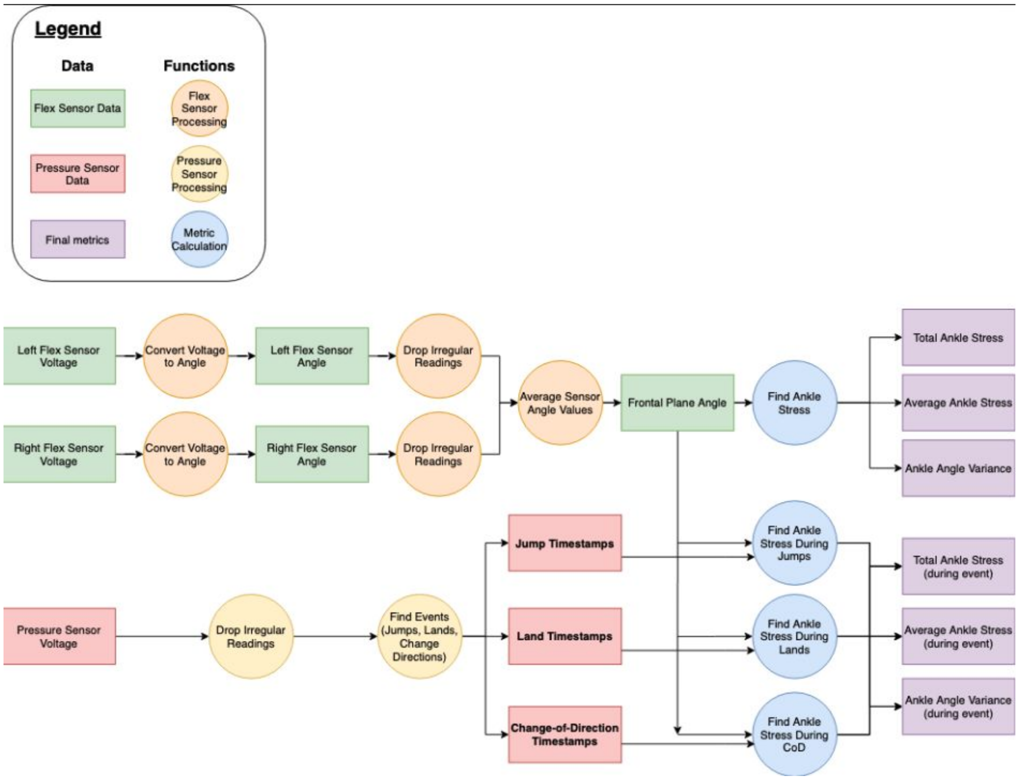

Figure 5: Raw Data to Metrics Flow

Total stress is defined as the area above the horizontal line of 70% of maximum ROM. This definition works to aggregate all moments when the athlete bends their ankle excessively, causing strain[6,7]. An example of these angle thresholds can be seen in Figure 6.

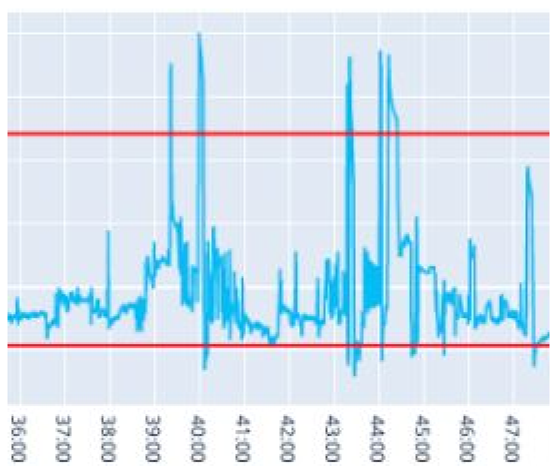

Figure 6: User Interface Representation of Ankle Angles

Average stress is total stress divided by the total number of minutes a player has played. This metric makes comparison of stress across players possible.

Ankle variance is simply the variance of angle measurements. This metric helps players understand if their ankle wobbles during jumps and landings, cases that have a high risk for injury.

2.6 User Interface

We created the user interface to show users three parts of information - raw data collection, ankle data metrics, comparison to other users.

We want the user to have access to raw data collection to determine when to start and stop data collection as well as check for data integrity.

For seeing data metrics, we allow the user to calculate their metrics across any period of time and for any key event of jump or landing. This tab of the user interface can be seen in Figure 7.

We did not implement comparison of data to other users yet, but we see this as a high impact feature for the future. The ability to compare their own metrics with other users' metrics will allow users to assess their injury risk even better.

