BME Design-Fall 2023 - NEHA KULKARNI
Complete Notebook

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BRYAN TOPERCER

on

Dec 15, 2023 @11:45 AM CST

Table of Contents

Team contact Information

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Thein-Nissenbaum	Jill	Client	thein@pt.wisc.edu		
Brockman	Joshua	Advisor	jmbrockman2@wisc.edu		
Kulkarni	Neha	Leader	nnkulkarni@wisc.edu	(608)512-9294	
Kaur	Simerjot	Communicator	kaur26@wisc.edu	(414)793-9967	
Wadzinski	Emily	BSAC	ewadzinski@wisc.edu	(608)957-9119	
Ryan	Orla	BWIG	orryan@wisc.edu		
Topercer	Brian	BWIG	topercer@wisc.edu		
Bhatia	Simret	BPAG	sbhatia25@wisc.edu	847-877-4344	

Project description

Course Number:

BME 200/300

Project Name:

Lower extremity force plates to determine accuracy of biomechanical movement of crew athletes during erging and sweep rowing

Short Name:

Force Sensor for Rowing Biomechanics

Project description/problem statement:

Many college rowing athletes, particularly women, are susceptible to lifelong lower back or hip injuries due to disparate weight distributions on each leg while rowing. This issue can be addressed through gathering real-time data on athlete biomechanics, but this data is often difficult to obtain. Collection and analysis of biomechanical data will enable athletes to adapt their technique towards better performance, and will assist coaches and trainers in preventing injury. The client, Dr. Jill Thein-Nissenbaum, has tasked the team with creating a force plate system that can collect biomechanical data from rowers' lower extremities. The team's goal is to create a wireless sensor system in the rowboat that will capture load distribution during time of use and will assess lower extremity asymmetry to establish risk stratification. Additionally, the team aims to translate the force plate system into a user-friendly interface that will enable coaches and athletes to understand essential biofeedback information, thereby improving both performance and safeguarding against injuries.

About the client:

Dr. Jill Thein-Nissenbaum - UW Athletics Physical Therapist

Tricia De Souza - UW Athletic Trainer

Sarah Navin - PT student and former UW Crew

2023/09/15 First Client Meeting

Title: First Client Meeting

Date: 9/15/2023

Content by: Simmi, Emily, Neha, Simret, Brian and Orla

Present: Simmi, Emily, Neha, Simret, Brian and Orla

Goals: Establish a baseline for the project and build a foundation on rowing and lower extremity asymmetry in rowing athletes.

Content:

Rowing team: 140 women, 55-65 men (Middle of tryouts, will be more people)

3 different squads, dif times (early mornings, afternoons too)

Docks get pulled in winter, then students move to rowing machine

Ergometer used for strength extension/flexion in the gym

- Noticed uneven shoulders, hips

Water technique is dif than the rowing ergometer

Boats aren't as level in water, used to leaning

Rowing to one side -> may not be pushing off evenly (sweep rowing)

In the boats, feet are different (quick release vs tied heels)

- Make force plates compatible to one boat

Look at th ebike in McClain center

Plan to meet at boats next week

- Can meet morning or afternoon, as well as at the boat house
- Trish can show video for erg
- See the foot stuff in the boat

Force plates in:

- People are more symmetrical on the erg and are asymmetrical on the boat
- Easiest thing to design for will be the erg because it is a more controlled environment, at least to start
- Take a look at equipment and determine what to start with
- Erg and tank are relatively similar so we could make plates that are compatible with both
- Don't need to be incredibly sensitive, just need to match

Tanking

- Foot plates same as erg, but now rowing asymmetrically

- Can make current and stimulates more of an actual environment

- Used to work on form or technique (not a lot of training w it)

- Can change speed of water

Types of foot rests:

- Shaped like a shoe where you slide your foot in

- You can strap your foot in onto a plate

- Quick release where the heel is attached to yours and moves with your foot

How long do you want to use the force plates

- Couple min

- Fresh vs fatigued

- But as they get fatigued there form changes so that might be worth to track

- Practices are 2-3 hours, beneficial to use force plates for practice

- Open to either option (mainly 5 min, fresh)

Water proof

- Gets wet pretty quickly

- They even row in the rain

- Water pools in bottom but doesn't usually get to the feet (only splashed, not submerged)

4 or 8 in a boat

Only a couple to start with - dependent on budget from rowing athletics

Trish will talk to coaches about budget (maybe between $100-500)

Data collection

- Need to know symmetry side to side

  - Not many more details past that

  - Only need magnitude

- Real time

- Maybe have a display on erg to show the student what is going on in the moment in order to correct for

Athletic trainers and PT will start with data

- Coaches will want data as well

- Athletes would also like to see to determine how to get better

- Biofeedback tool - use the data to make changes to technique (rehab)

1997 research where they used force plates in boats

- They will send article

Keep meetings at 12:15pm on Fridays

Conclusions/action items: In conclusion, our project will provide a new type of data in rowing, which is quantification on lower extremity asymmetry in rowing as there is already a lot of qualitative data on this subject. The coaches will only need the magnitude of force applied by the minute during rowing practice and we need to create an interface for real time data viewing for athletes. Action items are to learn about rowboats by visiting the boathouse and observing a rowing practice. We will also schedule a meeting to view a demonstration of rowing biomechanics and see the ergometer.

SIMERJOT KAUR - Sep 15, 2023, 8:21 PM CDT

[Download](#)

Client_Meeting_9_15.pdf (64 kB)

2023/09/19 - McClain Center Visit

Title: 2023/09/19 McClain Center Visit

Date: 2023/09/19

Content by:

Present: Simmi, Neha & Tricia, Sarah (clients)

Goals: Look at the ergometer and observe the watt bike.

Content:

- ergometer: Concept2
    - shows force vs time per stroke, helpful visual for athlete
    - foot plate has adjustable toe strap height, heel strap to lock onto shoe
    - heel can lift up and down, no specific pivot point
    - see attached photos
- erging mechanics
    - catch: full flexion at hip, knee, and ankle
    - drive: legs extend, elbows flex in
    - finish: full leg extension, full elbow flexion
    - recover: return to catch position by flexing at hip, knee, ankle and extending at elbow
- watt bike
    - no clarity on where sensors are located
    - measures force via watts - client doesn't any pure force readings, watts is ok
    - visual, real-time depiction of symmetry in display
    - accompanying app is optional
    - see attached photos
- literature review
    - got lots of articles (hard copies) related to lower back injuries and rowing mechanics
    - some are old but could still be helpful

Conclusions/action items: Consider replicating elements of the watt bike display to show asymmetry, and read the literature Tricia provided.

2023/09/20 - Rowing Practice Visit

Title: 2023/09/19 Rowing Practice Visit

Date: 2023/09/19

Content by: Simmi

Present: Team, Sarah (client)

Goals: Gain an understanding of the different rowing practice equipment and see rowing biomechanics on the water.

Content:

Rowing Observations

- Feet are fully planted and engaged when rowers push during drive
- There are shoes built into the rowboat foot plates so load cells need to be placed underneath
- Knee angles are not uniform in rowers during catch and drive phase of sweep rowing
- Knees should be pointed ahead while upper body turns during sweeping motion
- Force sensors can fix this form for driving phase
- A full force plate is too big to fit in the foot plates but individual load cells will be able to

Tank Observations

- Rowing simulation where we row against current, strength of current can be adjusted
- Movement of taking oar out of a water requires a lot of core strength and can cause rowers to lean towards one side
- Motion of hips flexing and extending is very forceful and repetitive
- Tank is more accurate than ergometer and can be used to test out force sensors before placing in boats

Taking Ergometer Apart

- The foot plate of the ergometer was taken apart and it revealed a hollow space beneath in which can be used to store circuitry
- There is a foot strap adjuster that can come in the way of our design
- We need to figure out how to make the design adjustable for rowers

Rowboat Foot plate:

Tank Foot Plate:

Ergometer Foot Plate Detached:

Conclusions/action items: Consider using tank instead of ergometer to place force sensors in and look into load cells.

2023/09/29 - 3rd Zoom With Client

EMILY WADZINSKI - Sep 29, 2023, 12:34 PM CDT

Title: Client Meeting Design Matrix

Date: 2023/09/29

Content by: Emily

Present: Team, Sarah (client), Tricia

Goals: Share design matrix

Content:

- shared that the tank would be the best to implement our design in

- clients agreed tank would be best for specific data collection if needed

- shared the three designs: mentioned cost

- client asked if they are all real time -> all designs are

- like ideas, wondered if adaptable to any computer - resistors need a microcontroller but then can go to any computer

- can just use double sided tape for resistors, less in the way (more compatible)

- 2in by 3/4in a good range for size? -> only picks up force in that area -> may need a larger range for big feet

- as long as resistors are on the contact areas then force readings should be effective

- in future, may look at having force sensors for the whole foot (bigger cell), for now just place on the same part of the foot for each athlete (standardized point)

- rather have the resistor adjust to same spot on athlete anatomically, not the same spot on the tank (in case they have different size feet)

- can play around with the resistor's placement, very movable

Conclusion:

- look into range of force to know the capacity of resistor, look into steady-state force exertion, check in with Dr. N

- figure out where payment is going through

2023/11/10 - Prototype Discussions

NEHA KULKARNI - Dec 13, 2023, 9:10 AM CST

Title: Client Meeting Design Matrix

Date: 2023/09/29

Content by: Emily

Present: Team, Sarah (client), Tricia

Goals: Share design matrix

Content:

- shared that the tank would be the best to implement our design in

- clients agreed tank would be best for specific data collection if needed

- shared the three designs: mentioned cost

- client asked if they are all real time -> all designs are

- like ideas, wondered if adaptable to any computer - resistors need a microcontroller but then can go to any computer

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- rather have the resistor adjust to same spot on athlete anatomically, not the same spot on the tank (in case they have different size feet)

- can play around with the resistor's placement, very movable

Conclusion:

- look into range of force to know the capacity of resistor, look into steady-state force exertion, check in with Dr. N

- figure out where payment is going through

2023/11/10 - Prototype Discussions

NEHA KULKARNI - Dec 13, 2023, 9:15 AM CST

Title: Client Meeting Design Matrix

Date: 2023/11/10

Content by: Neha

Present: Team, Sarah (client), Tricia, Jill

Goals: Share design matrix

Content:

- going with load cell instead of FSR --> more accurate and easier circuit implementation

- lots of ways to embed load cell

things to keep in mind:

- not making anything too big on top of the footplate

- needs to be even footing across footplate (if something is added to toe then something of even thickness needs to be added to heel)

- retain adjustability as much as possible

Conclusion:

3D print a housing that goes over flexfoot so flexfoot can still slide underneath.

2023/09/15 Week 1 Advisor Meeting

EMILY WADZINSKI - Sep 22, 2023, 1:23 PM CDT

Title: Week 1 Advisor Meeting

Date: 9/15/2023

Content by: Simmi

Present: All

Goals: Gain deeper understanding of lab archives expectations and relay week 1 progress to Dr. Brockman

Content:

- For progress reports, continue titling with date, team and which week we are on
- For lab archives, include the date and put in respective folders for organization
- Lab archives expectations are to include anything that you have researched, discussed and observed. Your thought process and progression should be very clear and there shouldn't be any gaps in your contributions

Conclusions/action items: Keep updating the lab notebook with sufficient detail that makes it easy to refer back to.

2023/09/22 Week 2 Advisor Meeting

EMILY WADZINSKI - Sep 22, 2023, 1:31 PM CDT

Title: Week 2 Advisor Meeting

Date: 9/22/2023

Content by: Emily

Present: All

Goals: Gain deeper understanding of lab archives expectations and relay week 1 progress to Dr. Brockman

Content:

- shared pictures of visits with client to advisor

- explained load cells vs force plates, and reasoning to not use force plates anymore

- checked in with pds deadline

- asked capacity of load cells, if the ones were are looking at can deal with positive and negative forces

- how are we going to stay in budget if load cells cost 2400 per person, can we get more?

- clear with the client goals -> is there a way we can look at asymmetry without looking at forces, even though the client wants us to find magnitude

    - can we use a seesaw method instead?

- would they be ok with one load cell per foot?

Conclusion:

Will look at our notebooks this weekend - ask client these questions

Add as much as you can to the notebook/what you think is best

2023/09/29 Week 3 Advisor Meeting

ORLA RYAN - Sep 29, 2023, 2:10 PM CDT

Title: Week 3 Advisor Meeting

Date: 9/29/23

Content by: Orla

Present: All (Simret virtually)

Goals: Get feedback from our advisor on progress thus far, especially our current leading design.

Content:

- we took turns reviewing LabArchives notebooks with our advisor

- went through our design matrix and pointed out top-scoring design

- discussed optimal ranges of sensitivity for force-sensitive resistors

    - also touched on Arduino processes in upcoming weeks, and intentions to begin programming soon

Conclusions/action items: Conduct more research on force-sensitive resistor options and begin tangible work.

2023/10/13- Week 5 Advisor Meeting

ORLA RYAN - Oct 13, 2023, 1:21 PM CDT

Title: Week 5 Advisor Meeting

Date: 10/13/23

Content by: Orla

Present: Orla, Simret, Emily, Simmi, Bryan

Goals: To update our advisor on our meeting with the bioinstrumentation professor and our material orders.

Content:

- The team filled our advisor in on our meeting with Dr. Nimunkar

- Going to test both cheap load cells and cheap force sensitive resistors (FSRs)

- Recommends getting actual stats

    - Real results, comparisons of accuracy from both methods

    - Have numerical data to round out report/testing

- Agreed with prototype testing of FSRs with in-between 3D-printed device (ex: plunger shape)

- went over process of ordering cheap load cell, FSR, and amplifier

Conclusions/action items:

We hope to receive the materials soon and begin setting up and testing the different prototypes.

2023/12/01 - Week 12 Advisor Meeting

ORLA RYAN - Dec 01, 2023, 1:18 PM CST

Title: Week 12 Advisor Meeting

Date: 12/1/23

Content by: Orla

Present: All

Goals: Communicate to Dr Brockman where we are currently at with our prototype, calibration, and testing.

Content:

- We filled him in on the structure of the load cell (little node that sticks up above the cell)

- Described the techniques we used to calibrate the device and generate quantitative data

- Suggested we use cardboard or other materials to help embed the cell (especially since our 3D print is delayed)

    - Could drill a hole in a plank of wood, for example

- Can still potentially pick up the 3D print (should it be successful) on Saturday

- Even if 3D print doesn't end up working, will accept rudimentary data as part of our display

- Tentative plan to hook up two load cells to different Arduinos, and then show the display on two different laptops

- move the load cell to each foot for testing (real time data not quite as important, measuring force output for each foot)

- Testing:

    - get Sarah's weight standing on one foot (to compare to output produced by load cell measurement)

    - if loading rates during the test produce a "freak out", can take notice of parameters (how fast can Sarah move before lag occurs?)

Conclusions/action items:

Meet with the client on Monday and conduct testing, considering other options rather than the 3D printed plate. We will likely end up coming up with a backup plan for the 3D printed plate.

09/26/2023 - Preliminary Design Brainstorm

Title: Preliminary Design Brainstorm

Date: 09/26/2023

Content by: Neha

Present: Team

Goals: Brainstorm preliminary designs and choose three to move forward with.

Content:

The team met and each person went around saying their idea for a preliminary design.

Bryan

- Load cell at heel to arduino to display
- 3D print housing for load cell
- Underneath foot plate

Orla

- Make own sensors with silicone, magnetic powder
- Four thin sensors
    - Two toe, two heel
- Direct contact with feet
- Connected to microcontroller, then to display

Simret

- Load cell on top of underside of bottom footplate
- 3 load cells connected to display

Simmi

- Two load cells, screwed in to the footplate, embedded
    - Not sticking out
- Toe and heel
- Display on center ledge

Emily

- Plate with load cells, two on each plate
- Four load cells
    - Two toe, two heel
- Computer could be display

Neha

- Force sensitive resistor
- Voltage divider circuit

3 chosen:

Silicone-magnetic load force sensors

Force sensitive resistor

Load cells

- One on toe, one on heel

- Underneath footplate

- Connected to arduino/microcontroller

- Display screen mounted on center channel

Conclusions/action items: Begin constructing the design matrix to evaluate these designs.

09/26/2023 - Design Matrices

NEHA KULKARNI - Oct 11, 2023, 11:16 PM CDT

[Download](#)

Design_Matrix.xlsx (7.91 kB)

10/12/2023 Meeting with Dr. Nimunkar

SIMERJOT KAUR - Oct 13, 2023, 11:20 AM CDT

Title: Meeting with Dr. Nimunkar

Date: 10/12/2023

Content by: Simmi, Simret

Present: Everyone

Goals: Gain insights into first steps of setting up the circuits and learn about reliability of force resistors and load cells.

Content:

- problem with force sensitive resistor
    - Not able to withstand force (ones that we found aren't from a well known vendor)
    - Not concentrated at the center
    - Have to concentrate all the force in the center for accuracy
- can find low cost load cells
- 3D print something (plunger) to bring force mainly in the center if using force resistor
- Experiment to determine how to attach the plunger to sensor
    - Possible casing to keep it clean
- First steps are to order a cheap force resistor and cheap load cell
- One group focuses on FSR and the other focuses on load cell
- Load cell website have documentation (hookup guides, step by step instructions, provides info on which amplifier is suited)
- Buy amplifier that comes with load cell
- Serial monitor can produce graphs
- Serial plotter website- simple way of demoing
- Digikey- two day shipping for $6.99
- Feedback data, visual feedback

Conclusions/action items: Action items are to order the materials for the force resistor and load cell and once materials have arrived, meet with Dr. Nimunkar again to start designing the circuit.

