**Characterization of Clubfoot Brace Fitting**

**Design Journal**

**Team B3**

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ME393 Mechanical Engineering Project

Professor Rosen and Professor Lima

Spring 2024

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**Links to Individual Background Research:**

Emily: [Zao\_Research.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EaoLK3GJrTBMtKdd63koVjIBVWAPrWg9nvmt_0zURtoPWw?e=Lwel8R)

Shahrin: [Background Research Senior Design Project.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/shahrin_khan_cooper_edu/EWDfWTcqlzpDqwMPw8h44AsBznDXP6mOTH5jbkD1tPvvYA?e=y5BXNS)

Afifa: [Areya\_Research.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EXRjmt2sYzlPr7yQ7ITFbPkBkDIum4X_ORUgmF9_3BdyzA?e=HaZ99o)

Alex: [Landinez\_Research2024.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/alexander_landinez_cooper_edu/EdP08iH24vNIpreg5vjQrgwBJVE2EM0fF_Kbxe0P0QTNdg?e=lmCoAr)

**Week of January 15**

Goals for this week:

Answer the following big questions about our project

1. What sensors are best for our project?
2. What are we measuring from the sensors and why?
3. Why do we need a microcontroller?
4. What are different types of microcontroller?
5. How do we determine what microcontroller do we need for our project?
6. What are app development platforms we can use?
7. What is our system going to physically look like?
8. How will we power our system?
9. What other medical devices have sensors?

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| Name | Tasks | Link to document/ Reference to research |
| **Afifa** | Research what sensors are best for our project and what we are measuring and why | [Clubfoot Q&A Doc.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EUdtXUu9X9dPjwIvqYTgqvsBjuILS03sj-ra5l8eRE4QHA?e=oFTvQ3) |
| **Alex** | Research how we will translate sensor data into visual aid for parents. Benefits and considerations to each method. Also depict what the system will physically look like |
| **Emily** | Research how we will translate sensor data into visual aid for parents. Benefits and considerations to each method. Also depict what the system will physically look like |
| **Shahrin** | Research what sensors are best for our project and what we are measuring and why |

Insights:

There are various uncertainties surrounding the project that we needed to address, and conducting this research proved invaluable in gaining an understanding of the multiple components and how to integrate them into our project. However, our lack of experience with microcontrollers and limited exposure to sensor technology made navigating the research and answering pertinent questions quite challenging. Recognizing this, we opted to consult with Mike Giglia regarding our project, seeing his insights and any suggestions he might have regarding the direction we should pursue.

**Week of January 22**

Goals for this week:

* Learn about types of smart sensors and how they can be used in our project from talking with Mike
* Compile our findings into a PowerPoint and figure out how data would be translated.

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| Name | Tasks | Link to document/ Reference to research |
| **Afifa** | Work on powerpoint regarding sensors in order to brief advisors about sensor options and progress | [Questions for Mike Giglia Meeting (1-24).docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EYeXo8yMDoJAmp8qSC16V5kBe6nA1MgvWPnOhJktUELhvg?e=dMIaFp)  [Presentation for January 31st meeting with Professor Rosen and Professor Lima.pptx](https://cooperunion-my.sharepoint.com/:p:/g/personal/emily_zao_cooper_edu/EYKQPeyG2ntPhu-_jWoeqtwBUP7wjxaddoYjElEiN4ixbA?e=6hwFN4) |
| **Alex** | Schedule meeting with Mike to learn more about sensors and set up. Record responses in the document. Work on powerpoint for specific sensor slides. |
| **Emily** | Work on powerpoint regarding sensors in order to brief advisors about sensor options and progress |
| **Shahrin** | Schedule meeting with Mike to learn more about sensors and set up. Record responses in the document. Work on powerpoint for specific sensor slides. |

Insights:

Force sensors, resistive sensors, and flex sensors are viable for our project. We will be able to take the data output from these sensors and correspond it to a pressure value. In terms of a deliverable, it is out of our scope to create a microcontroller or web application. Instead, we will aim to create a functional model hooked up to a computer and Arduino to show the proof of our concept. The battery, microcontroller, and website details can be explained separately as our completed model if we were given proper materials and resources.