Figure 7: User Interface Analyze Session Tab

3. Design Verification

3.1 Signal Collection

The signal collection unit is critical to collecting raw data from the user and transmitting that data to the signal processing unit via Bluetooth. In order to verify that the four flex sensors were behaving as we expected, we performed a similar test on each sensor individually. By measuring the output voltage of the sensor at 10 degree increments from 0 to 90 degrees, we were able to determine a line of best fit using linear regression. From there, we could also calculate the coefficient of determination which would tell us to what degree of precision we could map the bend angle given the output voltage of the sensor. Our goal was to achieve at least 90% accuracy for each of the flex sensors in order to ensure that we could properly map the ankle angle at all times. We were able to achieve this goal for each of the four flex sensors.

We performed a similar test for the pressure sensor, except this time we measured the output voltage of the sensor at 10 pound increments from 10 to 100 pounds. Again, we were able to determine a line of best fit and a coefficient of determination greater than 90%. Figure 8 shows the line of best fit and coefficient of determination for flex sensor #1, which was located on the inside of the ankle.

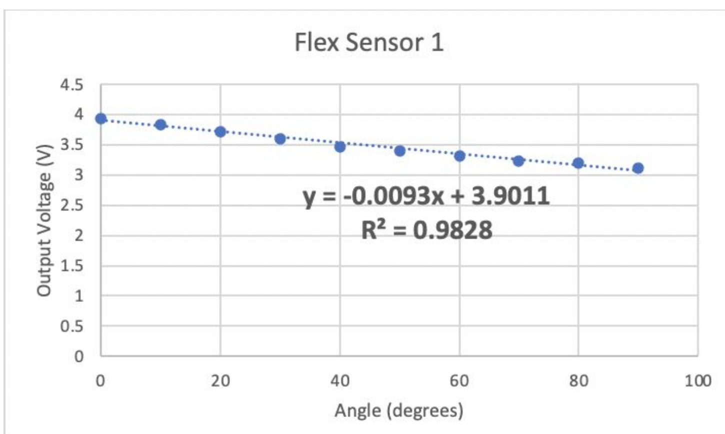

Figure 8: Flex Sensor #1 Bend Angle vs Output Voltage

The next step was to verify that the microcontroller was capable of reading any output voltage received from the flex sensors or pressure sensor. It was imperative for the functionality of our project that the ATMEGA 328p [8] was capable of reading these voltage values since the software had to be capable of receiving correct values. Due to the tests performed on the flex sensors mentioned previously, we were able to determine an absolute maximum and minimum value output by these sensors. We were able to determine that the microcontroller was able to read these values. It was also a necessity that the microcontroller was able to communicate effectively with the HC-05 Bluetooth module or else the software would not be able to receive the data from the sensors. By sending random voltage values from the microcontroller to the Bluetooth module, we were able to determine that this link was successful by having the computer effectively read these values.

The final step of testing the signal collection module was to ensure that the Bluetooth module was able to communicate with the computer containing the software up to 30 feet away and and that it would be able to stream data to the computer for a 30 minute period without dropping any of the data being sent. It was vital that the Bluetooth module would work at up to 30 feet away, since this is the width of a basketball court. The device working up to 30 feet away from the computer means that the computer can be stationed on the sideline with no worries of disconnecting from the hardware on the player's body. This was confirmed by using the device from 0 feet away to 30 feet away from the computer, moving away in 5 feet increments, and ensuring that the data was being streamed at each distance. Finally, the data was streamed for 30 minutes in order to ensure that there was no drop of any data throughout the entire period. This is because this is the length of a game of basketball and so we now ensure the device will stream data for the entire game.

3.2 Signal Processing

We also verified our software module that is responsible for processing raw data.

We observed that ankle angles were being correctly mapped by putting the sock on and bending the ankle in both planes. We incrementally bended our ankle in both planes and observed the angle change on our user interface. To differentiate motion in both directions in one plane, we verified that bending our ankle in one direction gives a positive value and bending our ankle in the opposite direction gives a negative value.

To identify jumps and landings properly, we also verified that our signal processing for the pressure sensor was correct. To perform verification, we put on the sock and jumped multiple times. We observed if the code picked up these jumps and landings with at least 90% accuracy and it did.

Finally, we needed to verify our metric generation was logical. Our metrics serve to inform users of the amount of stress their ankles withstand. To verify metrics *average stress* and *total stress*, we bent our ankle slightly in session one, then we bent it more in session two and then we bent it the most in session three. We confirmed that metrics in session one are less than those of session two and metrics in session two are less than those of session three. To verify metric *ankle variance*, we record three sessions of data again. In session one, we vary the ankle angle a little bit. In session two, we vary it more. In session three, we vary it the most. We confirm that metric *ankle variance* changes accordingly.

4. Costs

4.1 Cost of Parts

Table 2 shows the cost of all physical parts used in the design.