11/01/2023 - Initial Load Cell Circuit

ORLA RYAN - Nov 01, 2023, 9:08 PM CDT

Title: Building of Initial Load Cell Circuit

Date: 11/01/23

Content by: Orla

Present: Orla, Neha, Emily, Simmi

Goals: To build an Arduino load cell circuit for the team's initial prototype.

Content:

- Assembling Arduino prototype

- Worked to connect wires to appropriate ports

- Found Arduino Code example on SparkFun

    - Described as a way to connect/use a "Load Cell Amplifier"

- Calculated calibration factor, following steps on SparkFun website

- Went through a few rounds of troubleshooting

- Calibration factor was negative: -7050

- Tested accuracy using a known weight (iPhone 12 Pro) -- reported weight on Google is 0.4166 lb, Arduino reported 0.4 lb

- even pressure will be needed --> even slight offset of balance shifts the force reading (takes into account torque/bending)

- we will search for something small and circular to allow for more even distribution of pressure

- future plans:

    - Construct a platform for even pressure (likely one on both sides)

    - can test by placing known weights on platform

Conclusions/action items:

The team will present our design, alongside an erg, at this week's show and tell event.
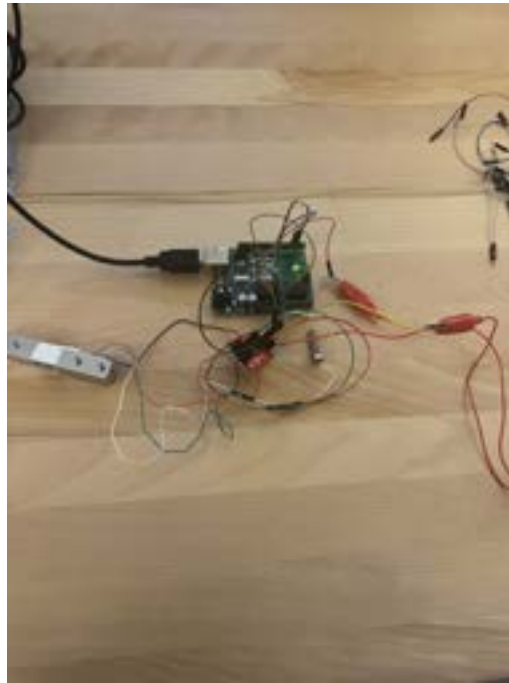
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IMG_5296.jpg (3.25 MB)

11/03/2023 - Show and Tell Notes

EMILY WADZINSKI - Nov 28, 2023, 9:28 PM CST

Title: Show and Tell Notes

Date: 11/3/2023

Content by: Bryan

Present: all

Goals: The goal of show and tell is to get advice from other groups on how we can imbed our load cell and improve our design in any way. Our main focus will be on getting different ideas of how the load cells can be used without interfering with rowers.

Content:

- Have an adjustable attachment to the shoes
- Build a cover and have springs to hit the force sensor
- 2 plates instead of 1
- Make a sock with force plates
- Have the two sensors be connected in the middle on a slider so it can be adjustable for each person
    - Have numbers to determine what the exact size is
- Thinner load cells between platform and slider
- Platform that can move with the foot
- Could be easier to embed load cell into heel rather than ball of foot
- Adjustable part that makes the load cell moveable, not fixed. Can gear towards different athlete foot sizes/positions
- Orthopedic sole insert measurer
- Remove the adjustable slider and replace it with a moveable slider for the load cell.
- Replace erg footplate with entirely new plate, functions similarly to a force plate
- Create high surface area plate that can project all force onto load cell
- Find thinner load cell if possible, could be easier to integrate

Conclusions/action items:

-Decide a way to imbed load cell into foot plates.

-Begin fabrication with actual load cells used for final product

11/10/2023 - Footplate Disassembly

EMILY WADZINSKI - Nov 28, 2023, 10:36 PM CST

Title: Footplate Removal

Date: 11/10/23

Content by: Emily

Present: Team

Goals: Take apart erg to better see how we can embed circuit

Content:

The footplate can be removed with a screwdriver. The circuitry could go in the department underneath. The plate can be cut or drilled into to place the load cell in or to make the cell placement adjustable.

Conclusion:

Start Solidworking

EMILY WADZINSKI - Nov 28, 2023, 9:00 PM CST

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EMILY WADZINSKI - Nov 28, 2023, 9:00 PM CST

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IMG_5410.jpg (2.98 MB)

EMILY WADZINSKI - Nov 28, 2023, 9:00 PM CST

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IMG_5411.jpg (2.8 MB)

12/01/2023 - SolidWorks Prototype Models and Dimensioned Drawings

EMILY WADZINSKI - Dec 15, 2023, 10:45 AM CST

Title: SolidWorks of Footplate

Date: 12/01/23

Content by: Emily

Present: Emily, Simmi

Goals: Make a model to base load cell fabrication off of

Content:

see attached

Conclusion:

Start fabrication

EMILY WADZINSKI - Dec 15, 2023, 10:46 AM CST
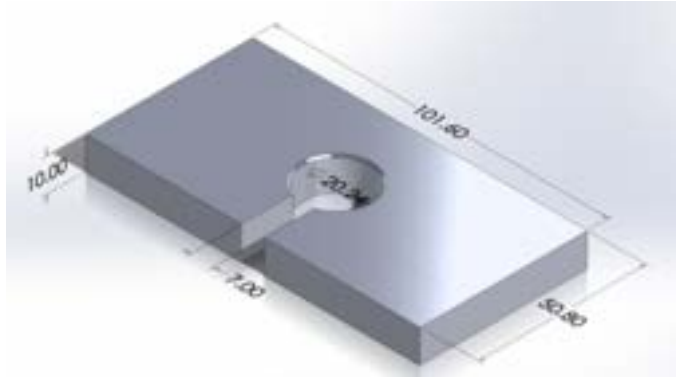
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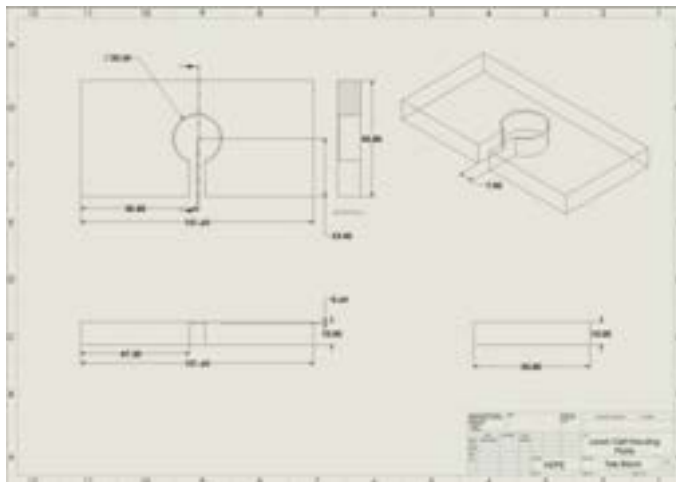
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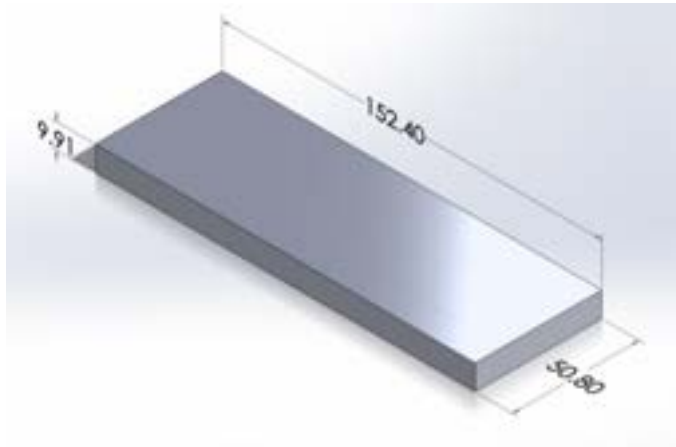
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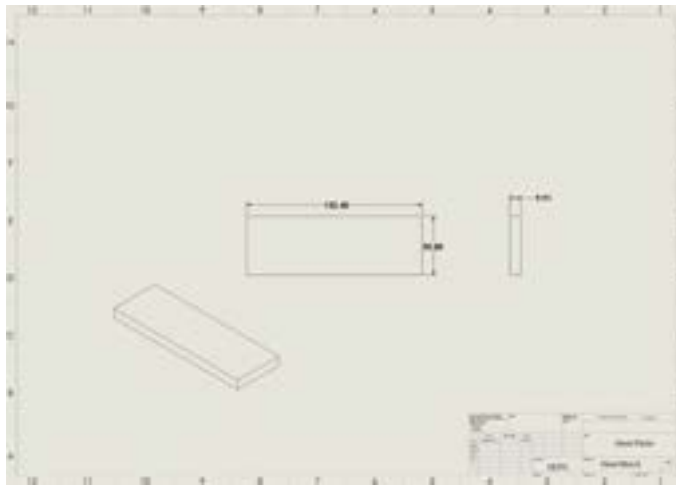
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10/12/2023 - Preliminary Prototype Materials

NEHA KULKARNI - Oct 12, 2023, 12:00 PM CDT

Title: Preliminary Design Brainstorm

Date: 10/12/2023

Content by: Emily

Present: Team

Goals: Find small prototypes we can test and compare designs with

Content:

https://www.digikey.com/en/products/detail/ohmite/FSR07DE/14552734 - FSR

https://www.digikey.com/en/products/detail/sparkfun-electronics/SEN-13879/6202732 - amplifier

https://www.digikey.com/en/products/detail/sparkfun-electronics/SEN-13329/7393715 - load cell

Conclusion:

Order these when approved by client

10/19/2023 Expenses Sheet

SIMRET BHATIA - Oct 19, 2023, 11:47 AM CDT

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Expense_Sheet_-_Sheet1.pdf (39.4 kB)

12/13/2023 FINAL Expenses Sheet

NEHA KULKARNI - Dec 13, 2023, 10:25 AM CST
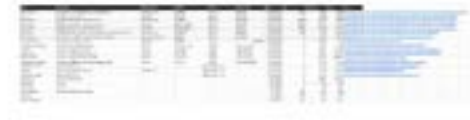
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FINAL_Expenses_Sheet_-_Sheet1.pdf (78.3 kB)

10/31/2023 - Soldering Amplifier

EMILY WADZINSKI - Dec 02, 2023, 6:36 PM CST

Title: Soldering Initial Circuit

Date: 10/31/23

Content by: Emily

Present: Simmi, Neha, Emily

Goals: Soldier amplifier for the circuit

Content:

A soldering iron was used by Simmi in the Makerspace to soldier wires to the circuit's amplifier.

Conclusion:

Build working circuit

EMILY WADZINSKI - Dec 02, 2023, 6:36 PM CST

[Download](#)

S1.PNG (6.39 MB)

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S2.PNG (7.29 MB)

11/15/2023 Footplate Measurements

SIMERJOT KAUR - Nov 15, 2023, 10:17 PM CST

Title: Footplate Measurements

Date: 11/15/2023

Content by: Simmi

Present: Simmi, Brian, Orla, Neha

Goals: Get precise measurements of all planes of the foot plate

Content:

Width of flex foot (toe)

2 13/16 inches

Width of heel flex foot

4 inches

Length of plate

12 inches

Width of plate

4.75 inches

Gap between

3.125 inches

Length of flex foot

13 inches

Top of the toe rest to heel

11.75 inches

Top of plate to the buckle

4.5 inches

Toe rest

4 inches wide 2.5 inches long

Triangle behind

5 inches x 5.75 inch x 7.75 inches

1 foot and 7.375 inches 10.75 inches

11/28/2023 - Footplate Drawn Dimensions

EMILY WADZINSKI - Nov 28, 2023, 10:33 PM CST

Title: Drawn Dimensions

Date: 11/28/2023

Content by: Emily

Present: Emily, Neha, Simmi

Goals: Remeasure plate for solidworks modeling

Content:

EMILY WADZINSKI - Nov 28, 2023, 10:33 PM CST
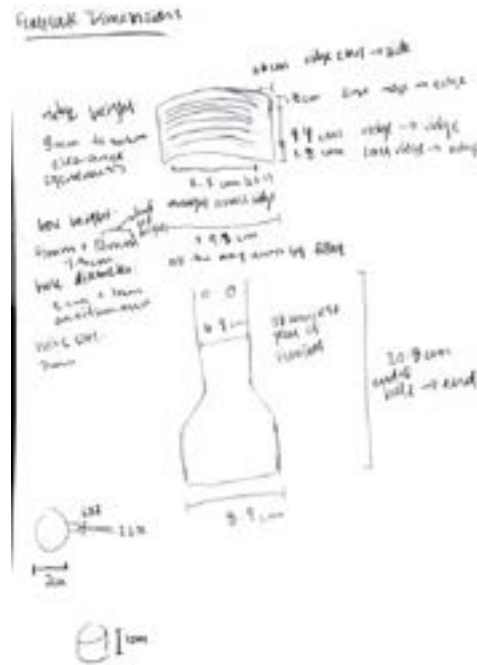
[Download](#)

Foot_dimensions.pdf (227 kB)

12/01/2023 - Plate Fabrication

EMILY WADZINSKI - Dec 02, 2023, 6:22 PM CST

Title:

Date: 12/1/2023

Content by: Emily

Present: Neha, Emily

Goals: Fabricate plate to set load cell as backup instead of the 3D print

Content:

Scrap material made of plastic was drilled into and sawed in the Team Lab to place the load cell into. Excess plastic bars will go on the heel portion of the footplate to take into account the added height from the toe piece.

Conclusion:

Use for testing on Monday.

EMILY WADZINSKI - Dec 02, 2023, 6:22 PM CST

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N1.jpg (2.78 MB)

EMILY WADZINSKI - Dec 02, 2023, 6:22 PM CST

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N2.jpg (2.45 MB)

EMILY WADZINSKI - Dec 02, 2023, 6:22 PM CST

Download

N3.jpg (3.22 MB)

Download

N4.jpg (4.04 MB)

12/04/2023 - Finishing Plate Fabrication and Final Prototype

Title:

Date: 12/1/2023

Content by: Emily

Present: Neha, Emily

Goals: Fabricate plate to set load cell as backup instead of the 3D print

Content:

We needed a top plate to go over the load cell to transmit the point load. Found more metal scrap in the TEAM lab that fit perfectly over what we made on Friday so we used that. Needed a way to adhere it to the plate while allowing some gap for the pin of the load cell. Adhesive velcro on the metal plate and plastic part was just the right size so that when pressure was applied to the top plate it made contact with the load cell inside. We stuck the metal and plastic together using velcro successfully, and decided to use duct tape or velcro to stick the housing to the erg footplate. To make a heel plate, we just used more of the same scrap so that everything was even thickness.
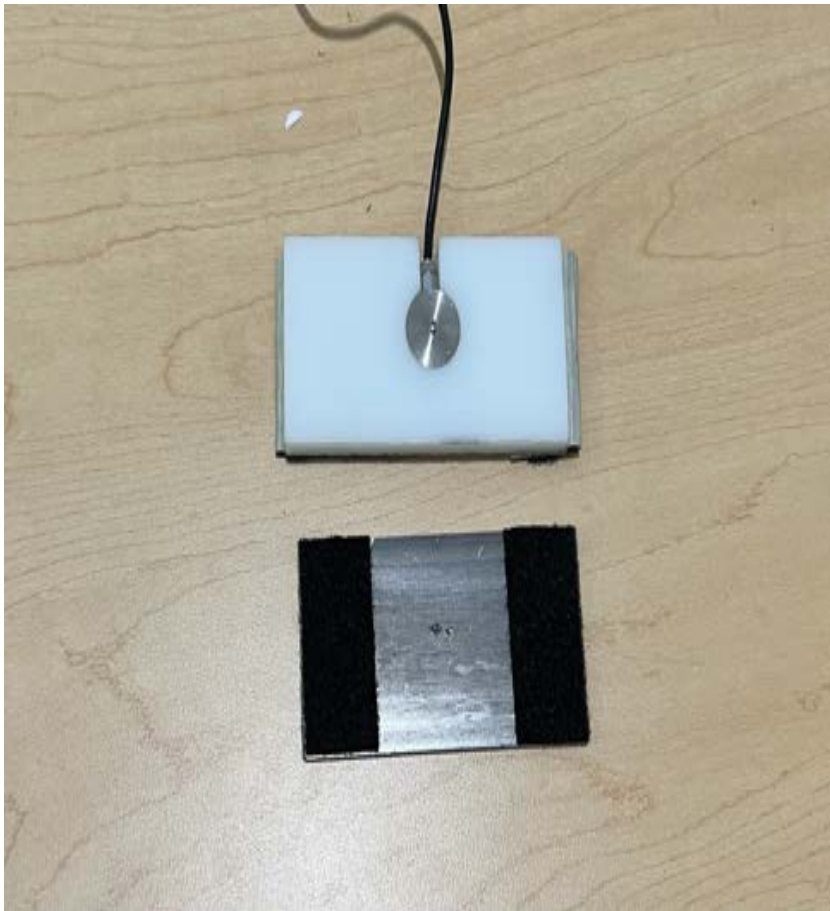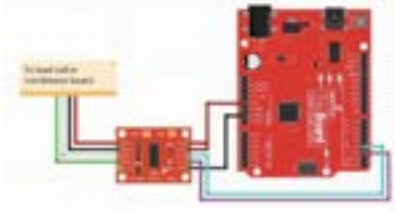
Conclusion:

Use for testing on Monday.

