Isaac Cheng CYSF Project 2025 Condensed Logbook

This is a condensed version of my logbook where I have summarized the entire project and split up my project into sections. These logbook sections correspond to the five design stages as outlined in Professor Alexander H. Slocum's e-book, FUNdaMENTALs of Design [29]: Explore, Experiment, Create, Detail, Build and Test. Between each section, I have merged some important files and some of the mentor feedback I received. I did not upload my full logbook because it is too long. However, I will bring the full, handwritten version with me to the fair for the judges to view.

Stage 1 - Explore: July 15, 2024-July 24, 2024

What happened:

- Got injured
  - While practising hurdling at school, I felt my leg go numb and I couldn't walk or move my leg without pain
- Met with Family Medicine doctor
  - My family medicine doctor told me it was probably just a partial hamstring tear and gave me a requisition for an ultrasound
- Applied for Specialist level care at University of Calgary
  - I applied for free specialist level care at the U of C Sports Medicine Centre by submitting a form online
- Learned about surface EMG sensors and found one that could run off an Arduino or Raspberry Pi
  - Interested by a project that used EMG sensor data in last year's science fair, I was excited to learn about EMG sensor that could run off of a Raspberry Pi, so I researched on Google for a couple of hours every day
- Learned about machine learning software such as TensorFlow
  - I wanted to find a solution for detecting muscle fatigue and I realized I could train a Machine Learning model to recognize certain fatigue patterns
- Did lots of research on different hamstring injury related topics

- I read several articles related to hamstring strain injures (HSI) and learned how sprint-based sports had very high rates of HSI

- Wrote up a CYSF project proposal for Dr. Ballinger
    - This proposal included research I had read about HSI and my proposed idea to place surface EMG sensors on each hamstring muscle to detect high levels muscle activation

- First medical appointment with Dr. Ballinger
    - I was X-Rayed and was informed I had suffered an ischial tuberosity avulsion fracture
    - I asked Dr. Ballinger if she could be a scientific mentor, and she agreed and gave me her email address

- Sent Dr. Ballinger an email requesting another meeting to answer some of my questions
    - Using the email address given at my appointment, I requested a meeting to ask her some questions related to my project

- Learned about muscle fatigue and filtering EMG signals
    - I learned from articles I read about Maximal Muscle Force and types of EMG filters such as a Butterworth filter

- Learned about different types of muscle contractions and anatomy specific vocabulary
    - This would later help me understand higher level articles related to muscle contraction and human anatomy in general

- Wrote up a questions sheet for Dr. Ballinger
    - These questions would be asked at our next meeting and would help me design my device

- Wrote a problem statement
    - My intention for my proposed device was to be used by teenagers to adults during activity to help prevent hamstring-related injury

- Made a use and function story chart

    - This shows how the device is intended to be used

- Drew some preliminary leg sleeve designs
    - These drawings included components such as batteries, microcontrollers, EMG sensors, and an LCD screen

- Second meeting with Dr. Ballinger
    - During our meeting, I asked her about my pre-planned questions and learned more about hamstring injuries in sports

<u>What I would do differently:</u>

Next time I would try to be as prepared as possible for my interview with Dr. Ballinger as my lack of knowledge was evident during our conversation.

<u>To work on next:</u>

Start finalizing design elements and ordering parts.

Appendix 1-1: (July 13, 2024)

Calgary Youth Science Fair Project Entry Information Sheet

Student Exhibitor Name:	Isaac Cheng
Student Exhibitor Email:	[redacted]
Student Exhibitor Phone:	[redacted]
School:	Colonel Irvine School
School Phone:	403-777-7280
Grade (2024-2025):	9
Adult Supervisor Name:	[redacted]
Adult Supervisor Email:	[redacted]

2024-2025 Project entry:

Division:	Mathematical and Computer Science
Topic:	Technology; Engineering; Human Health
Project Title:	TBD
Type of project:	Innovation
Project description:	My project addresses the problem statement: "How might we non-invasively monitor hamstring muscle activation in teenagers during physical activity to prevent hamstring injury and minimize downtime in play"
Project risk:	Low risk (Exercise testing within normal everyday activities)

Appendix 1-2: (July 14, 2024)

July 15th Meeting Questions

Problem statement:

How might we non-invasively monitor hamstring muscle activation in teenagers during physical activity to prevent hamstring injury and minimize downtime in play

Statistical Questions:

1. What are the general demographics at this clinic for patients with hamstring injury? Biological Sex? Age? Sport?

2. From your experience what hamstring muscle or muscles commonly suffer from overuse? Do they commonly lead to injuries? What about between different age groups?

3. What is the common severity of muscle injury in different age groups? For example, strain in kids or muscle tears in adults and teenagers.

4. From your experience is muscle fatigue a very common cause for Hamstring injury?

General Questions:

1. Are there any limitations with the use of Surface EMG sensors specifically when used with teenagers? What about adults and seniors? Are there any ways these limitations could be negated?

2. In article titled "Hamstrings force-length relationships and their implications for angle-specific joint torques: a narrative review" it says that they found peak electromyographic activity to occur between 40-50- or 90-105-degree angles of hip and 25-30 degrees of knee flexion. Do you know of any exercises I could do to test for the peak muscle activity in a patient's individual hamstring muscles while keeping the specific knee and hip angles for peak muscle activity?