**Week of January 29**

Goals for this week:

* Clarify our story line based off our feedback on the sensor presentation
* Figure out what data output we want
* Create PowerPoint and questions to ask doctors
* Solidify our knowledge on foot fit metrics and research done currently.

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| Name | Tasks | Link to Document/ Reference to Research |
| Afifa | Research Foot Fit Metrics and look into current papers about how they did so | [Qualifying a Proper Fit - Clubfoot.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EeMKhvuwMFdGptH4VOxw-5IB4NahG_97zjkUJqkzBXh4YA?e=yzMpN7)  [Foot Metrics.pptx](https://cooperunion-my.sharepoint.com/:p:/g/personal/emily_zao_cooper_edu/EdRWwhsTcsFIsC-tdyAJdckBxrJO3K4NYR0ahO-0hCgRMg?e=Tiq4xH) |
| Alex |
| Shahrin | Create questions and work on powerpoint for doctors, create timeline for the remainder of the semester | [Clubfoot Proposal for Doctors.pptx](https://cooperunion-my.sharepoint.com/:p:/g/personal/emily_zao_cooper_edu/EYSwtvYABalHp1WZ4nVkNYMBd4U0tLggTa6HATR--o3EYQ?e=cYuchP)  [Clubfoot Schedule Spring 2024.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/Ee8-ISJv9vNGlxpX2n607jgBC-7FCuQKWygELraJORlCKQ?e=zOhVtX) |
| Emily |

Insights:

Alex had a brief meeting with Professor Rosen, during which we discovered the need to clarify our product storyline and address any uncertainties within our project. When presenting our research and progress to Professor Baglione, she stressed the importance of initiating testing with sensors and a baby doll. Following this, we promptly met with Professor Rosen again to convey our product storyline and the feedback received from Professor Baglione. She approved our decision to finalize which sensors and baby doll we want to order. During our advisor meeting with Professors Rosen and Lima, they pointed out that we’re gathering unknown data regarding the relationship between clubfoot brace fitting and pressure for our visual product targeted at parents. However, they suggested reframing our project to focus on designing and conducting an experiment to obtain this data.

**Week of February 5**

Goals for this week:

* Decide on what sensors and baby doll to purchase
* Create testing plan
* Work on circuit design