12/13/2023 - Final Circuit Diagram and Code

NEHA KULKARNI - Dec 13, 2023, 12:37 PM CST

[Download](#)

Final_Prototype_-_Circuit_and_Code_.pdf (2.63 MB)

12/04/2023- Testing Protocol

SIMERJOT KAUR - Dec 14, 2023, 9:12 PM CST

Title: Testing Protocol

Date: 12/4/2023

Content by: Simmi

Present: Simmi, Emily, Neha, Bryan, Orla, Simret

Goals: Conduct testing on UW rowing athlete with accurate calibration and gather data to assess asymmetry in the rowers and for load cell accuracy determination.

Content:

1) Load Cell Calibration:

1. Obtain Calibration Weights: Acquire a set of calibration weights for the load cell calibration process.

2. Place 500g Weight on Load Cell: Put a 500g weight on top of the load cell within its housing.

3. Adjust Arduino Code Calibration Factor: Modify the calibration factor in the Arduino code until the load cell reading is accurate.

4. Repeat Calibration for 1kg Weight: Repeat the calibration process with a 1kg weight.

5. Repeat Calibration with Different Team Members: Conduct calibration with various team members standing on the prototype to ensure accuracy.

2) Team Member Weight Measurement:

1) Team member's balance on load cell scale

2) Most consistent reading from serial monitor is recorded

3) Member's balance on load cell scale for 2 trials

3) Testing on the Ergometer:

1**.** Secure Load Cell Housing on Flexfoot: Use duct tape to secure the load cell housing onto the toe rest of the Flexfoot.

2. Conduct In-person Testing with Former UW Rower: Perform in-person testing with a former UW rower.

3. Rowing Intervals with Real-time Force Output: Have the subject complete several 30-60 second intervals of rowing at steady state.

4. Monitor real-time force output display and store data on the Arduino.

5. Adjust Device Placement and Attachment: Make alterations during testing to improve device placement and attachment. Shift the box further down the footplate to better align with the metatarsophalangeal joint. Use Velcro for attachment, aiming for increased stability.

Conclusions/action items: Use this protocol to test the prototype.

12/01/2023 - Fabrication Protocol

EMILY WADZINSKI - Dec 15, 2023, 10:42 AM CST

Title: Fabrication Protocol

Date: 12/1/2023

Content by: Emily

Present: Emily, Neha

Goals: Make a new load cell housing instead of 3D printing.

Content:

Drill Press

1. Obtain one block of HDPE and three plates of steel from the UW Madison's TEAM Lab.
2. Locate the center of the HDPE block and mark it.
3. Move the drill press table to the desired height.
4. Lock the block in a vice, and center the block to the drill.
5. Secure the vise to the table with clamps.
6. Secure the drill chuck and install a center drill into it.
7. Turn on the drill press, and adjust the speed to 1000 RPM.
8. Using the quill handle, lower the center drill into the HDPE at the marked spot and peck drill into the block, not all the way through.
9. Turn off the press and raise the handle. Switch the center drill to a 51/64" drill bit.
10. Turn on the press and lower the handle, peck drilling all the way through the block.
11. Turn off the drill press, remove the block from the vise.
12. Clean away excess drill fragments.

Band Saw

1. Take the drilled HDPE block and make two marks along the width, each one inch from both ends of the length.
2. Grab a push stick and place the block on the table.
3. Align the saw to one of the marks.
4. Press the on button, and slowly push the block along the mark with one hand and the push stick.
5. Once the block completely passes through the saw, repeat steps for the other end of the block.
6. Turn off the machine.
7. Wipe away dust with a brush once the saw is fully off.

Conclusion:

Replicate when needed

11/28/2023 Large Load Cell Calibration Attempt

NEHA KULKARNI - Dec 13, 2023, 9:51 AM CST

Title: Load Cell Calibration with Known Weights

Date: 11/15/2023

Content by: Simret

Present: All

Goals: Calibrate the circuit for final testing

Content: (attached)

Conclusions: This doesn't seem like the best way to calibrate since the balancing was subject to error. We need a plate on top of the load cell so we can place the weights on that, and then we need to recalibrate.

EMILY WADZINSKI - Nov 28, 2023, 8:34 PM CST

Download

Calibration_Protocol_of_Circuit.pdf (26.8 kB)

12/01/2023 - Calibration and Weight Testing

NEHA KULKARNI - Dec 13, 2023, 9:52 AM CST

Title: Calibration and Weight Testing

Date: 12/1/23

Content by: Orla

Present: All

Goals: To use lab weights (and potentially our own weights) to calibrate the load cell, work on our final poster presentation, and check on 3D printer status.

Content:

- BME calibration weights were obtained and used to apply pressure on the load cell, watching the corresponding Arduino output

- At this point, the 3D print is not yet done -- we suspect this is because the infill is 100% (machine seems to be getting jammed at times)

- Started work on various sections of the final poster, using past templates as ideas to work off of

- Team took turns balancing weights on the load cell node, with a plan to average the calibration factors

    - each group member balanced weights with the minimum force possible, repeating to test that the result could be replicated

- 3D print will not be completed until tomorrow (Bryan checked with the MakerSpace), and so will have to be picked up over the weekend

- average of calibration factors was taken to produce quantitative data for final presentation/report

Conclusions/action items:

We will continue to work on our poster presentation, aiming to have it done by Wednesday so that we can print it properly. Also, we will meet on Monday with Sarah to test the device in rowing position.

12/04/2023 - Testing with Sarah and Jill

Title: Prototype Testing with Sarah and Jill

Date: 12/4/23

Content by: Orla

Present: All

Goals: Conduct testing with Sarah's standing weight and with the device attached to the erg.

Content:

- We met with Sarah and Jill in the ECB and assembled our ergometer for testing

- only one circuit was working today -- we hope to have the second one properly assembled by Friday for demonstration

- Circuit is now protected by box and load cell is attached to scrap plastic from the TeamLabs

- Sarah was asked to balance her whole weight on one foot, around where the load cell is located in the block of material

    - With fluctuating balance, reported weight ranged from 130lbs to 215lbs (Sarah's actual weight was somewhere around 175 lbs)

    - Ballpark estimate was correct/in the range of her actual weight, and would change every time she shifted as to be expected

- After assembling device/connecting it to the ergometer, Sarah strapped in and began rowing (rowing sessions were timed)

- Sarah/Jill noted that the toe on top of the device was slightly elevated (should be an easy fix, even it out on heel portion)

- Duct tape allowed the device to slide slightly (fastenings could be improved in future)

    - might need more adhesive surface than duct tape so that foot does not slide off

    - considered adding velcro to sides/beneath device

- Moved the load cell block down further to align more with the ball of foot/joint where force is output from

- Weren't sure of accuracy of numbers, but Sarah reported that the second position felt better/was likely to be better reading her applied effort

- Velcro was used to attach the (nonworking) load cell construction to the other foot to measure how it fit, felt for Sarah, and how much it moved around

    - Seemed more stable and looked less obtrusive

    - Possibly more reproducible and standardized (ability to create a system for moving load cell around in increments)

- Jill mentioned wanting to see any asymmetry in peaks of force/time graph as well as rate of force increase (slope of line in graph?)

-enough traction for Sarah while rowing on the load cell design

-left leg run 1 : peaks at 31, 28 lbs

-left leg run 2 (velcro alignment adjusted): peak at 36 lbs

-right leg around 28 pounds for drive phase (peaks: 40s)

-more flush shoes are recommended to wear as the heel of the flex foot interferes with wider shoes

Conclusions/action items:

Update our final poster presentation with our collected data and methods, and practice before Friday.

12/04/2023 - Final Load Cell Calibration

NEHA KULKARNI - Dec 13, 2023, 9:58 AM CST

Title: Final Load Cell Calibration

Date: 12/4/23

Content by: Neha

Present: Neha

Goals: To use lab weights (and potentially our own weights) to calibrate the load cell inside the prototype

Content:

- with load cell fully inside housing, placed 1kg weight centered on pin of load cell while Arduino was running calibration code

- adjusted calibration factor using a or z on serial monitor - settled on 4555 (positive so that compression numbers can be written to EEPROM)

- repeated with 500g weight (didn't bother going smaller bc we don't need that kind of sensitivity) --> 4555 still accurate calibration factor

- placed calibrated load cell in housing on carpet and team members stood on it, load cell was not accurate likely bc carpet was uneven and soft surface. Team moved to stairwell on hard surface and got accurate numbers:

Subject	Actual Weight (N)	Load Cell Reading (N)	Percent Error
1	889.64	889.64	0%
2	524.89	520.44	0.85%
3	511.55	498.20	2.61%
4	600.51	578.27	3.70%
5 (Rower)	778.44	778.44	0%
		Average Percent Error	1.43%

(we also had Sarah stand on it before she rowed)

Conclusions/action items:

Use 4555 as calibration factor as this seems to be accurate enough.

09/29/2023 - Preliminary presentation

NEHA KULKARNI - Dec 14, 2023, 10:31 AM CST

Title: Final PDS

Date: 12/14/2023

Content by: Team

Present: Team

Goals: Present our preliminary designs

Content:

Attached

Conclusions/action items: Move forward with the chosen design and receive feedback from client.

NEHA KULKARNI - Dec 14, 2023, 10:32 AM CST

Download

Prelim_Presentation_-_Rowing_Biomechanics_.pdf (3.08 MB)

12/14/2023 - Final PDS

NEHA KULKARNI - Dec 14, 2023, 10:30 AM CST

Title: Final PDS

Date: 12/14/2023

Content by: Team

Present: Team

Goals: Outline the specifications for our product.

Content:

Attached

Conclusions/action items: Continue modifying in future semesters, and continue to test and design according to these parameters.

NEHA KULKARNI - Dec 14, 2023, 10:30 AM CST

Download

PDS_-_Rowing_Biomechanics_2_.pdf (343 kB)

12/14/2023 - Final Poster

NEHA KULKARNI - Dec 14, 2023, 10:33 AM CST

Title: Final Poster

Date: 12/14/2023

Content by: Team

Present: Team

Goals: Overview our progress on the project this semester

Content:

Attached

Conclusions/action items: Receive feedback and continue building on our progress next semester.

NEHA KULKARNI - Dec 14, 2023, 10:34 AM CST

Download

NehaKulkarni_RowingBiomechanicsFINAL.pdf (4.73 MB)

9/13/2023 - Lateral Abdominal Symmetry in Rowers

NEHA KULKARNI - Sep 13, 2023, 10:36 PM CDT

Title: Lateral Abdominal Symmetry in Rowers

Date: 09/13/2023

Content by: Neha

Present: Neha

Goals: Understand how a test was conducted to examine muscle symmetry in rowers

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3273879/#B1

Citation:

N. W. Gill, B. E. Mason, and J. P. Gerber, "LATERAL ABDOMINAL MUSCLE SYMMETRY IN COLLEGIATE SINGLE-SIDED ROWERS," *Int J Sports Phys Ther*, vol. 7, no. 1, pp. 13–19, Feb. 2012.

Content:

- Helpful term: oarside vs non-oarside
- Used imaging to determine muscle thickness
- T-test to compare absolute and relative thickness
    - Used oarside as independent variable, then used age, gender, year of rowing experience
- Trunk creates and transfers forces from legs and arms to oar
- Rowing is asymmetric movement - rowers may only row on one side of the scull
    - This may create asymmetries in muscle
- Study excluded bilateral rowers and coxswain
- Intake questionnaire
    - Age, gender, side of rowing (oar on left or right), incidence of back pain
- Statistically significant difference in absolute thickness of TransverseAbdominus muscle between oarside and non-oarside
- No clinically significant difference in thickness

Conclusions/action items: Consider using the statistical methods of this paper to measure significance of symmetry.

9/13/2023 - Rowing Injuries, Risk Factors, and Role of Biomechanics

Title: Rowing injuries, Risk Factors, and Role of Biomechanics

Date: 09/13/2023

Content by: Neha

Present: Neha

Goals:

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7205948/

Citation:

S. Arumugam, P. Ayyadurai, S. Perumal, G. Janani, S. Dhillon, and K. A. Thiagarajan, "Rowing Injuries in Elite Athletes: A Review of Incidence with Risk Factors and the Role of Biomechanics in Its Management," *Indian J Orthop*, vol. 54, no. 3, pp. 246–255, Jan. 2020, doi: 10.1007/s43465-020-00044-3.

Content:

- Two types of rowing
    - Sweep rowing
        - Single oar handled by each member of the crew
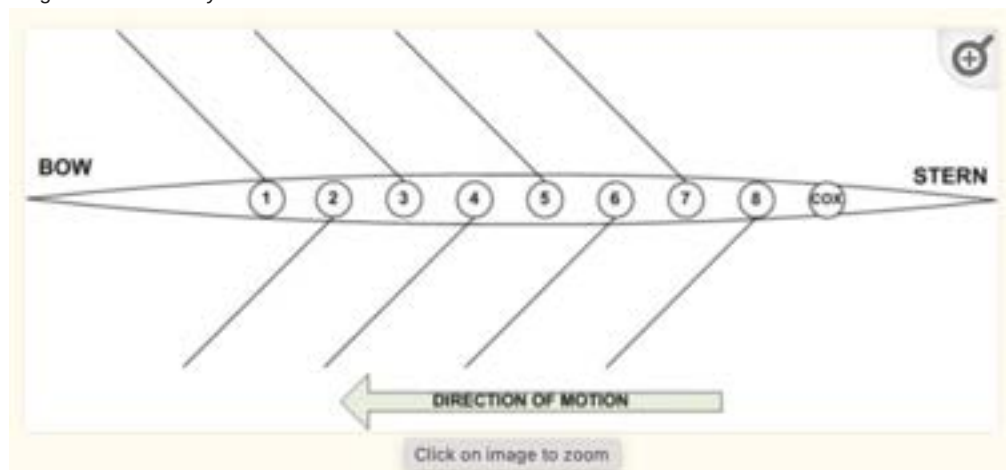
    - Sculling
        - Each athlete handles two symmetrical blades
- Phases of rowing stroke

1. Catch Phase
2. Drive Phase
3. Finish Phase
4. Recovery Phase

-
  - Catch: oars in water with hips and knees fully flexed
  - Drive: legs drive body back. Back, shoulder, arms as braced cantilevers so force can be transferred to oars from legs
  - Finish: legs fully extended, elbows flexed in body
  - Recovery: movement of hands away from body, forward flexion at hip and forward movement of spine towards catch position
- Common injuries
  - Low back pain
    - Lumbar spine injuries account for up to 53% of all reported injuries in rowing
  - Rib stress injury
    - 9-10% of all rowing injuries
- Biomechanical analysis
  - Instrumented foot stretcher on rowing machine
  - Load cells fixed onto footplates using screws
  - Rowing shoes fitted onto load cells
  - Toe and heel forces captured on left and right feet
  - BATLogic
  - Peak foot force = toe + heel
  - Heel asymmetry index
  - Heel engagement & its timing – qualitative

Conclusions/action items: Look into the instrumented foot stretchers and consider measuring symmetry based on the parameters used in this article.

09/17/2023 - Observations of good rowing mechanics

NEHA KULKARNI - Sep 21, 2023, 6:17 PM CDT

Title: Observations of good erging mechanics from video

Date: 9/17/2023

Content by: Neha

Present: Neha

Goals: Understand what "good erging" looks like.

Content:

- Was sent two videos (one back view and one side view) of good erging by client
- Observations on movement:
    - Catch phase
        - Heels lift slightly
        - Total flexion at hips, knees
    - Drive phase
        - Heels lower to stretcher
        - Knees extend
        - Hips extend from catch phase back to be almost level with torso
    - Finish phase
        - Knees fully extended
        - Hips fully extended
        - Elbows fully extended, closer to body
        - Torso lean back to almost 180 degrees with hips
    - Recovery phase
        - Lean forward causes knees to flex again, return to catch phase position
        - Arms dip down from chest height
- Observations on erg:
    - Straps around toes
        - Around where the knuckles are, medial to lateral
    - Heel pad that can pivot
        - Pivot point is around beginning of arch
        - Strap around back of heel on shoe
    - Seat is completely flat, no back support

Conclusions/action items: Keep these observations in mind as controls or comparisons for good vs bad erging (qualitatively). Keep the straps and configurations of the foot stretcher in mind when coming up with designs.

09/17/2023 - Observation of Rowing Tank in UW Boathouse

NEHA KULKARNI - Sep 21, 2023, 6:18 PM CDT

Title: Observations on rowing tank

Date: 9/17/2023

Content by: Neha

Present: Neha

Goals: Understand the how the rowing tank works

Content:

- Video sent by Tricia of rower rowing in tank in boathouse
- Tank allows rower to do sweep rowing, as opposed to sculling on the erg
- Rower rows against current
    - Water flowing on one side of the tank, current can flow at various speeds
- Rower sits on base of erg
    - Seat, slider, footplate are all same as erg
- Rotation of trunk during sweep rowing towards erg

Conclusions/action items: Consider putting the force plates/sensors on the tank instead of on the ergometer, since the tank more closely simulates the sweep rowing asymmetry.