3. What baseline data/tests could I do to measure muscle fatigue? Are there any signs of muscle fatigue besides reduced maximal muscle force?

4. Some studies have found evidence that some parts of muscles could be electromyographically "silent". From your professional experience, have you ever had an issue like this? Do you think it is likely that I would have issues like this?

5. If a teenager (13-19) was using up to 100% of their maximal muscle force consistently how much greater could they potentially be at risk of Hamstring

1

related injury (including applicable bone injuries) compared to if they were using 90 or 80% of their maximal muscle force? What about different ages?

EMG & Sensor Layout Questions:

1. If a user was given a proper diagram of the hamstring muscle anatomy, do you think that they could place three, "2.5 x 3.5 cm" surface EMG sensors onto their skin over the areas the Biceps Femoris & Semitendinosus muscles would be located?

2. Would NIRS muscle oxygen sensors be able to more precisely detect muscle fatigue than surface EMG sensors?

3. If placed correctly would having EMG sensor data from the semimembranosus increase the accuracy of detecting hamstring injury risk and abnormal use patterns? Roughly how much would it benefit the accuracy?

4. From the diagrams and literature, I have seen/read the semimembranosus muscle is depicted to not be very accessible, do you think the accuracy benefits of a having a surface EMG sensor on the semimembranosus outweigh the possible downsides of improperly placing the sensor (ex. Sensor cross talk & Placement on different muscles)?

5. Would placing a sensor on the medial portion of the Biceps Femoris muscle rather than 1 on the BFlh and 1 on the BFsh reduce the accuracy of the muscle activation data my sensor is able to detect? Why? By how much?

Future Meetings:

I would like to have another meeting sometime during the Fall or Winter season depending on my progress with making the device. During this meeting I would like to hopefully discuss how I could improve my device and inform me about any issues or mistakes I have overlooked.

At what times and days of the week are you most available to meet?

May I email you if I would like you to either review something or answer a question? I will try to keep it at a maximum once per month.

Thank you!

Thank you for generously spending the time to talk to me, I will email you again sometime in the Fall-Winter season to schedule another meeting!

Stage 2 - Experiment: July 25, 2024-July 29, 2024

What happened:

- I finalised my design specifications
    - My design will include 2 EMG sensors with one placed on the medial portion of the Biceps Femoris and the other placed on the Semitendinosus

    - A Raspberry Pi and an Arduino Uno R4 Wi-Fi will be used as the Arduino provides power for the sensors while being able to receive the data, meanwhile the Raspberry Pi will do all the complex computing.

- Met with mother to discuss the purchasing of parts and confirming the budget
    - We agreed on spending less than $500 and decided that we would go to Solarbotics, a local electronics part store, to buy parts I would need

- Asked my Physiotherapist to be my science fair project mentor
    - Having a mentor with a Biomedical engineering background will be extremely helpful for the duration of my project

- Bought the Netter's anatomy coloring book at the U of C bookstore
    - Having a diagram of the hamstring muscle group is important not only for personal use but for display on the presentation day

What I would do differently:

Next time I would finalize my design specifications a month before I start buying parts. This will allow me to have more time to think of what I needed.

To work on next:

I can start to make prototypes of the leg sleeve and start to make 3D models of some 3D printable components.

Stage 3 - Create: July 29, 2024-September 8, 2024

What happened this section:

- My parts from Digi key electronics had arrived
    - All my major components had arrived so I could get stated coding

- I made a prototype leg sleeve
  - I made my prototype out of cardboard with the objectives of fitting comfortably, and incorporating the sensor and microcontroller without making the sleeve feel bulky
  - I observed from my prototype that it needed Velcro to fit legs of various sizes, easily hid all of the EMG sensors, and had issues holding the Arduino around my leg without trying to bend it
- I realized I needed to buy some more components
  - I realized that I could not turn the Raspberry Pi on because I didn't have a Mirco SD card, a Micro HDMI to HDMI cable, and a Video capture card
  - I would also have issues connecting to a breadboard because of the Raspberry Pi male pins so I would need to buy Male-Female jumper wires as well
- Made 3 different versions of 3D printed cases for my Arduino
  - In the version 1 design, I accidentally forgot to join the bottom piece and the walls in the 3D model, so after I took the printed model off of the build plate the bottom fell off
  - In the version 2 design, I modeled it too small, so the Arduino did not fit in the case
  - In the version 3 design, I modeled it with the exact dimensions and added enough slots to save filament and weight
- Bought the extra parts
  - Now I could finally start working on the Raspberry Pi and the components that would connect to it
- Meeting with mother
  - Started to section up my logbook and insert reflection pages at the end of each section
  - Received some files that taught me how to present and how to design

What I would do differently:

If I ever do something like this, I will think about what parts I would need to make sure I would only need to buy parts once. I will also always add a millimetre of room to the inside dimensions of a model to make sure it will fit.