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| Name | Tasks | Link to Document/ Reference to Research |
| Afifa | Creating a testing protocol for testing on babies, update timeline for semester | [Testing Protocol.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EWZIHQuZ92BOlTiSbfEnrjUBMA1Eu0aCyWlAg-0hoU8_pA?e=6ijw5U)  [Clubfoot Schedule Spring 2024.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/Ee8-ISJv9vNGlxpX2n607jgBC-7FCuQKWygELraJORlCKQ?e=zOhVtX) |
| Alex | Working on the circuit design with circular piezoelectric sensor and square piezoelectric sensor, update design journal with circuit progress | **Small circular sensor (1738-SEN0294-ND)** **code:**  const int piezoPin = A0; // Connect the piezoelectric sensor to analog pin A0  const int ledPin = 13; // Connect an LED to digital pin 13  const int numReadings = 10; // Number of readings to average  const int pressureThresholdLow = 20; // Lower pressure threshold  const int pressureThresholdHigh = 1200; // Upper pressure threshold  const int activationTime = 500; // Activation time in milliseconds (5 seconds)  int readings[numReadings]; // Array to store readings  int index = 0; // Index for the current reading  unsigned long startTime; // Variable to store the start time    void setup() {  Serial.begin(9600); // Initialize serial communication  pinMode(ledPin, OUTPUT); // Set the LED pin as an output  }    void loop() {  int totalPressureValue = 0;    // Take multiple readings and update the readings array  for (int i = 0; i < numReadings; i++) {  readings[i] = analogRead(piezoPin);  totalPressureValue += readings[i];  delay(10); // Short delay between readings  }    // Calculate the average pressure value  int averagePressureValue = totalPressureValue / numReadings;  int Resistance = 10000;  int Voltage = 5;   // Convert average analog value to voltage (assuming a 5V Arduino)  float pressureVoltage = (averagePressureValue \* 5.0) / 1023.0;  float averageResistance = Resistance \*(Voltage - pressureVoltage)/pressureVoltage;  float averagePressure = pow((averageResistance/(153.18 \* 1000)),(-1/0.699));   // Print the averaged values  Serial.print("Average Analog Value: ");  Serial.print(averagePressureValue);  Serial.print("\tAverage Voltage: ");  Serial.print(pressureVoltage);  Serial.print("\tAverage Pressure (grams): ");  Serial.print(averagePressure);  // Check if pressure is within the specified range  if (averagePressureValue >= pressureThresholdLow && averagePressureValue <= pressureThresholdHigh) {  // Check if the LED is not already turned on  if (!digitalRead(ledPin)) {  // If the pressure is in range, start or update the timer  if (millis() - startTime >= activationTime) {  digitalWrite(ledPin, HIGH); // Turn on the LED  Serial.println("\tLED turned ON!");  }  } else {  // If the pressure is still in range, update the timer  startTime = millis();  }  } else {  digitalWrite(ledPin, LOW); // Turn off the LED  Serial.println("\tLED turned OFF!");  }    // Print a newline for better formatting  Serial.println();    // Add a longer delay, if necessary, to control the overall loop speed  delay(100);  }  **Findings from testing:**  The circuits for this sensor return analog values of pressure. The scale is not calibrated according to the pressure we need. The current sensor only converts pressure into voltage, but it returns analog values that hasn’t been converted to correlate the pressure to the output. |
| Shahrin | Research sensors to purchase and finalize list, research baby doll to purchase, create design matrix, update design journal, create drawing of experimental setup for brace and sensors | <https://cooperunion-my.sharepoint.com/:x:/g/personal/emily_zao_cooper_edu/EZx2fCEEHBRClhuySqDkdXMBmi-nbdgQ34SgchN7sGgF4A?e=QD6H4L>    A: Sketch of critical points on the foot and the boot for sensor placement. |
| Emily | Organize official research document, research sensors to purchase and finalize list, research baby doll to purchase, create design matrix, create drawing of experimental setup for brace and sensors |

Insights:

For this part, we similarly set up the sensor circuit to the one we had used to test them at the end of the last semester. We put the piezoelectric sensor (1738-SEN0294-ND) in parallel with a resistor and used the analog pin to get a numerical value based on how the sensor's resistance changed. Knowing the applied voltage (5 volts), we were able to find the resistance of the sensor at different pressures using voltage division. We created an Excel sheet last semester that tracked how different weights (varying from 20-120 grams) would be translated into different resistance values. We saw, as expected, that there was a negative exponential relationship between the force applied and resistance response. With this data, we were able to compare the values with the function given in the specs sheet given by the manufacturer and see if the sensor is properly calibrated (or at least in a reasonable range). Because the data aligned to a reasonable range, we were able to curve fit the resistance values of the sensor to get actual pressure values as a response from the sensor. We found that the best way to get a response was through a curve fit, as linearizing the data through the circuitry would require some form of feedback control. This week we also tested to see if there was any steady state error, or drift by pushing it, and saw if the value would go back to zero resistance when the load was taken off the sensor – we saw no drift after doing this for close to 30 minutes.

When researching sensors to test, we wanted to test different ones to determine which ones are best to implement for the final prototype. We picked a baby doll to order based on the size and cost. It was difficult to find a baby doll that has feet big enough for our brace and is priced at a relatively low cost. The baby doll we ordered may still be too small for the brace we have, but we will make it work. We also determined which sensor to purchase based on data collection, areas of interest on brace/foot, cost, and dimensions (shown in decision matrix linked above).