09/26/2023 - Interfacing Force Sensitive Resistors with Arduino

Title: 09/26/2023 - Interfacing Force Sensitive Resistors with Arduino

Date: 09/26/2023

Content by: Neha

Present: Neha

Goals: Understand what a force-sensitive resistor is and how it can be used.

Link: **https://lastminuteengineers.com/fsr-arduino-tutorial/**

Citation: "In-Depth: Interfacing Force Sensing Resistor (FSR) with Arduino," *Last Minute Engineers*, **Apr. 06,**
2020. https://lastminuteengineers.com/fsr-arduino-tutorial/ (accessed Sep. 26, 2023).

Content:

- Interlink Electronics owns the patent for FSRs
- FSR: variable resistor whose resistance varies with force applied
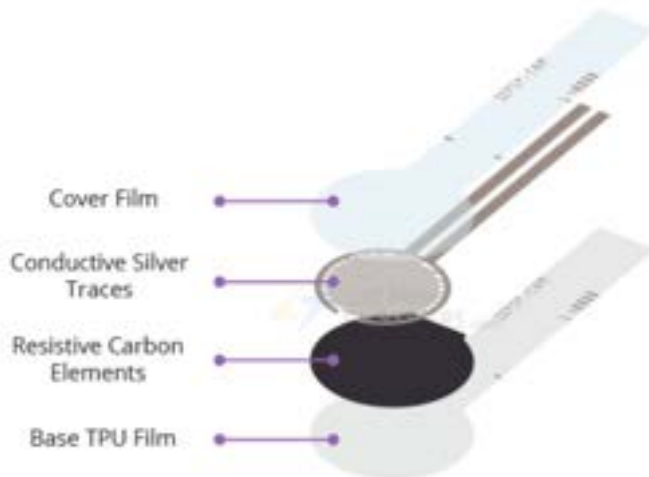
- Rectangular for broad sensing area, circular more for smaller sensing area
- Shorter range has higher sensitivity
    - When out of range, FSR cannot distinguish between different forces
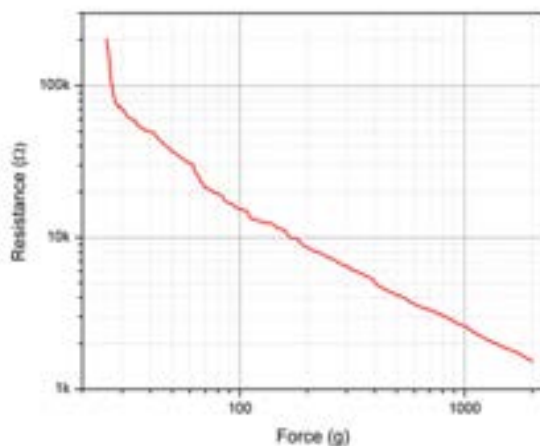
- Graphs like the above are used to go from resistance → force

5V

FSR

Analog voltage
● V_o

R   10K

GND
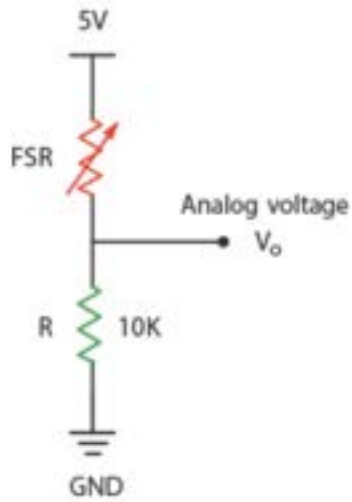
- Example circuit - easiest way to do it is a voltage divider

$$V_O = V_{CC} \frac{R}{R + FSR}$$

- Voltage divider equation

Conclusions/action items: Consider an FSR instead of a load cell; they seem more cost effective.

09/27/2023 - Flexiforce Load/Force Sensors

NEHA KULKARNI - Sep 29, 2023, 7:00 PM CDT

Title: 09/27/2023 - Flexiforce Load/Force Sensors

Date: 09/27/2023

Content by: Neha

Present: Neha

Goals: Understand the different specifications of the Flexiforce sensor and how to integrate it.

Links: **https://www.tekscan.com/store-category/force-sensors-flexiforce-0**, **https://www.tekscan.com/flexiforce-integration-guides**

Citations:

"Force Sensors (FlexiForce) | Tekscan." https://www.tekscan.com/store-category/force-sensors-flexiforce-0 (accessed Sep. 27, 2023).

"FlexiForce Integration Guides | Tekscan." https://www.tekscan.com/flexiforce-integration-guides (accessed Sep. 27, 2023).

Content:

- Largest force sensors:
  - Circular has sensing diameter of 25.40 mm
  - Square has sensing width of 50.8 mm
- Temp range from -40 to 60 degree celsius
- Capacities and recommended circuit:
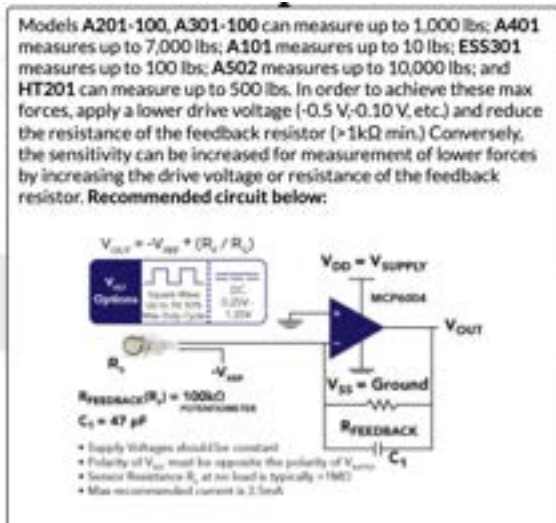
Conclusions/action items: Consider these capacities and sensitivities for our circuit.

09/29/2023 - Force Measurements on Ergometer

NEHA KULKARNI - Sep 29, 2023, 7:01 PM CDT

Title: 09/29/2023 - Force Measurements on Ergometer

Date: 09/29/2023

Content by: Neha

Present: Neha

Goals: Understand the magnitude of forces that are experienced by different parts of an ergometer.

Citation: N. Découfour, F. Barbier, P. Pudlo, and P. Gorce, "Forces Applied on Rowing Ergometer Concept2® :a Kinetic Approach for Development (P94)," *The Engineering of Sport 7* , vol. 1, pp. 483–490, 2008, Accessed: Sep. 29, 2023. [Online]. Available: http://bionics.seas.ucla.edu/education/Rowing/Biomechanics_2008_01.pdf

Content:

- Methods
  - Used force plates under stretchers
  - Force range on the plates is 5500 N for medial/lateral, anterior/posterior components, 21000 N for shear component
  - Cites a paper that said peak force for rowers is 900 N
- Foot stretcher force analysis
  - Propulsive phase
    - A/P force increases to 500 N
    - V force constant around 300 N
  - Recovery phase
    - Negative forces on force plate, meaning force applied is tensile on stretcher

Conclusions/action items: Note that we really only need force sensors that can go up to 900 N

Neha Kulkarni/Research Notes/Biology and Physiology/09/29/2023 - Mechanics and Biomechanics of Rowing Article from Tricia

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09/29/2023 - Mechanics and Biomechanics of Rowing Article from Tricia

NEHA KULKARNI - Sep 29, 2023, 7:03 PM CDT

Title: 09/29/2023 - Mechanics and Biomechanics of Rowing Article from Tricia

Date: 09/29/2023

Content by: Neha

Present: Neha

Goals: Understand more of the basics of rowing mechanics and how they are idealized.

Citation: (will try to get this from Tricia, she gave me paper copy)

Content:

- Biomechanical principles
  - All movements have to be performed such that the rower can transfer their physiologic performance into optimal propulsion
  - Long stroke necessary
    - 75% power to move oar, 9% to support horizontal movement, 16% to produce vertical movement
  - Movement needs to be as horizontal as possible so vertical displacement of center of gravity is minimized
    - To prevent losing length in the stroke
    - Vertical movement caused by leg flexion and upper body swing
    - To reduce vertical displacement, round back with minimal vertical movement of hands
  - Horizontal velocity of rower relative to boat should be as small as possible
    - Horizontal movements have to be performed with as little change in acceleration as possible

Conclusions/action items: Limiting vertical displacement is extremely important, which means legs need to provide a good base of support for the stroke to be as long as possible. This makes symmetry really crucial because asymmetry would produce vertical displacement.

10/11/2023 - Lower Back Pain in Intercollegiate Rowers

NEHA KULKARNI - Oct 11, 2023, 10:32 PM CDT

Title: Back pain in Intercollegiate Rowers

Date: 10/11/2023

Content by: Neha

Present: Neha

Goals: Understand prevalence and factors for back pain in rowers.

Link: no link, paper copy provided by Tricia

Citation: no citation yet, will ask Tricia for DOI of paper

Content:

- Rowing is frequently noted as having athletes who report back pain
- Notices of back pain first reported in 1980, when style of rowing switched from straight-backed swing to flexion and rotation of lumbar spine at beginning of stroke
- Prevalence
    - Lumbar injuries accounted for 25% of injuries recorded for 88 male rowers, 15.2% of injuries recorded for 84 female rowers
- Materials and methods
    - Surveys sent to 1480 intercollegiate rowers, 46% returned
    - Back pain defined as pain lasting at least one week
- Results
    - Higher mean height and weight significantly associated with back pain in men and women
    - Most common time of year to develop pain was winter
    - Common activities associated with back pain (most → least prevalent)
        - Outdoor rowing > weight lifting > ergometer training > indoor rowing > lifting boat
    - Training variables and association with back pain
        - 33% of rowers trained in indoor tank have back pain
        - Ergometer for more than 30 min associated with increase in back pain
- Discussion
    - Increased prevalence of back pain could reflect changes in the sport
        - Type and intensity of training
        - Changes in rower physique
        - Concept2 erg is way cheaper, making it more accessible to college teams so they started using it more
            - Coaches say erg is more difficult than boat
        - Weightlifting also introduces risk
    - Avg height and weight of rowers increased over the 20 year study
    - Quad muscle dominance can lead to buttocks moving back in boat prematurely → hyperflexion in lumbar spine (aka shooting the tail)

Conclusions/action items: This information is good to reference in the background section of our reports. It emphasizes that back pain is a real problem, and the development of the erg may have contributed to this. With these changes in the sport rowers have not been able to properly alter their technique.

9/13/2023 - Force Plates

NEHA KULKARNI - Sep 13, 2023, 9:23 PM CDT

Title: Sensors - Force Plates

Date: 09/13/2023

Content by: Neha Kulkarni

Present: Neha Kulkarni

Goals: Learn about what force plates are and what they are used for.

Link: **https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/B9780128129395000045#s0130**

Citation:

K. A. Lamkin-Kennard and M. B. Popovic, "4 - Sensors: Natural and Synthetic Sensors," in *Biomechatronics*, M. B. Popovic, Ed., Academic Press, 2019, pp. 81–107. doi: 10.1016/B978-0-12-812939-5.00004-5.

Content:

- Measure ground reaction forces of human movement
- Contains materials that generate electric field, strain gauges, or beam load cells that generate voltage that can be correlated with force
- Orientation of sensors determines orientation of forces that can be measured
  - Can also determine center of measure, center of force, and moments
- Helpful equations that can be derived from force plate measurements
  - Impulse

$$I_z = \int_{t_1}^{t_2} F_z(t)dt = m \int_{t_1}^{t_2} v_z(t)dt$$

  -
  - Velocity of center of mass at takeoff

$$v_{to} = \frac{1}{m}\int_{t_1}^{t_2} (F_z(t) - mg)dt$$

  -

$$\sum F = m\frac{dv}{dt}$$

  -

Conclusions/action items: Keep this background on force plates in mind, and use these equations when necessary.

9/13/2023 - Bertec Force Plates

NEHA KULKARNI - Sep 13, 2023, 11:13 PM CDT

Title: Bertec Force Plates

Date: 09/13/2023

Content by: Neha

Present: Neha

Goals: Understand the specifications and uses of Bertec force plates

Link: https://www.bertec.com/products/force-plates

Citation: "Force Plates," *Bertec*. https://www.bertec.com/products/force-plates (accessed Sep. 13, 2023).

Content:

- Designed for gait, balance, and performance analyses
- Load cells use strain gauges and transducers
- Analog signals sampled at 1000Hz
- Custom electronics process data
- Line of portable force plates
- Range of sizes
    - Portable: 15.75-23.62 in width and 23.62-35.42 in length
    - Fixed can go larger
- Measures forces and moments in x, y, and z simultaneously
- Signal fed to choice of amplifier: digital, analog, dual digital/analog
- Load capacities of 1000 lb, 2000 lb, 4000 lb
    - Only fixed force plates have 4000 lb

Conclusions/action items: See if these features can be emulated by a simpler and cheaper force plate of our own design. The portable force plates from Bertec are slightly too big and expensive, and most likely not waterproof.

09/21/2023 - Biorow Force Plates

Title: Biorow Force Plates

Date: 09/21/2023

Content by: Neha

Present: Neha

Goals: Understand the specifications and technology involved in Biorow force plates

Link: https://biorow.com/index.php?route=product/product&path=61_115&product_id=109

Citation: "2D_Stretcher," *Biorow*. https://biorow.com/index.php?route=product/product&path=61_115&product_id=109 (accessed Sep. 21, 2023).

Content:

- Load cells with strain gauges to measure forces in two directions
- Four load cells on a plate
    - One on toe, on heel for each foot

Variable	Whole stretcher sensor
Measured force range	From -800N to +3200N
Dimensions of each plate	345mm (W) 120mm (W) 30mm (H)
Weight	2.0 kg
Length of the cable	1.6m
Interface	analogue 0 – 5V
Number of data channels	4

-

-

Conclusions/action items: Consider the load cell placement used here, and the design of a load cell on top of the plate, and the whole plate screwed onto the stretcher.

09/29/2023 - Concept2 RowErg Force Curve

NEHA KULKARNI - Sep 29, 2023, 7:03 PM CDT

Title: 09/29/2023 - Concept2 RowErg Force Curve

Date: 09/29/2023

Content by: Neha

Present: Neha

Goals: Understand the force curves seen by athletes on the Concept2 Erg

Link: https://www.concept2.com/indoor-rowers/training/tips-and-general-info/using-the-force-curve

Citation: Cheri, "Using the Force Curve," *Concept2***, May 18, 2012. https://www.concept2.com/indoor-rowers/training/tips-and-general-info/using-the-force-curve (accessed Sep. 29, 2023).**

Content:

- The erg displays a force-time curve for each stroke that the rower can view in real-time

The Ideal Curve — Applying solid effort through the stroke results in this curve.

Peaks and Valleys — If your force curve resembles a distant mountain range, you need to work on making your transition from legs to back to arms smoother. Multiple peaks are good for hiking...but not for a force curve.

Double Diamond — Exploding at the catch—applying great force at the beginning of the drive—results in a sharp curve and steep drop; the whole curve is actually shifted to the left of the PM screen. This illustrates how varying the timing and emphasis of your legs, back and arms during the drive changes how and when force is applied.

- This appears to be the force curve as measured from the handle pulling, not on the foot.
- No display for symmetry

Conclusions/action items: Consider these curves as reference for ideal force-time curves and other graphical interpretations for flaws in rowing form.