To work on next:

Next, I will start working on the Raspberry Pi and connecting the LCD screen to it via a breadboard and headers

Stage 4 - Detail: September 8, 2024-January 20, 2025

What happened in this section:

- Learned how to use the purchased components
    - I learned how to upload code onto the Arduino which allowed me to learn how to use the sEMG sensors and apply simple filtering procedures on it
    - I also learned how to use the "*pybluez*" python library to allow me to connect my Arduino to the raspberry pi and transfer data using the mac address and 2 UUID's
    - Learned that my device had a Bluetooth range of approximately 30 meters
    - Finally, I learned how to wire the RBG LCD screen up by following Adafruit's guide online
- Met with mentors and discovered some new ideas on the project:
    - Learned from Mr. Schipilow about the possible uses of my device for those who are 1. Recovering, 2. Recently injured, and 3. Fully recovered/not injured
    - Not showing the sEMG values because it could be confusing to people
    - If I had access to unlimited funds and resources, ideally, I should run a large-scale study where a group of individuals would play soccer for a certain number of hours while another group would do the exact same thing but use my device either during pre-game warm-up or during active play

- Discovered gaps in my knowledge
    - My mentor Mr. Schipilow, asked what the values the Arduino was getting were and I was unable to explain so I later researched it and found out they were 10-bit ADC values
    - I also lacked knowledge in the trends of EMG muscle activation values during sub-maximal and maximal contractions

- Learned about the Neuromuscular Training (NMT) warm-up program developed by the University of Calgary
    - Dr. Ballinger introduced me to the NMT warm-up program during our meeting and I discovered how I could use it in conjunction with my device instead of having to create a muscle fatigue machine learning model

- Made design choices for my device
    - Decided to place the Arduino and battery pack inside a belt bag to reduce the weight of the leg sleeve such that it would have a greater chance at staying on the user's leg
    - Decided to make my leg sleeve out of a medical bandage as its stretchy material properties and size allowed me to fit all the components in it while also providing a tight fit
    - Decided to apply the filter function in the programming code that is made available for the sEMG sensors I purchased. The code has a notch, low pass, and high pass filtering functions.

- Created testing procedures for my device to be used with the NMT warm-up program
    - Chose 4 NMT warm up exercises (Skipping, Airplane Balance, Nordic Hamstring Curl, Squat Jump) for testing my device on the participants, and also to test my machine learning models on 3 of these exercises

<u>What I would do differently:</u>

Next time I would do more research into my field I was planning to talk to my mentors about since it was embarrassing not know what they were talking about. I would also research into the detail of my purchased parts to ensure that I used the proper code the first time and stop needing to go back and redo it.

<u>To work on next:</u>

Build the leg sleeve and test the MuscleWatch device on teenage participants

Appendix 4-1: (October 28, 2024)

Isaac Cheng 2025 Calgary Youth Science Fair (CYSF) project

Email: [redacted]

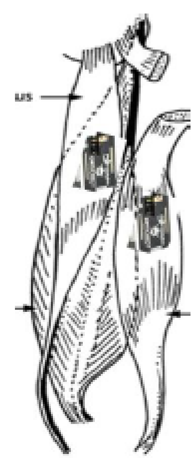
Phone: [redacted]

Background

Hamstring strain injuries (HSIs) are one of the most common injuries affecting sprint-based sports, accounting for up to 24% of all injuries in football, 17% of all injures in track and field and 22% of all injuries in rugby (Bramah et al., 2023). Currently, hamstring injury prevention and rehabilitation strategies primarily focus on building eccentric strength as eccentric training should in theory enhance the hamstring's ability to withstand hamstring strain (Bramah et al., 2023). However, only a small percentage of athletes partake in eccentric hamstring training as time with a physiotherapist is typically required to determine the needs of an individual and develop a personalised training plan. Additionally, many athletes still experience hamstring injury during sprint-based sport because most will unintentionally disregard their voluntary limit and try to run at their physical limit instead. This shows that eccentric exercises are not a great solution for everyone, but rather a small minority of people, hence the need for a way to prevent and rehabilitate those from hamstring injury.

Question

How might we non-invasively monitor hamstring muscle activation in teenagers during physical activity to prevent hamstring injury and minimize downtime in play?



Innovation Goals

I design my innovation device to monitor, detect, and alert users when their hamstring muscle activation is within a preset percentage of the user's maximal muscle activation, and thus reducing the risk of hamstring injury. The device will also be able to detect many muscle fatigue patterns and supply continuous hours of use without needing to recharge.