**Week of February 12**

Goals for this week:

* Revise testing protocol
* Work on a diagram for our set up
* Order sensor and baby doll

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| Name | Tasks | Links to Document/ Reference to Research |
| Afifa | Revise testing protocol, talk to Mike about sensor calibration and how to visualize our data | [Meeting with Mike - Feb 15,2024.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EXK4TsX1Jp1Ch89jbTYHZSEBeyK2FkYSv6_SVRldKLVH8Q?e=oETPu9) |
| Alex | Talk to Mike about sensor calibration and how to visualize our data |
| Shahrin | Met with writing center to reformat design journal, create sensor and foot diagram to show sensor placements | [Presentation for Feb 21.pptx](https://cooperunion-my.sharepoint.com/:p:/g/personal/emily_zao_cooper_edu/EenHTcXUeLlCuyZADtk0-jkBM7Aq7LXUu472iThLGXYiaA?e=NhcuiW)  [Clubfoot Bill of Materials.xlsx](https://cooperunion-my.sharepoint.com/:x:/g/personal/emily_zao_cooper_edu/EWk1pDUPm19KtKFUacrdjogBaCS-_hdkdpPYUltsyH41Jw?e=fqflZ9) |
| Emily | Order sensor and baby doll, edit testing protocol, create sensor and foot diagram to show sensor placements |

Insights:

We presented the sensors we had ordered, discussed their placement in the brace and foot, outlined the data output expected from the Arduino, and explained our plans for data conversion and analysis. However, during this discussion, we collectively realized that we lacked a cohesive plan for data analysis. Professors Rosen and Lima suggested creating diagrams illustrating the placement of sensors on the brace and foot, along with graphs depicting both raw data and our intended presentation format. They also recommended incorporating checkboxes into our schedule to track completed tasks, as despite our significant progress, we seemed to be experiencing a sense of stagnation as a group. Utilizing checkboxes would allow us to visually monitor our progress and maintain motivation.

To gain a better understanding of our data and how to visualize it, we scheduled a meeting with Mike Giglia. During our discussion, we explored the multidimensional nature of our data. Mike suggested representing the data either in three dimensions, with two dimensions corresponding to the straps and one dimension remaining fixed, or in four dimensions, with the addition of color as a representation of the fourth dimension. For testing purposes, he recommended maintaining one strap as a constant while adjusting the others to observe their individual effects. Additionally, Mike provided guidance on the materials needed to optimize our circuit for collecting more accurate data.

**Week of February 19**

Goals for this week:

* Test baby doll and analyze data
* Meet with Doug to discuss how to manufacture lining for boot
* 3D print baby foot and conduct initial testing