10/23/2023 - Concept2 Flexfoot Assembly

NEHA KULKARNI - Nov 11, 2023, 6:10 PM CST

Title: Concept2 Flexfoot Assembly

Date: 10/23/2023

Content by: Neha

Present: Neha

Goals: Understand the footplate specs and assembly specifications so we know how to embed the load cell

Link: https://shop.concept2.com/parts/87-flexfoot-gray.html

Citation: "Footstretcher Belly and Cover Kit, Right." Accessed: Nov. 11, 2023. [Online].
Available: https://shop.concept2.com/parts/441-footstretcher-belly-and-cover-kit-right.html

Content:

- Entire footplate and accessory parts sold separately
- They also sell the cover and flexfoot separately themselves
- Relatively cheap! $17.50
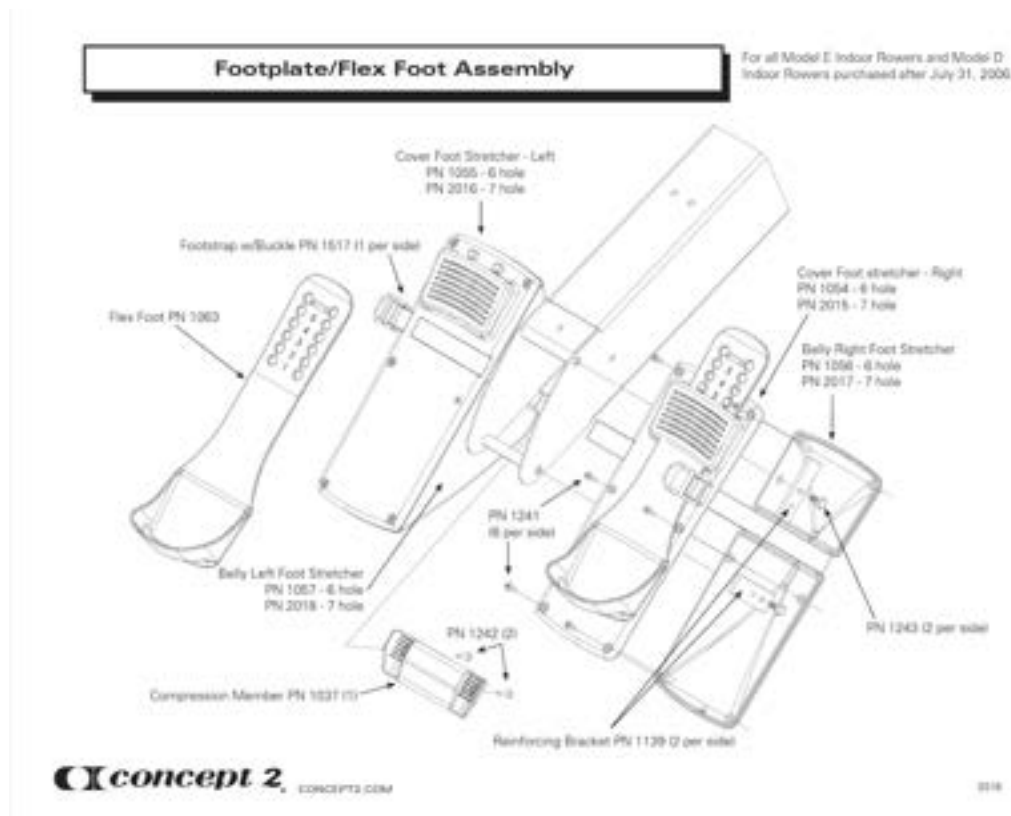
- Flex foot comes separately
- Cover foot stretcher is attached to the top part that the flex foot goes under - we could cut into this or cut out a portion of it and embed our load cell into it, then screw/glue it onto the erg so that it looks/feels the same as an unmodified erg

Conclusions/action items: Consider ordering these parts instead of 3D printing our own.

10/26/2023 - Types of Load Cells

Title: Types of Load Cells

Date: 10/26/2023

Content by: Neha

Present: Neha

Goals: Understand types of load cells and how they are best suited for different applications

Link: https://mhforce.com/types-of-load-cells/#:~:text=The%20four%20types%20of%20load,reference%20and%20field%20standards%20below.

Citation: "Types of Load Cells | Morehouse Instrument Company, Inc." Accessed: Nov. 11, 2023. [Online].
Available: https://mhforce.com/types-of-load-cells/

Content:

- S type

  - Typically used in applications under 50lbf
  - Suited for scales or tension applications
  - Very sensitive to off-axis loading
  - Compression output different based on loading through threads or flat side
  - Not right for calibration according to ASTM E74, ASTM E4, ISO 376, and ISO 7500
- Button

  - Very small - suitable for small spaces
  - High sensitivity to off-axis loading
- Single column / High stress

-
  - Good for general testing
  - Large and heavy
  - Can be nonlinear
  - Larger creep characteristics
  - Requires adapter
  - Sensitive to thread engagement

- Other types

-
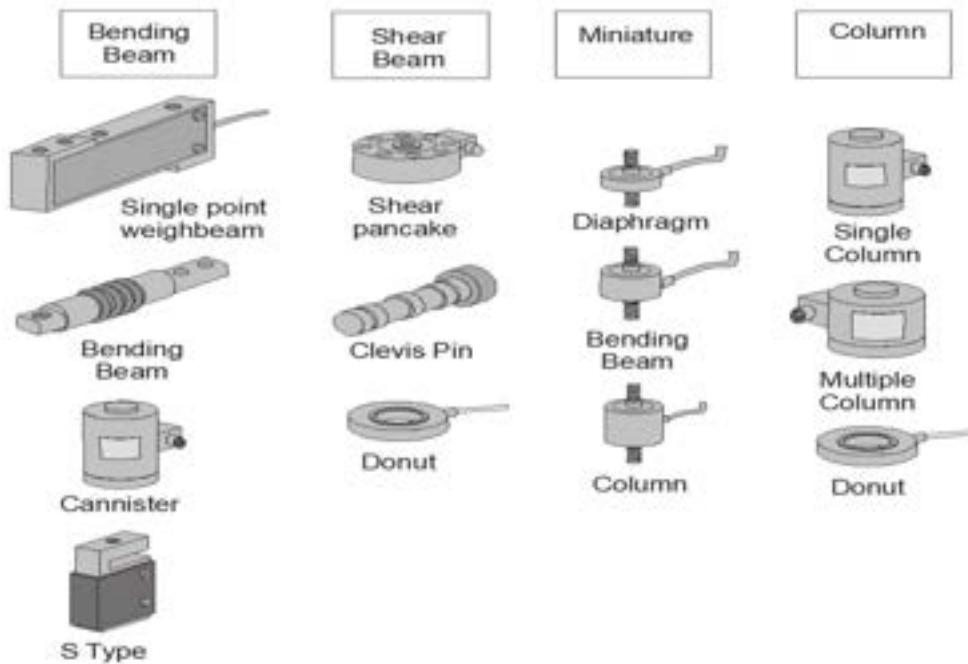
Conclusions/action items: Though the S-type is available on Sparkfun, it doesn't seem to be the best for our application. The column type doesn't seem right because of its size and sensitivity.

The button seems to be best since it is small, and we can embed it such that there is no off-axis loading.

09/20/2023 - ASTM F1250 − 20

Title: Standard Specification for Stationary Upright and Recumbent Exercise Bicycles and Upper and Total Body Ergometers (ASTM F1250 − 20)

Date: 9/20/2023

Content by: Neha

Present: Neha

Goals: Understand the standards involved in specifications for ergometers.

Link: **https://www.astm.org/f1250-20.html**

Citation: "Standard Specification for Stationary Upright and Recumbent Exercise Bicycles and Upper and Total Body Ergometers." **https://www.astm.org/f1250-20.html** **(accessed Sep. 20, 2023).**

Content:

- The standard outlines specifications required for total body ergometers
  - The ergometers mentioned are not rowing ergometers, but rowing ergometers would fall under this standard
- Components that apply to how we will modify the ergometer:
  - Pedals should maintain symmetry
  - Pedal surface should be slip-resistant
  - Testing for endurance:
    - 500000 vertical loading cycles

Conclusions/action items: Keep these in mind when creating our design, making sure not to alter the ergometer such that it fails to meet these standards.

09/20/2023 - ASTM F3021 -17

NEHA KULKARNI - Sep 21, 2023, 6:20 PM CDT

Title: Standard Specification for Universal Design of Fitness Equipment for Inclusive Use by Persons with Functional Limitations and Impairments - ASTM F3021-17

Date: 9/20/2023

Content by: Neha

Present: Neha

Goals: Understand what needs to be designed and included in the ergometer to make it inclusive to all rowers.

Link: https://www.astm.org/f3021-17.html

Citation: "Standard Specification for Universal Design of Fitness Equipment for Inclusive Use by Persons with Functional Limitations and Impairments" https://www.astm.org/f3021-17.html **(accessed Sep. 20, 2023).**

Content:

- Color contrast needs to be >=70% on the display
- Access to the seat/erg needs to be unimpeded on all sides
- Foot supports shall have a minimum length 300 mm (11.8 in.) and width 150 mm (5.9 in.).
- For seated cardio equipment, foot supports shall have foot retention, for example, raised guard, with a minimum height of 30 mm (1.2 in.) for a minimum of 80 % along the inside edge and 12 mm (0.5 in.) along a minimum of 80 % of outside edge.
- Tactile or kinesthetic feedback, for example, a click or responsive feel to the actuation, or audio feedback, or both, shall be provided on main controls to indicate successful activation.
- Numeric readouts, for example, LED/LCD, on the display related to the main controls shall have a minimum font size of 10 mm (0.4 in.) and be labeled to indicate function, for example, speed, time, or distance, and the correct unit of measurement should be displayed.
- Numeric readouts relating to the main controls shall have significant color value contrast from the adjacent surface of the equipment that they are primarily seen against (as defined in
- Visual feedback concerning performance shall be provided numerically at the end of exercise. The display shall continue to function to provide feedback for a minimum of 5 s after exercise has stopped
- For power driven equipment, visual feedback, for example, a light or 3–2–1 countdown, and non-visual feedback, for example, auditory through headphones, shall be provided immediately prior to the moving surface starting and stopping for all programs.

Conclusions/action items: Especially when creating the visual interface for our force sensors, make sure that these accessibility and inclusivity standards are met.

09/21/2023 - Patent - Rowing Performance Optimization System and Methods

NEHA KULKARNI - Sep 21, 2023, 6:39 PM CDT

Title: Patent - Rowing Performance Optimization System and Methods

Date: 09/21/2023

Content by: Neha

Present: Neha

Goals: Understand a patented design with force sensors on a rowing machine.

Link: **https://www.lens.org/lens/patent/137-741-912-002-321/frontpage?l=en**

Citation: L. Thomas, C. Manuel, G. Hayley, and C. Jordi, "Rowing Performance Optimization System And Methods."

https://www.lens.org/lens/patent/137-741-912-002-321/frontpage?l=en (accessed Sep. 21, 2023).

Content:

- Sensors on rower
- Sensors on boat
- Display
- Memory
- Sensor on oar collar
- Data is transferred via bluetooth
- One sensor could be a GPS
- Inertial measurement assembly: accelerometer/gyroscope
- Sensors are waterproof
- This patent feels more like proof of concept, not an actual design
- Patent is pending

- number: WO 2023/049531 A1

 Conclusions/action items: Consider the bluetooth method for communicating data.

10/10/2023 - NCAA Ethical Considerations

NEHA KULKARNI - Oct 11, 2023, 10:32 PM CDT

Title: Ethical Considerations - NCAA Rules

Date: 10/10/2023

Content by: Neha

Present: Neha

Goals: Understand NCAA rules about ethics and see if our device is in alignment with them

Link: https://web3.ncaa.org/lsdbi/search/bylawView?id=11561

Citation: "Legislative Services Database - LSDBi." Accessed: Oct. 11, 2023. [Online].

Available: https://web3.ncaa.org/lsdbi/search/bylawView?id=11561

Content:

- General principle of ethics
  - Athletes must act with honesty and sportsmanship
- Unethical conduct
  - Knowingly offering a student financial aid or inducing their commitment
  - Staff member arranging special meeting between athlete and agent, financial advisor
  - Knowingly providing banned substance
  - Engaging in competition under fake name/intent to deceive
  - Failure to provide full accurate info to NCAA
- Sports wagering
  - Internet wagering
  - Bidding on teams
  - Fantasy leagues

Conclusions/action items: Our device does not have the scope to violate any of these rules/definitions.

09/26/2023 - Preliminary Design - FSR Circuit

NEHA KULKARNI - Sep 29, 2023, 7:01 PM CDT

Title: 09/26/2023 - Preliminary Design - FSR Circuit

Date: 09/26.2023

Content by: Neha

Present: Neha

Goals: Create a preliminary design for a force sensor on the footplate of the tank ergometer.

Content:
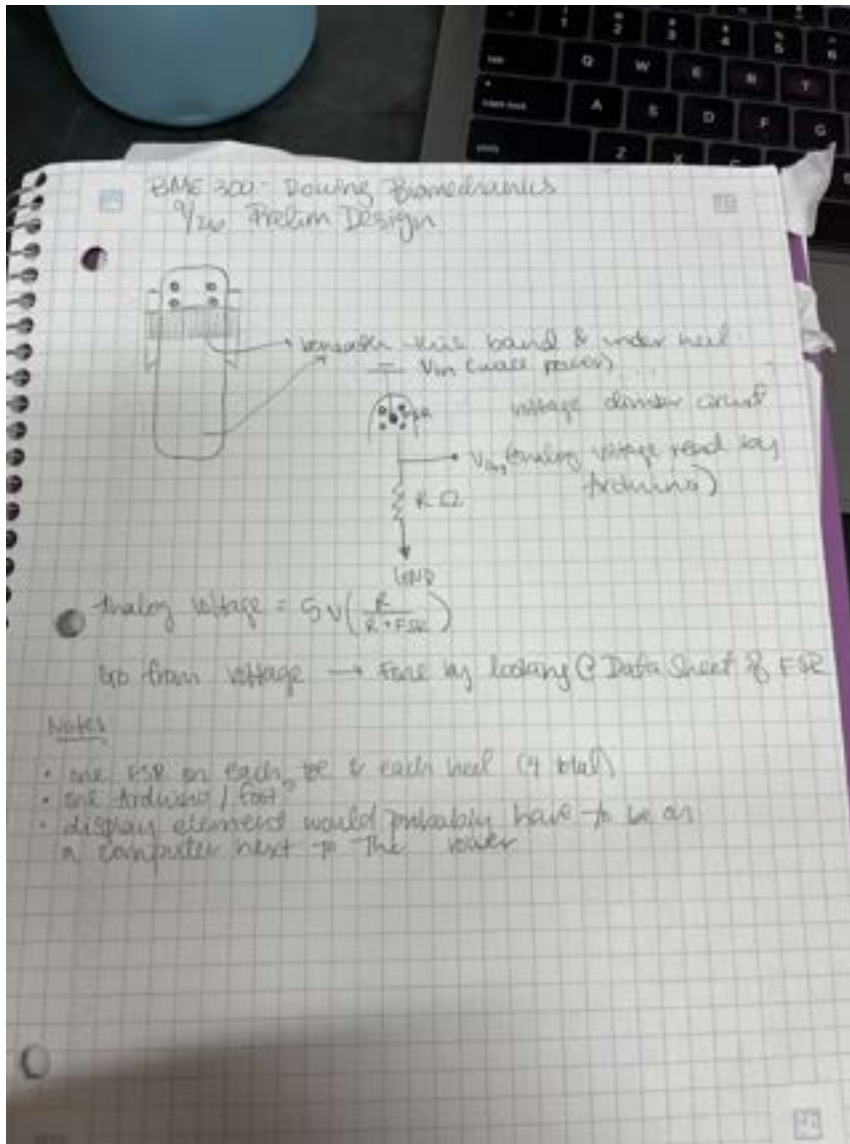
Conclusions/action items: Evaluate this design in the matrix after sharing it with the rest of the team and getting feedback.

10/09/2023 - Arduino EEPROM guide

NEHA KULKARNI - Oct 11, 2023, 10:33 PM CDT

Title: Arduino EEPROM guide

Date: 10/09/2023

Content by: Neha

Present: Neha

Goals: Understand EEPROM and how we can use it

Link: https://docs.arduino.cc/learn/programming/eeprom-guide

Citation: "A guide to EEPROM | Arduino Documentation." Accessed: Oct. 11, 2023. [Online].

Available: https://docs.arduino.cc/learn/programming/eeprom-guide

Content:

- What is EEPROM?
    - Memory that stores values even when board is turned off
- EEPROM functions
    - EEPROM Clear
        - Sets all bytes to zero
    - EEPROM Read
        - Reads data that has been written
    - EEPROM Write
        - Stores values read from analog input
    - EEPROM Update
        - Writes new data in a location only if it is different from previous data in that location
    - EEPROM CRC
        - Checks whether data has been corrupted

Conclusions/action items: Leverage these functions when storing rowers' data for later use, or to store data we can use in our display.

10/05/2023 - Analog Read Function

NEHA KULKARNI - Oct 11, 2023, 10:34 PM CDT

Title: Analog Read function on Arduino

Date: 10/05/2023

Content by: Neha

Present: Neha

Goals: Understand how to use the analog read function on Arduino

Link: **https://www.arduino.cc/reference/en/language/functions/analog-io/analogread/**

Citation: "analogRead() - Arduino Reference." Accessed: Oct. 11, 2023. [Online].
Available: https://www.arduino.cc/reference/en/language/functions/analog-io/analogread/

Content:

- Syntax
    - `analogRead(pin)`
- pin argument is name on analog pin to read output from
- pin has 5 V operating voltage
- Pins are numbered A0 to A5
- Max resolution is 10000 bit

Conclusions/action items: We can use this function to read output voltage from our circuit. The 10000 bit resolution is a limitation/consideration for our accuracy.

10/05/2023 - Arduino Specs

Title: Arduino Uno specifications

Date: 10/05/2023

Content by: Neha

Present: Neha

Goals: Learn more about the capabilities and limitations of the Arduino

Link: **https://docs.arduino.cc/hardware/uno-rev3**

Citation: "UNO R3 | Arduino Documentation." Accessed: Oct. 11, 2023. [Online]. Available: https://docs.arduino.cc/hardware/uno-rev3

Content:

- Tech specs

Microcontroller	ATmega328P	
USB connector	USB-B	
Pins	Built-in LED Pin	13
	Digital I/O Pins	14
	Analog input pins	6
	PWM pins	6
Communication	UART	Yes
	I2C	Yes
	SPI	Yes
Power	I/O Voltage	5V
	Input voltage (nominal)	7-12V
	DC Current per I/O Pin	20 mA
	Power Supply Connector	Barrel Plug
Clock speed	Main Processor	ATmega328P 16 MHz
	USB-Serial Processor	ATmega16U2 16 MHz
Memory	ATmega328P	2KB SRAM, 32KB FLASH, 1KB EEPROM
Dimensions	Weight	25 g
	Width	53.4 mm
	Length	68.6 mm

- Implications/limitations of these specs
    - 7-12 V input voltage - can wall power work?
    - I/O voltage of 5 V - limits resistors we can use and might change configuration
    - 1 kB EEPROM - limits how much data we can store

Conclusions/action items: We must keep these specifications in mind when building our circuit to maintain accuracy and prevent damage to circuit components.