Design Criteria

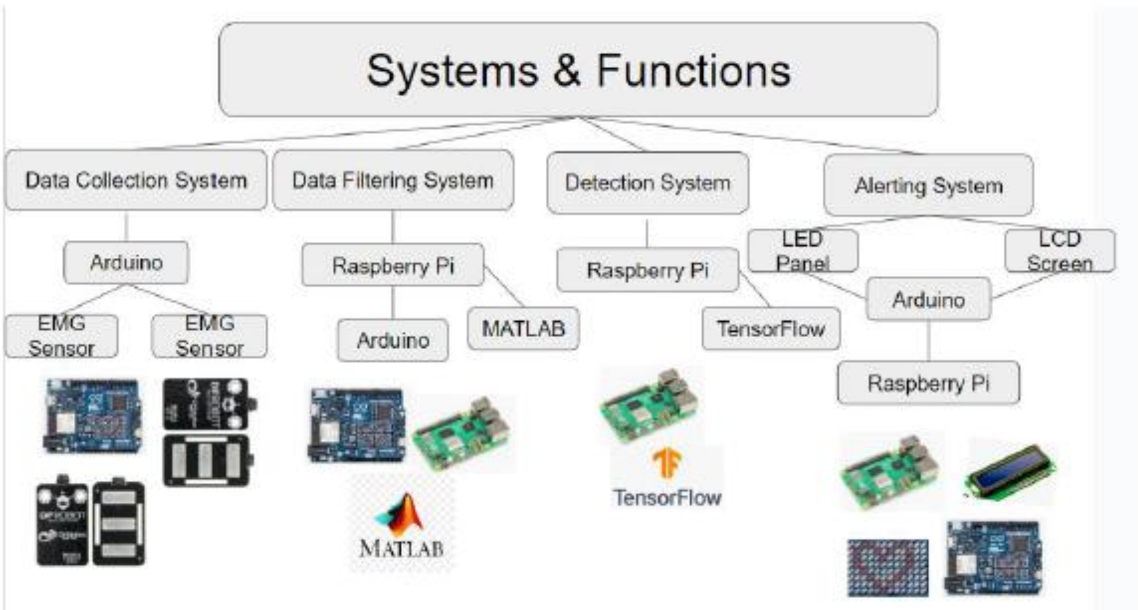
Safety: The device should be able to complete its function while not putting the user at risk of harm

Weight: The total weight should be bearable to the user for long periods of time and should not cause major discomfort when worn over the hamstring muscle

Accuracy: The device should be accurate to a minimum 80% of the set target muscle activation range

System-level design

The overall device will have 4 main systems that run concurrently, the data collection system, the filtering system, the detection system and the alerting system. The data collection process consists of the 2 surface EMG sensors who job is to intake muscle activation data, and relay it to the Arduino. From there, the Arduino will send the data wirelessly via Bluetooth to the Raspberry Pi microcontroller, which is responsible for both the filtering process, in which a bandpass filter is applied via MATLAB and the detection process, during which the data is run though a TensorFlow machine learning model designed to recognise muscle fatigue patterns and values that are past the preset limit. Finally, during the alerting system process, the Raspberry Pi will send an alert signal back to the Arduino which will use the onboard LED lights and LCD screen.



2

Target Milestones / Timeline

June 2024	Idea exploration, literature review, preliminary strategy
July 2024	Design concept, system level design
Aug-Sep 2024	Design of hardware systems, prototyping
Oct 2024	Fabrication of hardware systems
Nov 2024	Programing of hardware systems
Dec 2024	Design iteration, fabrication refinements
Jan 2025	Testing and refinement
Feb 2025	Field testing, data analysis
Mar 2025	Project submission and presentation

Citations

Bramah, C., Mendiguchia, J., Dos'Santos, T., & Morin, J.-B. (2023). Exploring the Role of Sprint Biomechanics in Hamstring Strain Injuries: A Current Opinion on Existing Concepts and Evidence. *Sports Medicine*, *54*(4), 783–793. https://doi.org/10.1007/s40279-023-01925-x

Appendix 4-2: (October 28, 2024)

Current Progress Report

Note: Refer to Component Funnel Chart

Completed:

- I have connected and powered on all the components needed in Modules A, B, C, D, and F.
- I have finished and combined the code for Modules B & D

Working on:

- Writing the code for Module F and combining it with the code for Modules B & D
- Making the code for Module A and syncing it up with the code for Modules B, D, and F
- Testing the EMG sensors (Module B) on hamstring muscles instead of forearms

To work on next:

- Create the leg sleeve and remaining 3D printed components
- Combine the components with the leg sleeve to make a test prototype
- Start working on making code for Module C (Will not be completed for a few months)

Appendix 4-3: (October 29, 2024)

Gmail

Isaac C [redacted]

Science Fair Project Update

2 messages

Isaac C [redacted]
To: [redacted]

Tue, Oct 29, 2024 at 6:52 AM

Dear Mr. Schipilow,

Over these past few months I have been working on my science fair project as mentioned during my first appointment. I have attached 3 PDF files, the first of which is my current project progress report that I have made, detailing what steps I have completed, and what steps I am currently working on. The second of which is my Component Funnel Chart which breaks down my device into modules to demonstrate the purpose of each component. Lastly, the third PDF file is my Project Overview Sheet that I gave you to look over during our first appointment. Together these three files should give you a good overview of my overall progress so far.

If possible, I would like to request 3 in-person 1-hour meetings with you to seek your professional advice. For the first meeting, I am targeting a time in the next 2-3 weeks for a systematic design review. For the other 2 meetings I propose that they will occur sometime this winter (early December-January). Please let me know what day/time works best for you, I am flexible. We can discuss during my 4:20 physiotherapy appointment this afternoon.

Thank you so much,

Isaac Cheng

3 attachments

CYSF25-Project_Progress_Report.pdf
42K

Coase-to-Fine Funnel Chart-pdf.pdf
53K

Isaac C-CYSF25-Science Fair Project Overview Sheet.pdf
207K

Isaac C [redacted]
To: [redacted]

Tue, Oct 29, 2024 at 6:57 PM

Hi Mr. Schipilow,

Thank you for offering to meet with me on Tuesday, November 12 from 11:30-12:30. As discussed earlier, I would appreciate it if you would:

- Ask lots of questions
  - To see if there are design aspects I have missed or things I didn't know about
- Suggest how to communicate to a wide audience
  - In explaining my design process and showcasing my device in a non-technical way
- Provide feedback
  - Feedback on my design process and the effectiveness/optimization of my device such as potential applications for clinical rehabilitation

I will send you another email by end of day Sunday (Nov. 10), with some documents for our meeting on November 12th.