Table 2: Cost of Parts

Part Name	Cost Per Part ($)	Number of Parts	Total Cost ($)
ATmega328P Microcontroller	$2.08	1	$2.08
HC-05 Bluetooth	$9.44	1	$9.44
SEN 08606 - Flex Sensor	$15.95	4	$63.80
SEN 08685 - Pressure Sensor	$19.95	1	$19.95
9V Battery & Charger	$10.99	1	$10.99
Battery Holder	$2.43	1	$2.43
LM2596 Buck Converter Module	$1.93	1	$1.93
16 MHz Crystal and two (2) 20pF capacitors	$4.24	1	$4.24
Plastic Box	$6.13	1	$6.13
Strap	$7.89	1	$7.89
Total			**$128.88**

4.2 Cost of Labor

Table 3 shows the cost of all labor associated with the design.

Table 3: Cost of Labor

Name	Hourly Rate ($)	x	Hours Per Week	x	Number of Weeks	x	Overhead Factor	=	Cost ($)
Skyler Shi	$40		10		14		2.5		$14,000
Matt Miller	$40		10		14		2.5		$14,000
Erin Sarver	$40		10		14		2.5		$14,000
Total									**$42,000**

4.3 Total Costs

Table 4 shows the total costs associated with our ankle injury prevention device.

Table 4: Total Costs

Type	Cost ($)
Parts	$128.88
Labor	$42,000
Total	**$42,128.88**

5. Conclusion

5.1 Accomplishments

Our team is proud to have built an athletic sock that informs and protects basketball players from potential injury. We were able to successfully integrate hardware with software using Bluetooth. We also successfully defined some metrics that inform the user of ankle injury risk.

To spark the reader's imagination, here are some potential questions our product can help athletes and coaches answer:

1. Is a player more injury-prone when they are fatigued?
2. Are a player's jump and landing mechanics sustainable?
3. Should we cut back a player's playing time to reduce injury risk?
4. How important is it to do ankle warm-ups? Does it increase ankle ROM?
5. Does the player have limb dominance that will put more stress on one foot than another?

5.2 Uncertainties

The largest uncertainty that our product faces is the adequacy of flex sensors. When our team framed our solution, we naturally thought of flex sensors as a solution since they very simply model angles. After working with flex sensors, we understand each one of them is governed by a slightly different equation due to their 30% resistance tolerance.

This is a nuisance to potentially mass-producing this product and making it commercially viable. Our software would need to ingest different flex sensor equations for each product.

Hence, in the future, we will research other types of sensors to circumvent the volatility of flex sensors.

However, we would like to emphasize that a flex sensor is still a reliable sensor once its governing equation is found. A specific flex sensor does not deviate from its governing equation.

5.3 Ethical Considerations

The IEEE code of ethics holds engineers to high standards. Our team committed ourselves to these standards.

In particular, code of ethics items one and five are most related to our project [9].

> *To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment;*

Our team realized the importance of safety in a well-being product. We minimized the weight of the product to imitate a normal sock so that the athlete does not feel different while in motion. Wires steered clear of the bottom of the floor to avoid tripping. Connecting wires all had insulation to prevent wire-to-skin contact. In the future, we will also waterproof this product for even better safety.

> *To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others;*

We made honest and realistic claims of our product. We do not claim that the product prevents injuries from happening to the player. We claim that the product can help monitor the stress of a player's ankle, helping them prevent potential injuries. By making honest and realistic claims, we will not promote overconfidence in a player when using the sock.

5.4 Future Work

In this semester, our team implemented a minimum viable product that helps users assess their ankle stress and protect them from unnecessary injuries. By improving our product even more, we can make the product commercially viable.

1. Configure additional sensors to measure full ROM

   We placed four flex sensors onto our sock to capture motions into two planes. More flex sensors can be placed to more accurately capture user motion in a combination of these two planes. We will definitely also consider alternatives to flex sensors to improve accuracy and lower cost.

2. Make packaging more compact and waterproof

   Our current packaging separates the flex sensors and pressure sensor from the microcontroller unit because it was easier to make. A better physical design will have all hardware components on an ankle sleeve that the user can easily slip on and off. It should also be waterproof to accommodate for the user's sweat.

3. Store user data on backend web-servers

   Due to time limitations, we did not implement any permanent data storage for the users. In the future, we want to enable users to compare their data across time and also against other users. We need to implement a software backend to accommodate this.

4. Show comparison data to users

   One key part of the User Interface was not implemented due to time constraints. In the future, we wish to enable users to compare their data against other users to understand how they stand in a population of users.