10/18/2023 - Load cell vs FSR

Title: Load cell vs FSR

Date: 10/18/2023

Content by: Neha

Present: Neha

Goals: Understand the relative pros/cons of load cells and FSRs

Link: https://www.tekscan.com/resources/whitepaper/load-cell-vs-force-sensor

Citation: "Load Cell Vs. Force Sensor | Tekscan." Accessed: Oct. 20, 2023. [Online].
Available: https://www.tekscan.com/resources/whitepaper/load-cell-vs-force-sensor

Content:
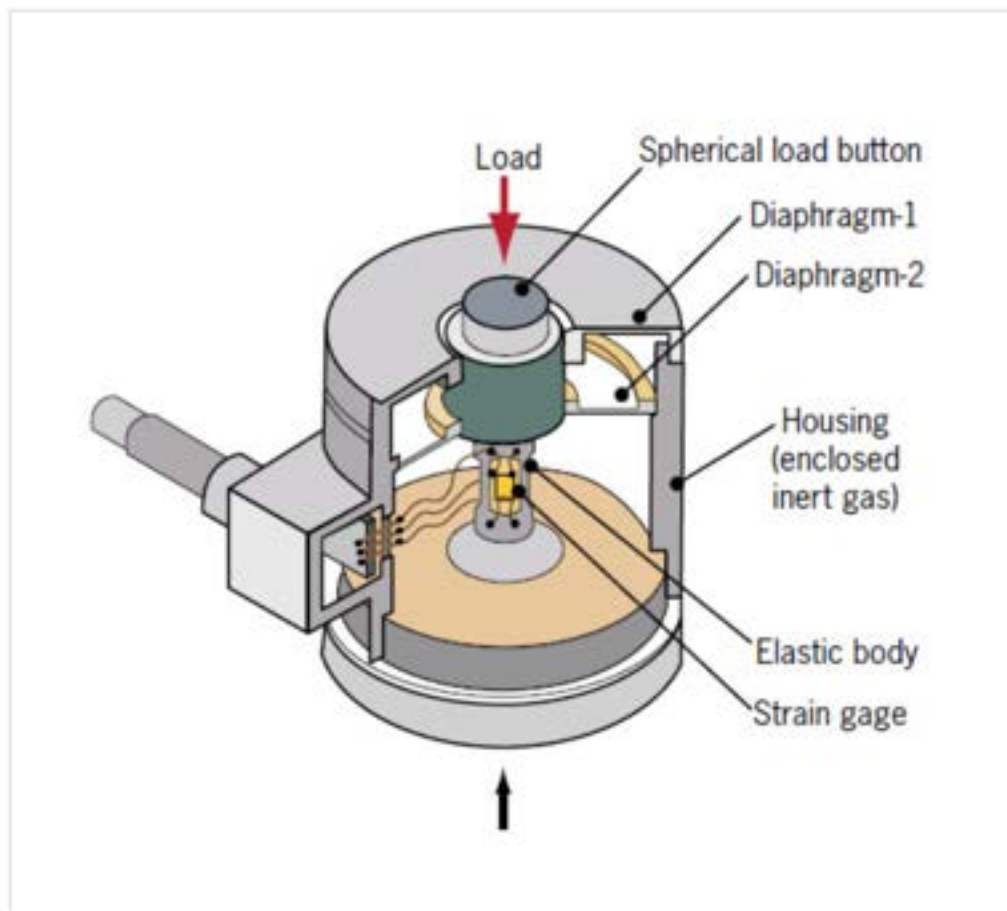
Typical Load Cell

- Load cell
    - Very accurate
    - Pre-calibrated
    - Readily available
    - Bulky
    - Costly signal conditioning electronics
    - Not great for incorporating into other designs
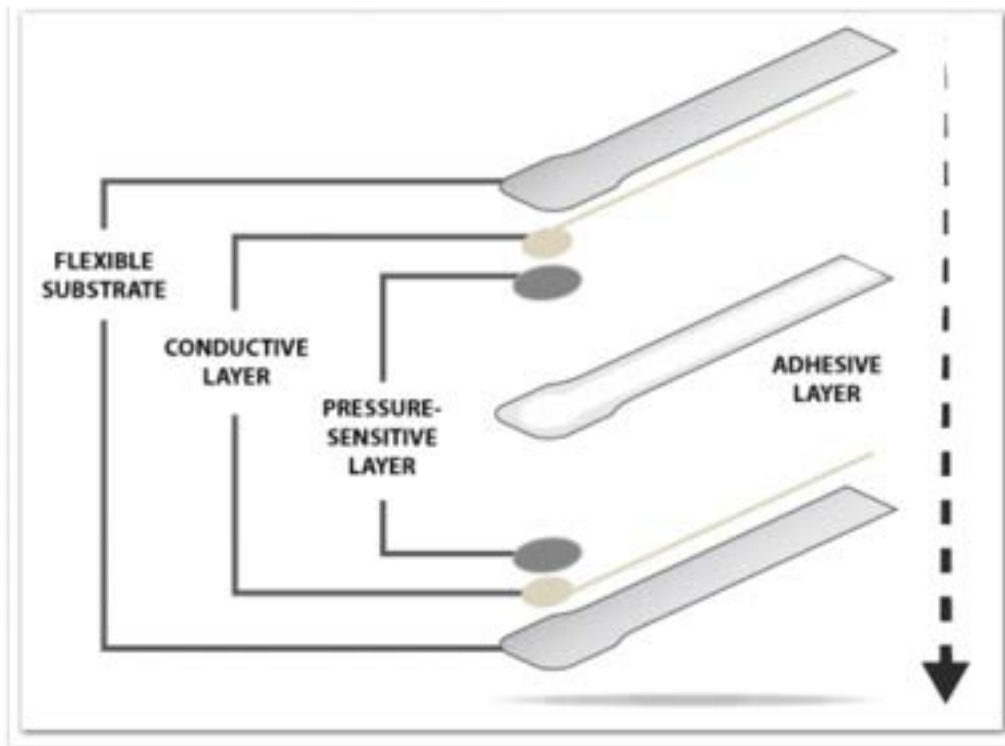
Force Sensor Construction

- FSR
    - Thin and flexible construction → unobstructive measurement
    - Readily available
    - Inexpensive signal conditioning electronics
    - Good for design-in applications
    - Customizable
    - Thin, lightweight, low power requirements
    - Less accurate
    - User calibrated

Conclusions/action items: Based on these pros/cons, it seems like FSRs might be more suited to our application with the budget we have right now. However, the load cell would be a good future direction to move towards because of its accuracy.

10/20/2023 - Difference between force measurement techniques

NEHA KULKARNI - Oct 20, 2023, 10:10 AM CDT

Title: The Difference Between Force Measurement Techniques

Date: 10/20/2023

Content by: Neha

Present: Neha

Goals: Understand more about the different force measurement techniques out there and how they compare

Link: https://www.tekscan.com/thank-you/download-now-difference-between-force-measurement-techniques?aliId=eyJpIjoiQkxHSW1BRzJCUXR2MHhTWSIsInQiOiJKZ0xodjBKMWVzOVdxcjBkVjlLNjF3PT0ifQ%253D%253D

Citation: "The Difference Between Force Measurement Techniques | Tekscan." Accessed: Oct. 20, 2023. [Online].
Available: https://www.tekscan.com/thank-you/download-now-difference-between-force-measurement-techniques?aliId=eyJpIjoiQkxHSW1BRzJCUXR2MHhTWSIsInQiOiJKZ0xodjBKMWVzOVdxcjBkVjlLNjF3PT0ifQ%253D%253D

Content:

- Most common force measurement methods: FSRs and load cells
- Load cells
    - Utilize strain gauges that change resistance as they deform
    - Setup: 1-4 strain gauges, one- or two-beam setup
        - One beam: load cell is fixed on beam end, loaded on free end
        - Two beams: load cell fixed between two beams, loaded in center
- FSR
    - Unloaded FSR has Mega-ohm resistance (very high)
    - Loaded FSR decreases resistance to kilo-ohms
- Load cells are extremely accurate when calibrated for absolute measurements
- FSRs are better for relative force measurements - changes in force
    - Avg error 4-10% for absolute measurements depending on calibration
- Linearity
    - How closely sensor output conforms to straight line drawn between max and min measurements/calibration pts
    - Load cells exhibit nonlinearity at lower end of their range
    - Thru mode FSRs are linear throughout their range
    - Shunt mode FSRs deviate from linear behavior even within her range
        - Need more calibration points
- Load capacities
    - Load cells have more dynamic load ranges
    - FSRs are designed for smaller load capacities
    - Temperature or humidity can affect drift in load sensing capabilities of load cells
- Electronics and maintenance
    - Load cells require conditioned power source supplying voltage
        - Need dedicated digital signal processing
    - FSRs can usually just use simple voltage divider/op amp circuit
- Design considerations
    - Load cells can be bulky, higher cost
    - FSRs are flat, flexible, low-cost, easily integrated

Conclusions/action items: This source also seems to imply that FSRs are better suited for our current application since they are cheaper and more easily integrated into existing equipment.

10/30/2023 - Load Cell Hookup Guide

Title: Load Cell Hookup Guide

Date: 10/30/2023

Content by: Learn how to hook up and use the load cell we ordered

Present: Neha

Goals: Neha

Link: https://learn.sparkfun.com/tutorials/load-cell-amplifier-hx711-breakout-hookup-guide?_ga=2.211034453.1907082278.1698769345-1449665479.1698769345&_gac=1.27596494.1698769345.Cj0KCQjwy4KqBhD0ARIsAEbCt6jftOPZCexTRzRP0PtrKEHjHqId-ksl1G9FCY59wY-A8Xm32bhY9JwaAqcvEALw_wcB&_gl=1*nrqf5b*_ga*MTQ0OTY2NTQ3OS4xNjk4NzY5MzQ1*_ga_T369JS7J9N*MTY5ODc2OTM0NC4xLjAuMTY5ODc2OTM0NC42MC4wLjA.

Citation: "Load Cell Amplifier HX711 Breakout Hookup Guide - SparkFun Learn." Accessed: Nov. 11, 2023. [Online]. Available: https://learn.sparkfun.com/tutorials/load-cell-amplifier-hx711-breakout-hookup-guide?_ga=2.211034453.1907082278.1698769345-1449665479.1698769345&_gac=1.27596494.1698769345.Cj0KCQjwy4KqBhD0ARIsAEbCt6jftOPZCexTRzRP0PtrKEHjHqId-ksl1G9FCY59wY-A8Xm32bhY9JwaAqcvEALw_wcB&_gl=1*nrqf5b*_ga*MTQ0OTY2NTQ3OS4xNjk4NzY5MzQ1*_ga_T369JS7J9N*MTY5ODc2OTM0NC4xLjAuMTY5ODc2OTM0NC42MC4wLjA.

Content:

- We ordered a bar type load cell
  - Ideally we should have two plates screwed into it on both sides

  - This would produce a torque which can be read by the strain gauge, which is more accurate than a direct load on this type of load cell
- Error sources
  - Load cells can be +/- 5% off due to
    - Temp, creep, vibration, drift, electrical/mechanical interference
    - Allow for easy calibration and adaptable code to minimize this error
- The amplifier we ordered is color-coded to the elements of the wheatstone bridge inside the load cell
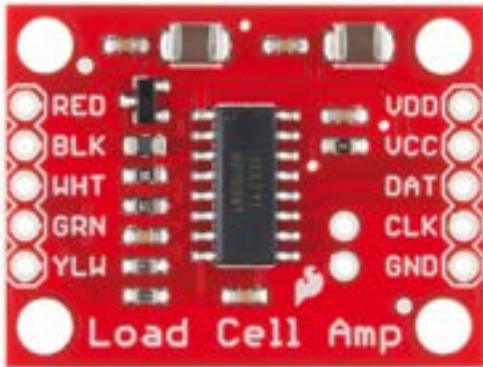
Wheatstone Bridge Node	"Typical" Wire Color
Excitation+ (E+) or VCC	RED
Excitation- (E-) or GND	BLACK or YELLOW
Output- (O-), Signal- (S-), or Amplifier- (A-)	WHITE
O+, S+, or A+	GREEN or BLUE

- Arduino hookup
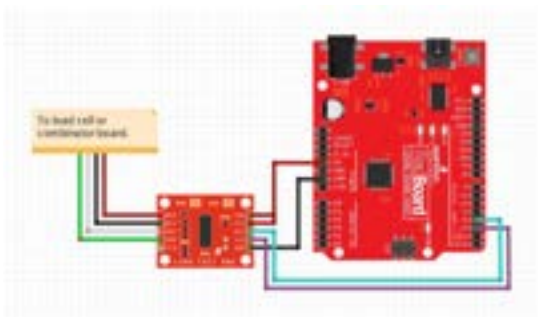
- Code
    - Need the [HX711 Arduino library](#) installed and imported
    - Calibration
        - Goal: find calibration factor that allows for accurate readings going forward
        - Process
            - Place known weight on load cell setup and manually adjust calibration factor until desired reading is reached on serial monitor

Conclusions/action items: Follow these instructions when setting up and calibrating our circuit with the bar load cell and amplifier that we ordered.

11/3/2023 - Show and Tell Reflection

NEHA KULKARNI - Nov 11, 2023, 6:13 PM CST

Title: Show and Tell Reflection

Date: 11/3/2023

Content by: Neha

Present: Team

Goals: Show our circuit and the ergometer to other teams and get their feedback/ideas on how to move forward with embedding the circuit into the erg

Link: N/A

Citation: N/A

Content:

- Circuit performance
    - Was working on/off → connections were loose
    - More accurate when load was applied on edges
        - Makes sense bc moment reading is more accurate than direct load
- Ideas on how to embed
    - Instead of putting something on the ergometer, more people suggested putting sensors directly on the athlete
        - Ex. compression sock
        - Ex. adjustable shoe sole
    - Split up the heel and toe load cells so they can move in different directions/independently of each other
        - Similar to shoe size measurer

    - Replace erg footplate with entirely new one
- Client's thoughts
    - Client really liked ideas that allowed for the most adjustability to each athlete and repeatability between trials on one athlete
    - Sock/shoe ideas were favored

Conclusions/action items: Consider making something that the athlete can wear or slip into that is also adjustable. Shoe size measurers are a really good basis for our application.

11/5/2023 - Ideas on how to embed load cell

Title: Ideas on embedding load cell

Date: 11/5/2023

Content by: Neha

Present: Neha

Goals: Come up with ideas on how to embed load cell into foot plate

Link: N/A

Citation: N/A

Content:

Title: Ideas on embedding load cell

Date: 11/5/2023

① existing fot plate
w/ Flexfit removed
• = load cell

anchor rods

rods containing load
cells that are adjustable
to diff shoe sizes

pro: adjustable, minimal modifications beg
con: protrudes from footplate
=> uneven contact surface

② rods containing load
cells

locking mechanism

pro: no anchor rods => less protrusion
still adjustable
con: still not perfectly flush w/
contact surface

③ new footplate w/ adjustable
load cell locations
pro: can get even
contact surface
con: hard to fabricate!

Conclusions/action items: Present these ideas to the team and to the client and get their thoughts

11/9/2023 - Final load cell option

Title: Final load cell option

Date: 11/9/2023

Content by: Neha

Present: Neha

Goals: Find a load cell with the right capacity for us to order as our final

Link: https://www.sparkfun.com/products/13332

Content:

- This load cell is good because it has a 200kg capacity
    - Approximately 440 pounds, well over what we need based on prior research (see 9/29 entry)
- Also relatively inexpensive - only 64 dollars each
- Sparkfun compatible - we don't need another amplifier
- Very small - good size
    - 20mm x 11mm, 2000mm Wire

-

Conclusions/action items: Ask client to order four of these for us with 2-day shipping.