Thank you,

Isaac

Appendix 4-4: (November 12, 2024)

Gmail

Isaac C [redacted]

Post-design review reflection

1 message

Isaac C [redacted]
To [redacted]

Tue, Nov 12, 2024 at 7:15 PM

Hello Mr Schipilow,

Thank you for taking the time to meet with me this morning. I appreciate the tips you gave me on how to communicate my device's purpose and uses, especially with those who may not know much about this topic.

I am considering the following ideas you mentioned during the meeting to improve my device, and help diversify its possible areas of use.

- Personalization (What could I change in the hardware/software to make the device more suitable for the user's purpose?)
- Different monitoring modes (How could I modify the colors and text displayed on the LCD screen to fit the sprint training plan of a non-injured athlete vs. an athlete currently in rehabilitation, 1 week after a grade 2 muscle tear?)
- Whether to display the sensor data or not? (Showing the sensor readings may be beneficial to those who understand the meaning however, some users may misinterpret the values and become confused)
- How the difference between submaximal and maximal muscle contractions will impact the EMG sensor values (submaximal contractions tend to cause EMG sensor values to rise while maximal contractions will cause values to fall due to fatigue)

I will give you much advance notice prior to scheduling a second review, most likely in early January given the holidays.

Thank you so much again for your time and insightful feedback. Have a great rest of your week.

Isaac Cheng

Appendix 4-5: (November 12, 2024)

Gmail

Isaac C <[redacted]>

Journal articles and summary

2 messages

John Schipilow <[redacted]>
To: Isaac C <[redacted]>

Tue, Nov 12, 2024 at 8:45 PM

Hi Isaac,

Here are the journal articles I mentioned earlier. Again, I don't think these are critical, but I'm sending them just in case they are helpful to add to your reference list, or if you find them helpful to discuss EMG activity in a rehab/performance context. You can scan the abstract (summary at the start of the article), especially the objectives/conclusions, to determine if it's worth your time reading in more detail.

Royer: Brief article about some general interpretation of EMG data.

Tsaklis: Gives you an idea of EMG activity in the hamstring with some specific exercises.

Tillaar: Another one looking at EMG activity with different exercises, but a little more complex.

Sole: Shows a reduction in strength and EMG activity for the hamstring muscle when it's lengthened, specifically in a population with previous hamstring injuries.

Nakao: This is an article that looked at the stress strain relationship of the different hamstring muscles in isolation using cadaver tissue. Figure 5 shows a higher amount of stress (stress = force per unit area) on the muscles for a given strain (strain = change in length). Note that there is more stress on semimembranosus and biceps femoris for a given strain relative to semitenindosous. I just thought that was interesting, but may also help you justify placing a sensor on more than one specific muscle.

Summary of Our Discussion:

Overall, you're doing great! Lots of thought put into the project and you're covering all the main points, and quite honestly, I find it all very impressive. To make things a bit more streamlined or understandable to a general audience, here are some of my main points:

In a clear and concise way, it may be helpful to outline the following in point form (or something easy to read):

1) problem,
2) objective,
3) related to both objective and design, you can maybe mention a few examples of when the data may be applicable ("minimize risk of aggravating injury" - don't exceed threshold with sustained submaximal activity or when reintroducing an activity for the first time after an injury vs. "Sport-specific loading for return to sport" - slowly progress to maximum activation for sport-specific training when the injury is healed in order to try and prevent re-injury).
4) state how you will define/determine maximum threshold
5) picture of where to put the sensors

Again, I'm not saying to leave out complicated details, as those are certainly necessary (especially with the design), but if some of the big picture stuff is simple and clear you may have an easier time drawing some interest.

You're doing great, so I don't want this to be overwhelming, just things to consider as you start to compile your project and any display that goes with it.

Hope that helps!

John Schipilow, P.T., MSc.PT, MSc.BME, BSc.Biomech.
Physiotherapist - University of Calgary Sports Medicine Centre
[redacted]

5 attachments

Royer 2005.pdf
177K

Tsaklis et al 2015.pdf
3603K

Tillaar et al 2017.pdf
1167K

Sole et al 2011.pdf
1067K

Nakao et al 2024.pdf
2224K

Isaac C [redacted] Tue, Nov 12, 2024 at 8:53 PM
To: John Schipilow <[redacted]>

Thank you so much Mr. Schipilow for your detailed recommendations. I really appreciate it.

I will take some time to digest and incorporate your advice into both my design and my project.

Thank you,

Isaac
[Quoted text hidden]

Appendix 4-6: (November 24-25, 2024)

Gmail Isaac C [redacted]

Nov. 26 Design Review Meeting at 5:00-5:30pm

3 messages

Isaac C [redacted] Sun, Nov 24, 2024 at 9:13 PM
To: Karen Ballinger [redacted]

Hello Dr. Ballinger,

This is to confirm I am available to meet with you on Tuesday, Nov. 26 @5pm as scheduled.