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Appendix A Requirement Verification Table

Module	Requirements	Verification	Verification Status
Battery	1. Stores and reliably provides 9V for at least a 30-minute period.	1. A) Use the battery charger to provide the battery with full charge. B) Connect the battery to an LED to know whether it is discharging or not. C) Discharge the battery to make sure that it lasts for at least 30 minutes.	Y
DC-DC Buck Converter	1. DC-DC buck converter provides 5V (± 5%) from a 9V source.	1. A) Connect the output of the DC-DC buck converter to an oscilloscope. B) Connect the input of the DC-DC buck converter to a 9V DC source. C) Adjust the converter's potentiometer until the output voltage reaches 5V. D) Measure the voltage to ensure that it remains stable at 5V (± 5%).	Y
Flex Sensors	1. The output voltage of the flex sensor must correspond to the flex sensor resistance, which is determined by the bend angle. The relationship between the bend angle and output voltage must be linear.	1. A) Connect an oscilloscope to a test circuit containing a voltage source and a flex sensor and another resistor of constant value. B) Measure the voltage across the flex sensor at flat, and at angles	Y

		varying from 0-90° in increments of 10°. C) Create a line of best fit for output voltage versus bend angle. D) Ensure that the coefficient of determination is greater than 90%.	
Pressure Sensor	1. The pressure sensor must be able to read values in the range of 0-100 pounds in order to help identify key events such as jumps, lands and push offs.	1. A) Connect an oscilloscope to a test circuit containing a voltage source and a pressure sensor and another constant resistor. B) Measure the output voltage of the pressure sensor with weights ranging from 0-100 pounds, in increments of 10 lbs. C) Create a line of best fit for output voltage versus bend angle. D) Ensure that the coefficient of determination is greater than 90%.	Y
Bluetooth Transmitter	1. The transmitter must be able to transmit data to a device at least 30 feet away.	1. A) Connect the Bluetooth module to the microcontroller or Bluetooth interface app. B) Send a signal from the Bluetooth transmitter 0-30 feet away, in increments of 5 feet, to ensure that the module can communicate with the user interface at least 30 feet away.	Y
Microcontroller	1. Must be able to communicate with the Bluetooth module.	1. A) Connect the Bluetooth transmitter to the microcontroller chip and make	Y

	2. The microcontroller's ADC will be required to read voltage values from the sensors ranging from 3 V to 4.2 V.	sure the transmitter and receiver are connected using the Arduino serial monitor. 2. A) Connect the oscilloscope to the analog pins and send varying voltages to them using a flex sensor. B) Compare the oscilloscope values to the values read by the microcontroller.	
Bluetooth Receiver	1. Software module receives data without loss through Bluetooth for a 30 minute period.	1. A) Verify that values are sent to the software module accurately: Set-up independent flex sensor and pressure sensor. B) Activate sensors to their minimum and maximum values and observe values received via Bluetooth. C) Confirm if values received align with our understanding of the sensors. D) Verify that no data is lost: Activate a sensor for 10 seconds. E) Calculate expected number of samples using sampling frequency. F) Check if the Bluetooth system received that many samples during the duration.	Y
Model to Map Ankle Angle and Identify Key Events	1. Model maps out ankle angles on the frontal plane accurately.	1. A) Have the user move the frontal plane across its full motion - start at 23° inversion and step to 12° eversion with 1° increments. B) Confirm if flex angles calculated	Y

	2. Model determines when jumps and landings are occurring accurately.	align with physical measurements of ankle angles. C) Have the user move the sagittal plane across its full motion - start at 15° dorsiflexion and step to 40° plantar flexion with 1° increments. D) Confirm if flex angles calculated align with physical measurements of ankle angles. 2. A) Have the user jump in a variety of different ways. B) Confirm if jumps are detected by model with at least a 90% accuracy. C) Confirm if landings are detected by model with at least a 90% accuracy.	
Model to Determine Injury Risk	1. "Total Ankle Stress" calculation reflects how much a user is utilizing their ankle muscles accurately. 2. "Ankle Variance" reflects how destabilized the user's ankle is.	1. A) Record or simulate three sessions of data. B) In the first session, have the ankle flex to its maximum range of motion. C) In the second session, have the ankle be in a neutral position. D) In the third session, have the ankle move around and stabilize at its neutral position for intervals. E) Verify if "Total Ankle Stress" for session 1 is the largest, followed by session 3, followed by session 2. 2. A) Record or simulate three sessions	Y

		of data. B) In the first session, have the ankle wobble largely during a jump/landing. C) In the second session, have the ankle be stable during a jump/landing. D) In the third session, have the ankle wobble mildly during a jump/landing. E) Verify if “Ankle Variance” for session 1 is the largest, followed by session 3, followed by session 2.	
User Interface	1. The interface must be able to display the processed data to the user within 1/2 second of the data being sent from the signal collection module.	1. A) Start with the completed signal collection circuit and signal processing module. B) Keep the flex sensor at an angle that is within 0 and 50°. C) Make sure the interface displays that the ankle is in safe angle range. D) Bend the angle to 90°. E) Make sure the interface displays that the ankle angle is at an unsafe angle range within 1/2 second of bending the sensor.	Y