2023/12/03 - Arduino EEPROM code writing & testing

NEHA KULKARNI - Dec 03, 2023, 10:27 AM CST

Title: Arduino EEPROM writing

Date: 2023/12/3

Content by: Neha

Present: Neha

Goals: Figure out the best way to store load cell readings on the Arduino for later analysis

Content:

- Arduino has 1024 addresses to write integers from 0-255

- Issues:

    - scale.get_units() function outputs a float

        - This would take 4 addresses per float

    - scale.read() function outputs an integer that is much larger than 255 (0 load corresponds to 25000)

        - This is the "raw" reading from the load cell

- To solve issue 1

    - Try EEPROM put function

        - EEPROM put can write float data to an address

        - Test 1:

            - Implement delay in code (3 sec)

            - Implement address counter

            - Apply varying loads every 3 seconds for about 15 seconds

            - EEPROM.put (addr, scale.get_units())

            - addr = addr + 1 (increment counter each time so that it writes to subsequent addresses each reading)

            - FAILED

                - Did not successfully write any kind of float value

                - Used EEPROM.get() function to read vals

        - Test 2:

            - Implement delay in code (3 sec)

            - Implement address counter

            - Apply varying loads every 3 seconds for about 15 seconds

            - EEPROM.put (addr, scale.get_units())

            - addr = addr + 4 (increment counter each time so that it writes to every 4th address each reading since floats take 4 addresses)

            - FAILED

                - Same results as Test 1

        - Abandoned put function after this attempt → writing float is not a viable option at this time

- To solve issue 2

    - Divide scale.read() function by 1000 and round it off to an integer, then write that to EEPROM using write function

        - Will have to manually re-calculate actual load from .read() function output in analysis code

            - Using function definitions in library of scale.get_units() and calibration factor

        - Test:

            - Same delay, addr counter, varying load applied as .put() tests

            - EEPROM.write(addr, val)

            - addr = addr + 1

            - SUCCESSFULLY WROTE VALUES

                - But attempts to re-calculate actual load from written val were way too off

                    - Written val: 25, re-calculated val: 4.262

                    - This is not accurate at all, and only got worse as load was applied → not a viable option

                    - Ideally there should be a datasheet where we can create a fit to go from raw val to load val, but our load cell doesn't have one

    - Try just rounding off the load value itself and writing that

        - This worked

        - Disadvantage: rounds off value so not entirely accurate

Conclusions/action items: Implement this code (pasted below) during final testing.


```
#include "HX711.h" //This library can be obtained here http://librarymanager/All#Avia_HX711
#include "EEPROM.h"

#define calibration_factor 5865 //This value is obtained using the SparkFun_HX711_Calibration sketch

#define LOADCELL_DOUT_PIN  3
#define LOADCELL_SCK_PIN  2

HX711 scale;
int addr = 0;

void setup() {
  Serial.begin(9600);
  Serial.println("HX711 scale demo");

  scale.begin(LOADCELL_DOUT_PIN, LOADCELL_SCK_PIN);
  scale.set_scale(calibration_factor); //This value is obtained by using the SparkFun_HX711_Calibration sketch
  scale.tare(); //Assuming there is no weight on the scale at start up, reset the scale to 0
  Serial.println("Readings:");
  for (int i = 0 ; i < EEPROM.length() ; i++) {
   EEPROM.write(i, 0);

}}
```

```
void loop() {
  delay(3000);
  float val = scale.get_units();
  int val_int = int(round(val));
  Serial.print("Reading: ");
  Serial.print(val_int); //scale.get_units() returns a float
  Serial.print(" lbs    ");//You can change this to kg but you'll need to refactor the calibration_factor
  Serial.print(addr);
  Serial.println();

  EEPROM.write(addr, val_int);
  addr = addr + 1;


}
```

2023/03/28 - Green Permit

Title: Green Permit

Date: 03/28/2023

Content by: Neha Kulkarni

Present: Neha Kulkarni

Goals: Obtain a green permit for fabrication of the sample holder.

Content:

A photo of the green permit is attached.

Conclusions/action items: Use the permit for fabrication of the sample holder.

NEHA KULKARNI - Mar 28, 2023, 11:01 PM CDT
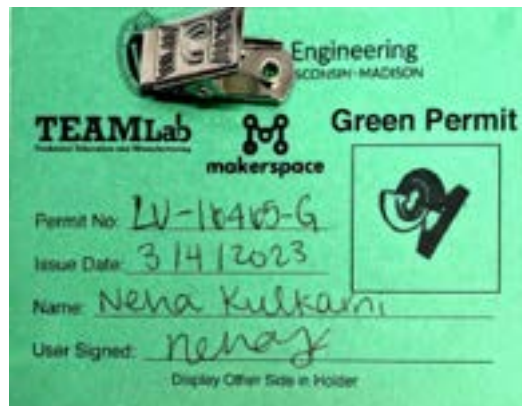
Download

greenpermit.pdf (391 kB)

2023/09/13 - Labral Injuries of the Hip in Rowers

SIMRET BHATIA - Oct 09, 2023, 5:02 PM CDT

Title: Labral Injuries of the Hip in Rowers

Date: 9/13/2023

Content by: Simmi

Goals: Learn about a common hip injury in rowers and how that relates to uneven weight distribution

Source:

[1] R. E. Boykin *et al.*, "Labral injuries of the hip in rowers," *Clinical Orthopaedics & Related Research*, vol. 471, no. 8, pp. 2517–2522, 2013. doi:10.1007/s11999-013-3109-1

Content:

visual of hip flexion during rowing:

-Rowing requires a lot of repetitive motion that can cause tear in the labral tissue of the hip

-Average age in the study was 18.5 years old, 85% women and 15% male

-risk of labral injuries of the hip can be heightened for those with anatomic abnormalities (another important reason to have force plate data)

-scully: type of rowing where hips are equally compressed at the catch and extend into hip extension into the catch

- most commonly cited injuries in rowers are those of the lumbar spine and stress fractures of the ribs

-mechanism of repetitive hip hyperflexion (with internal rotation in certain situations) can predispose rowers to injuries of the labrum

Conclusions/action items: Proper form in rowing is especially important due to the repetitive and forceful moves that are required by the sport.

2023/09/21 Rowing Biomechanics Terms and Form

SIMERJOT KAUR - Sep 21, 2023, 11:30 PM CDT

Title: Rowing Biomechanics Terms and Form

Date: 9/21/2023

Content by: Simmi

Goals: Learn proper rowing vocabulary for design reports and learn about proper form and how to design around it.

Source:

K. HASE, B. J. ANDREWS, A. B. ZAVATSKY, and S. E. HALLIDAY, "Biomechanics of Rowing. II. A Control Model for the Simulation Study of Rowing and Other Human Movement.," *JSME International Journal Series C*, vol. 45, no. 4, pp. 1082–1092, 2002, doi: https://doi.org/10.1299/jsmec.45.1082.

Content:

-The flexion and extension of the legs, the swing of the upper body from the hips and the vertical movement of the hands and arms cause certain vertical displacements of body parts.

-Equal work, realised through extreme tension of the different muscle groups, results in various local loads. The higher loads manifest themselves in the smaller muscle groups (i.e., the arms), and the lower loads in the larger muscle groups (i.e., the legs)

-During drive, the legs are fully extended, this will be when we measure load distribution

-The center of gravity (CG) can be calculated by analysing the sequence of the movement of the body joints. The movement of the CG horizontally and vertically during the stroke cycle is important for the forces exerted by the rower

-Vertical movement of the centre of gravity produces a dipping of the boat and creates even greater resistance. Large and fast changes in the horizontal movement of body weight also increase the changes in the velocity of the boat.

-The efficiency of an individual rower in a crew can be increased with dynamic measurement devices, such as force transducers, in the boat. In the end, the practical education of biomechanical concepts and the simplification of scientific research into language that can be understood by the coaches and the rowers is our goal.

-Most objectives of biomechanical research are to explain the propulsion-causing powers and accelerations of the rowing stroke during competition, both in theory and in practice.

-it makes more sense to improve the time of the movements during the drive where the body parts work synchronously (this is what the force sensors will measure)
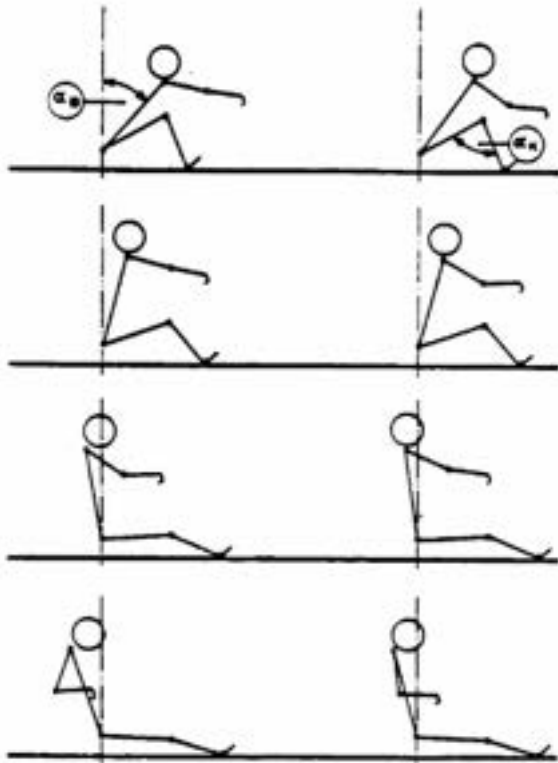
Figure 2: Measurement of the length of the stroke from pictures made looking down from a bridge.
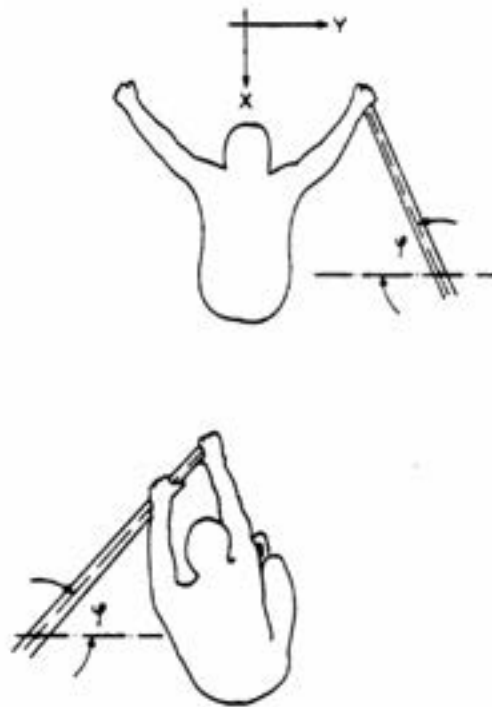
Conclusions/action items: In conclusion, this paper affirms the lack of research in lower extremity biomechanics research and the importance of force time graphs in the boat for improving athlete performance. Knowing the proper form for rowing will be helpful in making sure the design won't affect their technique.

2023/09/21 Reflection from Rowing Practice, McClain Center Visit, Rowing Videos

SIMERJOT KAUR - Sep 22, 2023, 1:02 PM CDT

Title: Reflection from Rowing Practice and McClain Center Visit

Date: 9/21/2023

Content by: Simmi

Goals: Learn specific client requirements, try out the machine and observe rowing technique in real life.

Content:

- At rowing practice, I noticed some of the people who did sweep style rowing had their knees angled to various different degrees during catch and drive phase (also shown in rowing videos)
- During sweep rowing, Sarah said that knees should be pointed straight ahead of the boat or angle slightly.
- This non-uniformity in form is something we aim to fix with our design.
- When I tried out the tank which is a rowing simulation that mimics a strong water current, I noticed how difficult it is to keep a symmetrical form.
- Pushing off from foot plate to go from catch and drive, I noticed that I tended to push off with the upper side of my feet.
- But the proper form mentioned by Sarah and Adrienne (rowers) was to plant all of the foot during drive.
- Force sensors can be used to detect if rowers leaning to much on the side they are sweep rowing

Conclusions/action items: In conclusion, read literature from Tricia and research how load cells work.

2023/10/11 Rowing Injuries: An Updated Review

SIMERJOT KAUR - Oct 11, 2023, 10:07 PM CDT

Title: Rowing Injuries: An Updated Review

Date: 10/11/2023

Content by: Simmi

Goals: Read the article that Tricia gave and learn more about rowing injury causes.

Source: [1] J. S. Thornton *et al.*, "Rowing injuries: An updated review," *Sports Medicine*, vol. 47, no. 4, pp. 641–661, 2016. doi:10.1007/s40279-016-0613-y

Content:

Collegiate style rowing is considered flatwater rowing discipline.

The largest risk factor for rowing injuries remains rapid increases in training frequency, intensity and volume.

Injuries to the lumbar spine account for 2-53% of all injuries in rowing making it the most frequently injured region.

Majority of lower back injuries are associated with training volume and kinematics

End range of hyperflexion and twisting forces are exacerbated at the catch, estimated compressive loads placed on the spine reaching 4.6 times the rower's mass

Curvature of the spine is necessary for its load-bearing function which performs best with load distributed evenly through the vertebrae

achieving proper hip ROM and training lumbar extensor endurance is crucial to maintaining healthy levels of flexion

Conclusions/action items: In conclusion, proper hip flexion during catch and drive is crucial for preventing injury.

2023/10/11 Sweep Rowing and Lumbar Spine Injury

SIMERJOT KAUR - Oct 11, 2023, 10:33 PM CDT

Title: Sweep Rowing and Lumbar Spine Injury

Date: 2023/10/11

Content by: Simmi

Goals: Understand what good form is in order to point it out while watching rowers. Learn about all the important terms and common injury reasons for the sport.

Source:

D. A. Reid, "Factors contributing to low back pain in rowers," *British Journal of Sports Medicine*, vol. 34, no. 5, pp. 321–322, 2000. doi:10.1136/bjsm.34.5.321

Content:

The rowers typically row in pairs, fours, or eights. In contrast to sculling, where each rower has two oars, sweep rowers have only one oar, which is usually held with both hands. The rowers work in unison to propel the boat forward, and coordination is crucial for a successful and efficient stroke. Here is an overview of the best form in sweep rowing and how lumbar spine stress can be caused with lower extremity movement:

Best Form in Sweep Rowing:

Lower Body: The power in sweep rowing comes from the lower body. The rower initiates the stroke by pushing with their legs. This movement involves extending the knees and hips, driving the seat toward the stern of the boat.

Body Swing: After the leg drive, the rower swings their upper body back, maintaining a straight back and pivoting at the hips. This sequence allows the rower to transfer the power generated by the legs to the oar.

Arm Pull: Once the legs and body have been engaged, the rower uses their arms to complete the stroke, pulling the oar through the water in a straight and horizontal path.

Recovery: After the stroke is completed, the rower performs the recovery phase. This involves moving the hands away from the body, feathering the oar (turning it flat), and bending the knees to return to the starting position.

Lumbar Spine Stress and Lower Extremity Movement: The lumbar spine, or lower back, can be subject to stress in sweep rowing, especially if proper technique and form are not maintained. Here's how lower extremity movement can impact the lumbar spine.

Improper Technique: If a rower fails to engage their lower body properly during the drive phase, they may compensate by overusing their back muscles to pull the oar.

Overexertion: Rowers who push too hard without proper form or take too many strokes without adequate rest can experience lumbar stress due to fatigue. To minimize lumbar spine stress, it's essential for rowers to focus on maintaining proper form, building core strength, and ensuring that power primarily comes from the legs during the drive phase.

Conclusions/action items: There are a lot of components to good form but most focus on lower body and hip exertion. Knowing this can help us pinpoint what kind of data we want to present.

2023/10/11 Sport Specific Conditioning to Prevent Injuries

SIMERJOT KAUR - Oct 11, 2023, 11:00 PM CDT

Title: Sport Specific Conditioning to Prevent Injuries

Date: 10/11/2023

Content by: Simmi

Source: Allen, Kristen MS, ATC, CSCS; Jones, Margaret T. PhD, CSCS. Sport-Specific Conditioning to Prevent Injuries in Rowing. Strength and Conditioning 20(1):p 35-41, February 1998.

Goals: Learn about specific sport conditioning techniques employed by rowers to prevent injuries and if we are able to implement it into our design.

Content:

Co-contraction of the hamstring and quadriceps intitiate the drive phase with the power primarily provided by the quadriceps

Legs extend while shoulder and back remain in front of the hips to maintain the forward angle. Once the legs are almost in full extension, should and torso pivot over the hips.

Injury prevention exercises should focus on flexibility, bilateral strength, agonist, antagonist and stabilizer and muscles of the abdomen and low back, commonly referred to as the cpre musculature.

Hamstring tightness can result in limited rotation of the pelvis and excessive stretch of the low back structures.

Total hip flexors coupled with weak abdominals cause the pelvis to rotate anteriorly resulting in an increased lordotic curve which places excessive stress on the lumbar spine, ligaments and muscles.

Static stretches should be held for 6-30 seconds and repeated 2-3 times. This increases range of motion

Developing bilateral strength include: pelvic muscle must be in balance to execute a rowing stroke. Asymmetrical musculature creates an uneven pull on the pelvis which increases the stress in the lumbar spine/sacral area resulting in low back pain. There must be an ideal balance between muscle development and maintainance of flexibility. Muscle imbalance can be corrected through strength training the weaker structures and develop the stabilizers.

Conclusions/action items: It was very useful learning that asymmetry can orginate from the pelvis. This will be useful in pinpointing joint areas.

2023/10/11 Strengthening of Muscles to Prevent Lower Back Pain

SIMERJOT KAUR - Oct 11, 2023, 11:09 PM CDT

Title: Strengthening of Muscles to Prevent Lower Back Pain

Date: 10/11/2023

Content by: Simmi

Goals: Learn about the important muscle groups and injury prevention methods for rowers

Source: "Back & spine: Greenberg Regenerative Medicine: Bryn Mawr, PA," Greenberg Regenerative Medicine, https://greenbergregen.com/back-spine/ (accessed Oct. 11, 2023).

Content:

The main muscles that contribute to lower back pain are hamstring, piriformis and gluteus maximus.

Hamstring Curls on a Swiss Ball: Lie on your back with your feet on a Swiss ball. Lift your hips off the ground, forming a straight line from your shoulders to your heels. Bend your knees and roll the ball toward your buttocks using your heels. Extend your legs, rolling the ball away, and repeat. Perform 2-3 sets of 12-15 repetitions. Deadlifts: Deadlifts with proper form can strengthen the hamstrings, glutes, and lower back. Be sure to start with light weights and perfect your form before increasing the load.