I have attached to this email a Design Brief which includes some of the questions for our discussion.

Proposed Agenda

- 10 min - Device demo set up + Design brief review
- 5-10 min - Device Demo
- 10 min - Questions / Discussion

Thank you,

Isaac Cheng

DesignBriefForReview-2024-11-26.pdf
686K

Isaac C [redacted] >

[Quoted text hidden]

DesignBriefForReview-2024-11-26.pdf
686K

Karen Ballinger [redacted] Mon, Nov 25, 2024 at 10:33 AM
To: Isaac C [redacted]

Hi Isaac,

Thank you for sending along the information prior to our meeting. Looking forward to it!

Dr. Ballinger

From: Isaac C [redacted]
Sent: Sunday, November 24, 2024 9:13 PM

Appendix 4-7: (November 26, 2024)

DesignBriefForReview-2024-11-26

CYSF Project Title:

A Muscle Watch: A Personalized Device for Hamstring Injury Prevention Using Surface Electromyographic Sensors and Machine Learning

Overview - Project Background

Hamstring strain injuries (HSI) are commonly seen in sprint-based and stretching sports [1,2], which are acquired either acutely or due to overuse [3]. In acutely acquired injuries, a person may have taken an awkward fall, twisted their leg, or performed a motion that caused the muscle to tear or strain. However, in overuse injuries, the muscle fails due to excessive biomechanical strain overload [2] and incomplete healing [3]. Those at risk of an overuse injury are generally endurance and "industrial athletes", employees who use their musculoskeletal system to perform their jobs [8].

Youth are at a higher risk of sport-related injury given a lack of awareness of the risk or prevention strategies [6]. It is common to see acute HSI occur in young athletes aged between 15-17, specifically in running-based sports such as football, soccer, rugby [4,5] where 47% of these injuries are reported to have occurred while sprinting [1]. The recurrence rate of injury upon return to play is also very high at approximately 18% [1].

Preventative strategies are critical in ensuring youth's lifelong participation in sport, which will allow them to reap the many health benefits associated with an active lifestyle [6]. To date, preventative measures such as eccentric strength training have been introduced to and supplemented into the training plans of many competitive athletes in team sports. The rationale is that eccentric training will develop the tissue architecture and thus, enhance the capacity of the hamstrings to withstand strain [1]. Eccentric strengthening programs such as the Nordic Hamstring exercises have proven to reduce injury rates, however, the significance of HSI continues to rise [1]. Training interventions are often limited to usage in sports team settings that are run by trained coaches. As a result, vulnerable youth of any age including those who do not train with teams, live in rural and Indigenous communities and/or with disabilities may not have knowledge or access to such injury preventive strategies [6].

Wearable technologies (WT) are devices that are worn on the body, non-invasive, and incorporate sensors, processing units, communication units, and power sources [7]. Today, WT are widely used in sports to measure and monitor athletic performance not just for performance optimization but also for injury prevention and rehabilitation [7,6]. Continuous real-time data provided before, during, and after training, as well as during normal daily activities, can be analyzed to maintain a healthy balance between high athletic performance and overexertion [7].

The consensus statement on youth running states that reducing injury risks requires the consideration of the complex interaction of various intrinsic risk factors (such as sex, previous injury, Body Mass Index, age) and extrinsic risk factors that impact training (such as terrain, pace, intensity and training errors) in runners [9]. Current recommendations from biomechanical modelling studies of HSI are that "successful injury prevention strategies require a more multifactorial and individualised approach, targeting both factors influencing tissue strain, such as mechanics and strain capacity" [1]. As such, personalized WT devices are thought to hold promise in offering real-time athletic performance monitoring feedback tailored to an individual athlete's goals and needs.

Project Objectives

Problem: How might we non-invasively monitor hamstring muscle activation in teenagers during physical activity to prevent hamstring injury and minimize downtime in play?

Proposed Solution: To create a personalized, wearable leg sleeve device (to be worn on the back of the thigh) equipped with surface electromyographic (sEMG) sensors to provide real-time feedback on hamstring muscle activation. The obtained EMG signals are then processed and evaluated against a safety threshold. If the threshold is exceeded, an alert will be generated informing the user that they are at risk of HSI.

Intended Users:

- Preadolescents and adolescents who are new to a specific sport and/or unaware of their own biomechanical strain limits
- Vulnerable youth who do not have access to professional trainers or coaches in team sports
- Individual athletes of all ages who are undergoing functional rehabilitation of sport injuries
- "Industrial athletes" who have been cleared to return to work after HSI in the workplace