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| Name | Tasks | Links to Document/ Reference to Research |
| Afifa | Meet with Mike to discuss op amps, low pass filters, and how to reduce noise from sensors. Revised testing protocol. Worked on figuring out how our data will be displayed in a graph as seen in slide 5 of the powerpoint link. Tested baby doll with one of our current sensors with whole group. CAD baby foot and 3D print, also scan inner lining from brace from AACE lab. Test printed foot with sensor within the brace with Shahrin. | [Testing Protocol.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EWZIHQuZ92BOlTiSbfEnrjUBMA1Eu0aCyWlAg-0hoU8_pA?e=6ijw5U)  [Presentation for Feb 21.pptx](https://cooperunion-my.sharepoint.com/:p:/g/personal/emily_zao_cooper_edu/EenHTcXUeLlCuyZADtk0-jkBM7Aq7LXUu472iThLGXYiaA?e=OLbHvV)  Image preview  : CAD of baby foot model with edits made in Blender.  Image preview  B: PLA print of baby foot from AACE lab. |
| Alex | Meet with Mike to discuss op amps, low pass filters, and how to reduce noise from sensors. Also determined what additional sensor related equipment to purchase based on talking to Mike as seen in powerpoint slide 4. Tested baby doll with one of our current sensors with whole group. CAD baby foot and 3D print, also scan inner lining from brace from AACE lab. |
| Shahrin | Finalized diagram of foot and sensor schematic. Edited onshape CAD to depict sensor placements as seen in powerpoint link slide 2. Tested baby doll with one of our current sensors with whole group. Test printed foot with sensor within the brace with Afifa. | [Presentation for Feb 21.pptx](https://cooperunion-my.sharepoint.com/:p:/g/personal/emily_zao_cooper_edu/EenHTcXUeLlCuyZADtk0-jkBM7Aq7LXUu472iThLGXYiaA?e=OLbHvV)  [Clubfoot Official Research Document.docx](https://cooperunion-my.sharepoint.com/:w:/g/personal/emily_zao_cooper_edu/EVEjH8kLr8hAj2NMwYIq6XAB2FPLp91ECgzqFlWS-JYD8w?e=wMWKIU) |
| Emily | Formatting our research document that compiles all our group research. Drew foot diagram for sensor placement on top of the foot as seen in powerpoint link slide 3. Tested baby doll with one of our current sensors with whole group. |
| Baby Doll Testing:    A:Experimenting with a large baby doll's feet.  From these pictures it can be seen that the baby doll foot is too small and not properly shaped for the boot.  Image preview Image preview  B: Testing small circular piezoresistive pressure sensor (1738-SEN0294-ND) using the baby's foot for pressure readings.  Sensor is placed on the flat bottom of the brace boot. The picture of the circuit can also be seen above. The circle sensor from last semester was being used in this test.    Baby doll data from Arduino.  Image preview Image preview  C: Attaching the small circular piezoresistive sensor (1738-SEN0294-ND) on Emily's boot for testing.  Sensor was placed in Emily’s shoe and data was collected with her sitting, standing, and just barely contacting the sensor.  image  D: Serial Monitor readings from a test run using Arduino Uno. Range test for the sensor was conducted using Emily's foot. A maximum of 76674.72 grams of load was measured using the pressure sensor while standing on the sensor.  Emily standing while wearing sensor (she is applying pressure).  image  E: Serial Monitor readings from a test run using Arduino uno. Testing while Emily is sitting. A maximum of 0.17 grams was measured using the same circular piezoresistive sensor (1738-SEN0294-ND).  Emily sitting and barely contacting sensor within her shoe.  Image preview  F: The same sensor (1738-SEN0294-ND) is placed on the heel of Peter's boot. Testing conducted measured load on the sensor while Peter stood.  Placed sensor inside Peter’s shoe now to see if there is a difference.  image  G: Serial Monitor reading from Arduino Uno. Max load measured is 99664.60 grams while standing  Peter standing with sensor in his shoe.  image  H: Serial Monitor Reading from Arduino Uno. Load is measured while the feet barely contacts the surface of the sensor.  Peter barely contacting sensor within his shoe.  Arduino code for baby doll, testing with actual feet, and 3D printed foot:  const int piezoPin = A0;   // Connect the piezoelectric sensor to analog pin A0 const int ledPin = 13;     // Connect an LED to digital pin 13 const int numReadings = 10; // Number of readings to average const int pressureThresholdLow = 20;  // Lower pressure threshold const int pressureThresholdHigh = 1200; // Upper pressure threshold const int activationTime = 500;       // Activation time in milliseconds (5 seconds)    int readings[numReadings]; // Array to store readings int index = 0;             // Index for the current reading unsigned long startTime;   // Variable to store the start time    void setup() {   Serial.begin(9600); // Initialize serial communication   pinMode(ledPin, OUTPUT); // Set the LED pin as an output }    void loop() {   int totalPressureValue = 0;      // Take multiple readings and update the readings array   for (int i = 0; i < numReadings; i++) {     readings[i] = analogRead(piezoPin);     totalPressureValue += readings[i];     delay(10); // Short delay between readings   }      // Calculate the average pressure value   int averagePressureValue = totalPressureValue / numReadings;   int Resistance = 10000;   int Voltage = 5;    // Convert average analog value to voltage (assuming a 5V Arduino)   float pressureVoltage = (averagePressureValue \* 5.0) / 1023.0;   float averageResistance = Resistance \*(Voltage - pressureVoltage)/pressureVoltage;   float averagePressure = pow((averageResistance/(153.18 \* 1000)),(-1/0.699));    // Print the averaged values   Serial.print("Average Analog Value: ");   Serial.print(averagePressureValue);   Serial.print("\tAverage Voltage: ");   Serial.print(pressureVoltage);   Serial.print("\tAverage Pressure (grams): ");   Serial.print(averagePressure);   // Check if pressure is within the specified range   if (averagePressureValue >= pressureThresholdLow && averagePressureValue <= pressureThresholdHigh) {     // Check if the LED is not already turned on     if (!digitalRead(ledPin)) {       // If the pressure is in range, start or update the timer       if (millis() - startTime >= activationTime) {         digitalWrite(ledPin, HIGH); // Turn on the LED         Serial.println("\tLED turned ON!");       }     } else {       // If the pressure is still in range, update the timer       startTime = millis();     }   } else {     digitalWrite(ledPin, LOW); // Turn off the LED     Serial.println("\tLED turned OFF!");   }      // Print a newline for better formatting   Serial.println();      // Add a longer delay, if necessary, to control the overall loop speed   delay(100); } | | |
| Initial 3D Printed Foot Testing:  Initially tried to calibrate circle sensor (1738-SEN0294-ND) with mass weights.  Image preview  A: Circuit board set up for small circle sensor (1738-SEN0294-ND) for calibration. Mass used was 100 grams in this picture and placed sideways. Same circuit is used for printed foot testing.  Image preview  B: Serial Monitor Reading from Arduino Uno. Average pressure reading is consistently reading 305.98 grams for 100 gram mass.  Image preview Image preview  B: 3D printed baby foot is placed into the boots and bar brace.  Image preview  C: Circle sensor (1738-SEN0294-ND) is taped underneath toe area of printed foot on top of thin metal sheet.  Image preview  D: Serial Monitor Reading from Arduino Uno. Values for pressure fluctuate a lot. The highest pressure reading in this picture is 31.69 grams.    *E: Look at potential circuit, including an active low pass filter using an operational amplifier 741, and an arduino uno microcontroller. For this circuit, the cut off frequency is dependent on two of the resistors and both capacitors, in which the frequency will be set at the fluctuation in voltage divided by the sampling time step (with the data above it was seen to be around 0.6 volts per second).* | | |