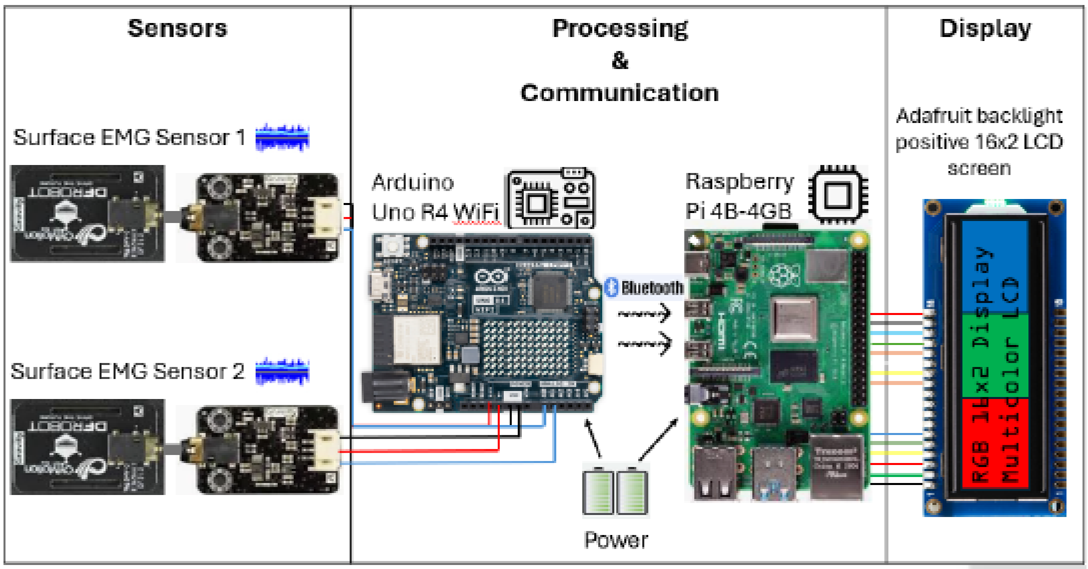
System Overview:

1. **Sensors:** 2 sEMG sensors, equipped with dry electrodes, to be placed on the Semitendinosus (ST) and the Biceps Femoris (BF) according to SENIAM recommendations [10]. The EMG electrodes detect the electrical signals originating from these two hamstring muscles (ST and BF) that are measured in microvolts.
2. **Microcontroller:** Arduino UNO R4 - Takes EMG values and applies a low-pass filter before relaying the data to the Raspberry Pi
3. **Processing unit:** Raspberry Pi 4B - Detects values that are too large and tells the display to turn red and communicate an alert
4. **Communication unit:** Bluetooth Low Energy (BLE)
5. **Display unit:** RGB Backlight Positive LCD 16x2 display
6. **Power unit:** 2 Power Banks (one for Arduino and one for Raspberry Pi)

System Demonstration:

- I will demonstrate my device is operational from collecting raw EMG data to alerting the user (as shown in the system diagram)

A Muscle Watch: System Design Diagram



<u>Questions for discussion</u>

The judging rubrics state that "honest comparisons are made to alternative or previous solutions where possible".

- Do the previous solutions for hamstring injury prevention mostly involve eccentric strength training (e.g. Nordic hamstring exercises, explosive laying kick exercise)?
- Are there any other clinically proven prevention strategies that I am unaware of?
- How would I demonstrate that a personalised WT device can achieve similar, if not better, results than previous solutions?
- Human hamstring fatigue detection vs. Machine Learning detection model

How do I ensure that the sensors will stay on the recommended spots during the duration of the activity?

- Tape down the sensors with athletic tape (regardless of textile material used)
- Elastic bandage
- Compression sleeve
- Silicone or sticky tack on the elastic band

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Given the device's limited Bluetooth range (approximately 30m), how could I test my device on others in a low-risk manner?

- Light jogging (within range)
- Jumping
- Cycling on a stationary bike

Next Steps (late Nov 2024 to early Jan 2025):

1. **Implement Design Modifications as recommended by Mr. Schipilow:**
    a. Personalization (Hardware/Software)
    b. Different monitoring modes (Performance vs. Standard)
    c. Display the sensor data or not?
2. **Research and Implement sEMG data analysis on Arduino - (FFT)**
3. **Continue Prototyping the leg sleeve** - Test with different textile materials and sensor adhesion
4. **Set up Machine Learning (Tensorflow)** - Train a Pattern Recognition model to detect certain data patterns and alert when detected
5. **Testing** - Test device on myself and other adolescent users (with parental consent) to learn if all needs are met

<u>Stage 5 - Build and Test:</u> January 21, 2025-March 18, 2025

<u>What happened in this section:</u>

- Begun coding the machine learning models in Jupyter lab on the Raspberry Pi
    - Downloaded Jupyter lab and learned how to open it on my Raspberry Pi through the Raspberry Pi terminal
    - Learned how to open files and new terminal windows in Jupyter lab
    - Watched various videos on Pandas, TensorFlow, NumPy, and machine learning models
- Finished up Arduino code
    - Discovered that there is a limit on the flow rate of the samples so that my 62.5 samples a second becomes 8
    - Discovered that the best down sampling sizes between 4-8 to prevent loss of features in the data