Insights:

From our meeting with Mike, we determined extra components we need for the circuit to get more precise and accurate data. From our baby doll testing, the baby’s feet were too small for the brace and we could not obtain any pressure data. We decided to 3D print a baby foot that will fit in the brace along with a resin liner to put the sensors on. From our meeting with Professor Rosen and Professor Lima, we need to show them more of our physical testing progress instead of starting the meetings with the research we conducted. We were encouraged to continue testing and collect data. After the advisor meeting, we put the sensor into our shoes and saw what data we’re collecting. Since the force we were applying from our adult foot to the sensor was near the extremes of the force range for the sensor, the pressure data collected was not quite accurate as the pressure readings were larger than they actually were.

Calibrating the small circular sensor (1738-SEN0294-ND) revealed that the sensor may be damaged. The pressure reading from the sensor was much higher than the actual mass being placed on the sensor. Last semester, the mass weights gave a reading while playing flat on this same sensor. However, in this test the same sensor was not giving any reading if the masses lay flat- a reading was given if the mass was placed sideways near the center of the sensor. More testing should be conducted to fully verify whether the sensor is damaged.

Testing with the printed baby foot showed better results than when we were using the baby doll. The sensor gave a reading, however the pressure readings were fluctuating although the sensor was not being shifted within the brace after initial placement. The results are promising however, and more testing will be conducted with the printed baby foot with the other sensors that we received recently.