    - Best squared ADC value threshold is between 120000-140000
- Designed various 3D components while working on the leg sleeve
    - Designed the Track Tightener pieces, sEMG sensor covers, amplifier board covers, Arduino and battery pack case (to be placed inside the fanny pack), and the micro processing receiving module case to house the components connected to the Raspberry Pi
- Begun training the machine learning models
    - Learned how to collect examples in specific amounts of time to use to train the model
    - Learned how to train a machine learning model using optimiser SGD with a fully connected Neural Network (NN)
    - Learned how to set the number of hidden nodes in a dense layer
    - Learned how to shuffle the data to prevent the model from learning the patterns in which I ordered my examples specifically with the "proper" exercise fidelity in the first half of the dataset followed by the "improper" examples that made up the rest of each of the training, validation and test datasets
    - Learned how to test the machine learning models on my validation data sets and testing data sets using the library "matplotlib" and Scikit learn metrics to plot the loss and accuracy of each model
    - Found that sigmoid activation of both layers in my neural network with a learning rate between 0.1-0.001 resulted in the best results
    - Learned how to change the classification threshold in the Squat Jump model to reduce the amount of false negative in the validation and testing data sets
    - Made the final code for each of the three models including the calculation of the MuscleWatch's predicted RPE
- Uploaded code to the Github repository for public viewing & learned how to provide credit for the sources and libraries I used to code the MuscleWatch
    - Uploaded all the code used for my final design
    - Made sure to give credit to others created the videos, articles, and software I used in this project.
    - Made sure to add a message at the top of every file and in the README.MD section of the repository about my usage of AI to partially generate some of the code
- Tested the MuscleWatch on each of the participants
    - Tested the device on 11 participants in my living room

    - Found that some of the participants needed extra pressure on the back sensors to push it tight against their leg so I wedged in some of my extra 3D printed Track tightener pieces
    - Began to use an extra elastic bandage to secure the leg sleeve as the sleeve was gradually sliding off some of the participants
- Results of the testing of the MuscleWatch
    - Found that the MuscleWatch accuracy was way less than the accuracy of the model on my validation data
    - Found that the accuracy of the MuscleWatch was worse on dynamic exercises like the Squat Jump and better on repeatable exercises such as the Nordic Hamstring Curl
    - Although the area where the MuscleWatch predicted RPE the best was with the Squat Jump
    - MuscleWatch was overall reported to be comfortable and useful

<u>What I would do differently:</u>

- Begin working on the machine learning models and reaching out to participants earlier as the scheduling, and the training, of the models take way more time than anticipated
- Manage my time better by doing something everyday to reduce workload closer to the deadline

<u>To work on next:</u>

- Finalize the drafts from previous write ups and the documents I have created to submit the final write up on to the CYSF portal
- Prepare the trifold and the oral presentation for the fair
- Review information I have learned from this project over the course of the previous 9 months

Appendix 5-1: (February 13-14, 2025)

Gmail

Isaac C [redacted]

Project Feedback

2 messages

John Schipilow [redacted]
To: Isaac C <[redacted]>

Thu, Feb 13, 2025 at 9:24 AM

Hi Isaac,

I read through your documents. Here are a few comments:

PROBLEM:

Motivation Section:

- Paragraph 2 - I believe you meant to say “Adolescents” (not adolescence) in this case? Minor detail...

- I really like Point ii in your third paragraph about lack of awareness and lack of access to professional coaches or trainers. In addition to your other info, I think this will really help people understand the practical implications of your project, and it's also something that most people can relate to. Same thing with the following two paragraphs. Good job.

Project Objectives:

- I like how your Motivation section finished with exercise fidelity and then you immediately tied in your project to exercise fidelity in the first paragraph of Project Objectives.

- Good job explaining the three phases.

Method/Device Component/Material and Cost:

- All well explained and broken down into components.

PART III:

- I think you made a good decision to validate your tool against existing research (SHRed) and visual assessment of exercise fidelity. This will go a long way in backing your tool, but also demonstrates a high level of critical thinking, which is very important when developing a new method or technology.

- I like the comfort rating scale being included in your simulation design. This is the type of thing that can be easy to overlook when you're focused on the technology, but would be a likely question from judges (e.g. so it works well, but will people wear it?). If it's comfortable, great! But even if it ends up not being as comfortable as desired, that is something that could eventually be addressed in “limitations” or “future considerations” for your project if there isn't time to actually address that.

OVERALL:

- This looks great! I think you made a good decision validation against existing programs (from a local university, too!). I think you have a good balance of emphasizing the technology and machine learning, but also keeping in mind what judges might consider more “real life” or “practical” aspects of your technology (e.g. is it comfortable, does it align with RPE, do participants find it useful, etc).

- I don't think you need to change anything at this point. Let's see where your validation takes you and go from there. Excellent job!

Please let me know if you have any questions or concerns. I'll hang on to your documents in case I need to refer back to the at any time. Keep up the good work!

Take care,
John

John Schipilow, P.T., MSc.PT, MSc.BME, BSc.Biomech.
Physiotherapist - University of Calgary Sports Medicine Centre
[redacted]

Isaac C <[redacted]> Fri, Feb 14, 2025 at 6:29 PM
To: John Schipilow <[redacted]>

Hello Mr. Schipilow,

Thank you for taking so much time to read through my documents and provide detailed comments. I really appreciate your feedback.

Status Update:
I have just finished testing each of the three machine learning models and they are performing end to end as expected. I am also updating the surveys participants will fill out after using the device.

At this point, I am comfortable with starting the validation study tomorrow. Once the validation study is completed, I will create, and share with you and Dr. Ballinger, a video demonstrating the device and its applicability to hamstring injury prevention.

If all works out as planned, I will share with you the final writeup in early March before submitting them online by March 17.

Thank you,
Isaac C
[Quoted text hidden]