Piriformis Stretch: Sit on the floor with one leg straight and the other ankle crossed over your knee. Gently push the knee of the crossed leg away from your body. Hold for 15-30 seconds, and then switch legs. Repeat 2-3 times on each side. Clamshell Exercise: Lie on your side with your legs bent at a 90-degree angle. Keeping your feet together, lift your top knee as far as you can without moving your pelvis. Lower it back down. Perform 2-3 sets of 12-15 repetitions on each side. 3. Gluteus Maximus Exercises: The gluteus maximus is the largest muscle in the buttocks, and a weak gluteus maximus can lead to lower back pain.

Conclusions/action items: In conclusion, these main muscle groups contribute to lower back and have relation to being strained when there is asymmetry.

2023/09/14 - Components of Force Plates

SIMERJOT KAUR - Sep 14, 2023, 1:40 PM CDT

Title: Components of Force Plates

Date: 9/14/2023

Content by: Simmi

Goals: Learn about how force plates work and how they can be integrated into rowboats.

Source:

"Force plate," Kistler, https://www.kistler.com/US/en/force-plate/C00000113 (accessed Sep. 14, 2023).

Content:

-force plates are a measuring platform with a piezoelectric force sensor in every corner

-measures the ground reaction, at rest the ground reaction corresponds the weight of the body

-a three component force plate contains piezoelectric sensors that measure the forces in the three main axes: the vertical, horizontal and the transverse direction. This information can be used to answer questions or analyze the movement of the center of mass.

-there are mobile and permanently installed force plates. Usually, the force plate is installed flush with the underlying group so it facilitates natural movement.

- For simple analyses, e.g., for vertical jumps, a portable 1D-force plate is sufficient
- Trainers and coaches usually work with a portable three-component force plate for recording the balance and stability of their athletes

-In research, permanently installed 3D-systems are normally used. To record complex movement patterns, force plates are used in combination with video cameras or motion-capture systems.

-Kistler is a potential manufacturer of force plates we can purchase from

Conclusions/action items: We need to figure out how to embed the force plate effectively in the rowboat in order to mimic natural movement.

2023/09/14 - Methods of Getting Real Time Data

SIMERJOT KAUR - Sep 14, 2023, 2:08 PM CDT

Title: Methods of Getting Real Time Data for Rowing Athletes

Date: 9/14/2023

Content by: Simmi

Goals: Learn about current limitation and benefits of getting real time data in rowing athletes.

Source:

 M. Ebnali *et al.*, "AR-coach: Using augmented reality (AR) for real-time clinical guidance during medical emergencies on Deep Space Exploration Missions," *Healthcare and Medical Devices*, 2022. doi:10.54941/ahfe1002100

Content:

- For boat training, they used the NK SpeedCoach GPS and Empower Oarlock. Data was synced to NK LiNK through Bluetooth, and from there is easy to export to Rowsandall

Kinovea, a tool you can download for free to track movement of body parts and other objects and annotate the video and give feedback

Technique, allows you to shoot a few strokes, annotate the video in a minute and immediately share with the rower

So in conclusion, using an online data platform enables you to

- Communicate the Training Plan and monitor its execution in one central place
- Look at every stroke in every session (even if you're on the other side of the Atlantic)
- Ask for specific video to diagnose technique issues and make recommendations
- Monitor fitness and technique progress (or lack thereof) as the season progresses
- Reduce the amount of time a coach spends fiddling with spreadsheets and enable them to focus on what the data tell him about performance

Most of the real time data is based on getting upper extremity and tracking consistency in the power used to row.

Work Per Stroke Guidance

For steady state, try to work around 420 J on static, slightly lower on slides

SPM	Power (Watt, static)	Pace (/500m, static)	Power (Watt, slides)	Pace (/500m, dynamic
16	112	02:26.2	96	02:33.9
18	126	02:20.6	108	02:28.0
20	140	02:15.7	120	02:22.9
22	154	02:11.5	132	02:18.4
24	168	02:07.7	144	02:14.5
26	182	02:04.4	156	02:10.9

Conclusions/action items: In conclusion, there are a lot of methods on obtaining minute by minute data on other aspects of rowing but lower extremity data is still not well known to this field.

2023/09/21 Load Cell Transducers

SIMERJOT KAUR - Sep 22, 2023, 10:47 AM CDT

Title: Load Cell Transducers

Date: 9/21/2023

Content by: Simmi

Source: "Load Cells & Force Sensors," *https://www.omega.com/en-us/*, 2018. https://www.omega.com/en-us/resources/load-cells

Goals: Learn about load cells and how they can be placed in the design

Content:

- Load cells are transducers that convert mechanical force to a electrical output signal

- strain gauge load cells are the most common load cell

- Pneumatic load cells are sometimes used where intrinsic safety and hygiene are needed, and hydraulic load cells are considered in remote locations (boats?)

- A load cell works by converting mechanical force into digital values that the user can read and record

- Hydraulic load cell sensors are force-balance devices, measuring weight as a change in pressure of the internal filling fluid

- Strain gauge load cells must be connected to an electric circuit that is capable of measuring the minute changes in resistance corresponding to strain

- Piezoresistive force sensors generate a high level output signal, making them ideal for simple weighing systems

-There are also compression and tension load cells

Conclusions/action items: Consider using strain gauge load cells or compression load cells as they seem the most relevant to our application.

2023/09/21 Load Cell to Microcontroller to Make Graph Display

Title: Load Cell to Microcontroller to Make Graph Display

Date: 9/21/2023

Content by: Simmi

Source:

R. Kulkarni, "ARDUINO!!! — — — Load," *Medium*, Aug. 18, 2023. https://medium.com/@iamRadhaKulkarni/arduino-load-9f35dbe4bc1e (accessed Sep. 22, 2023).

Goals: Learn about inner workings of load cells and how microcontrollers can be paired to make a display of force output

Content:

- When force is applied on one end of the load cell, the spring element present inside the load cell gets slightly deformed and changes its shape.
- It results in the alteration of resistance in the strain gauges which can be measured as voltage.
- change in voltage is proportional to the applied force which can be calculated from the load cells output
- HX711 interface module will amplify the low voltage output of the load cell and send it to Arduino to calculate the weight
- The arduino code used in the website creating a table and graph that showed the strain experience in the load cell and the corresponding weight.
- However for our application, we need a force vs time graph so we will need to look into code that can take continuous input from the sensor and create graphs based by the second

Strain gauge load cell diagram:
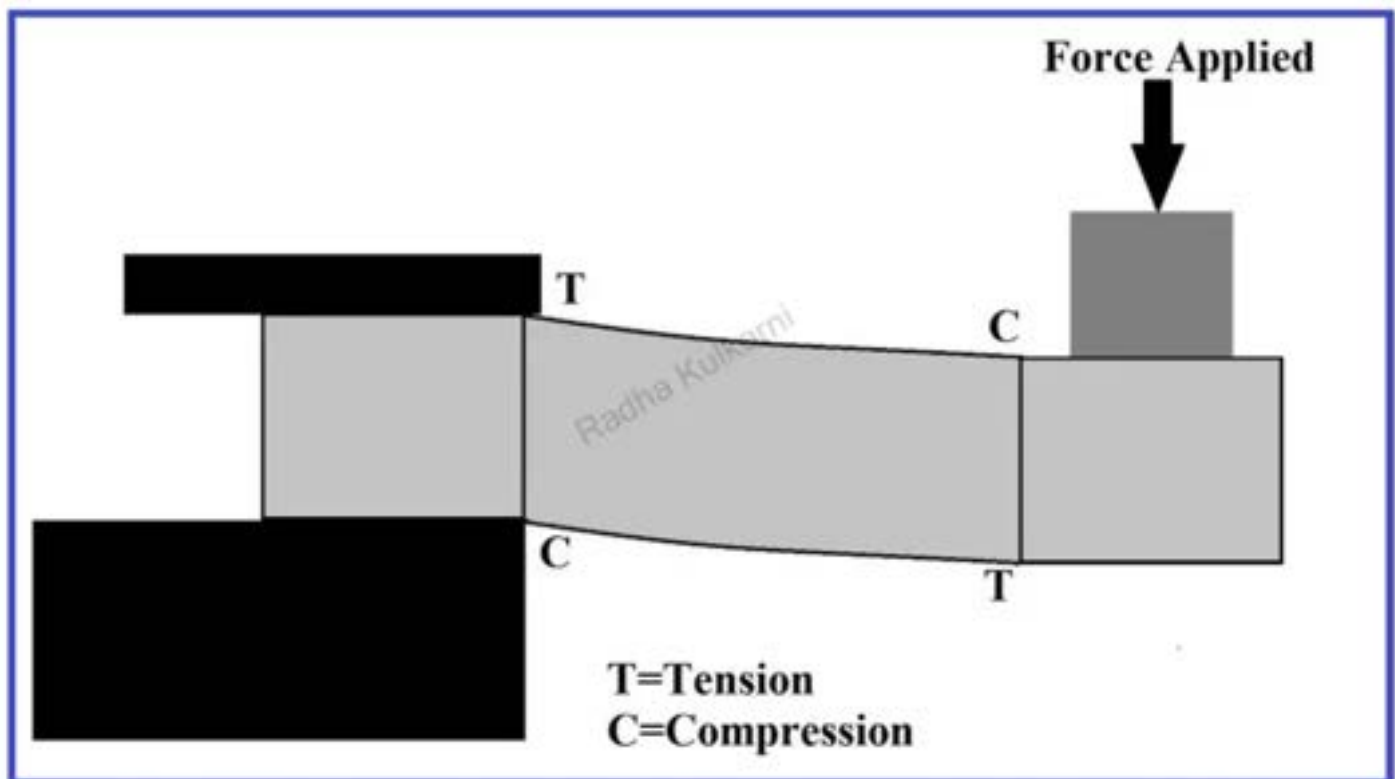
Visual of full system diagram:
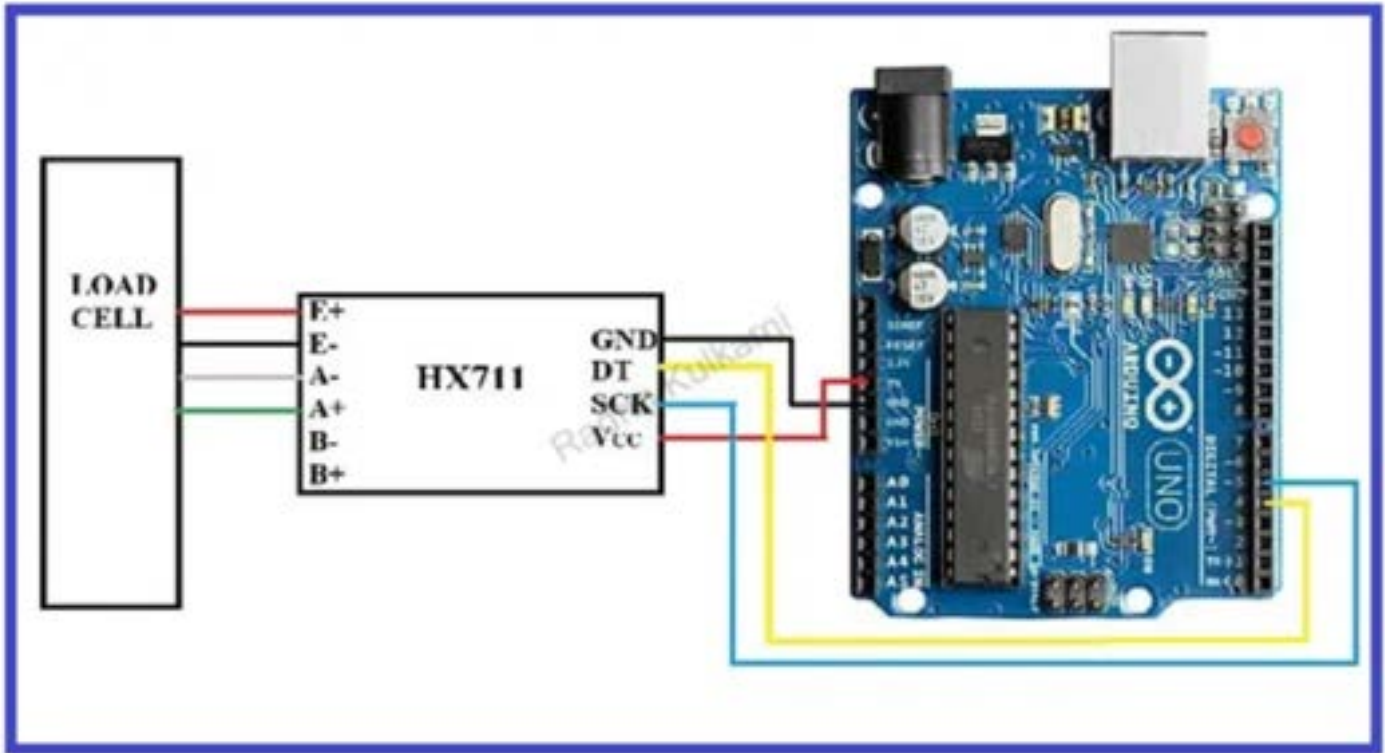
Conclusions/action items: Look into how arduino code can be used for second by second data and different interface instead of HX711.

2023/09/23 Force Resistors

SIMERJOT KAUR - Sep 29, 2023, 8:15 AM CDT

Title: Simmi

Date: 9/29/2023

Goals: Learn about force resistors and how they can be applied to measure force magnitude.

Source:

Ada, Lady. "Force Sensitive Resistor (FSR)." *Adafruit Learning System*, learn.adafruit.com/force-sensitive-resistor-fsr/overview. Accessed 29 Sept. 2023.

Content:

Force resistors are very thin sensors that detect pressure through compression.

The 1/2 inch diameter in the middle of the sensor is the component that is sensitive to pressure

FSRs are a resistor that changes its resistive value (in ohms Ω) depending on how much it is pressed.

Sensors are fairly low cost, and easy to use but they're rarely accurate. They also vary some from sensor to sensor perhaps 10%.

While FSRs can detect weight, they're a bad choice for detecting exactly how many pounds of weight are on them. For accuracy isn't a target for us, we more so want to get precise measurements from each leg that shows if they are similar in the magnitude of force they apply.

They are also water resistant!
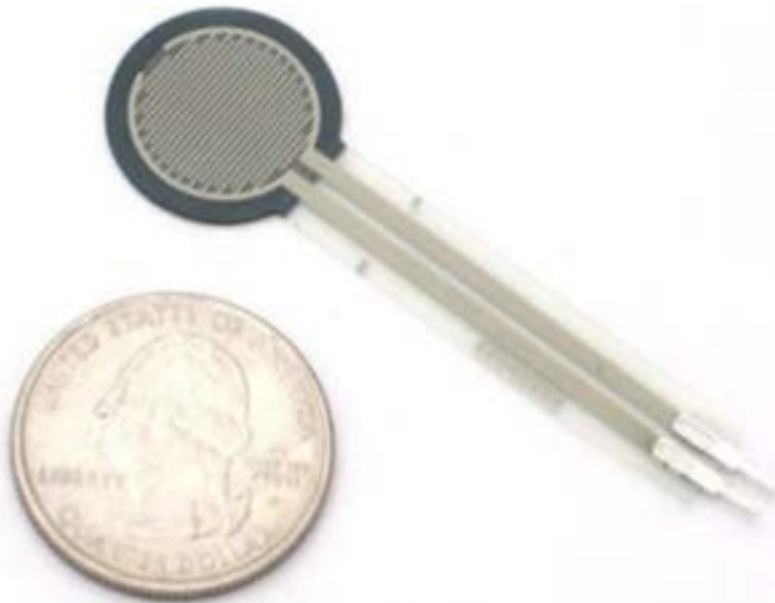
Conclusions/action items: In conclusion, force resistors seems really easy to implement and there is already a lot of circuit diagrams and code to set up the sensor system. However, force resistors aren't accurate but action items are to ensure that they will still have precision.

2023/09/23 Ergometer Accuracy

SIMERJOT KAUR - Sep 29, 2023, 10:54 AM CDT

Title: Ergometer Accuracy

Date: 9/23/2023

Content by: Simmi

Source: G. Treff, L. Mentz, B. Mayer, K. Winkert, T. Engleder, and J. M. Steinacker, "Initial Evaluation of the Concept-2 Rowing Ergometer's Accuracy Using a Motorized Test Rig," *Frontiers in Sports and Active Living*, vol. 3, Jan. 2022, doi: https://doi.org/10.3389/fspor.2021.801617.

Goals: Gather quantitative values for accuracy of ergometers in mimicking real life rowing.

Content:

-The Concept 2 (C2) rowing ergometer is used worldwide for home-based training, official competitions, and performance assessment in sports and science.

-Accuracy was assessed as the difference in mechanical power output between C2 and a reference system during steady

-During steady simulated rowing, differences between C2 and the reference system ranged 2.9–4.3%. Differences were not significantly affected by stroke shapes (P = 0.153), but by stroke rates ranging 22–28 min−1

-It ranges 0.2–1.9%, once the flywheel has been sufficiently accelerated. Inaccuracy increases with uneven rowing, but the stroke shape has a marginal impact.

-The highest degree of inconsistency during all our experiments was observed during the start strokes

-The ergometer shows that are the most inaccuracies when there is inconsistent technique which is heightened during real time rowing

Conclusions/action items:

In conclusion, the ergometer is mainly to point out consistent technique in stroke but when it comes to hip mobility, it is not a reliable to device to train for rowing.

2023/10/11 3D Printing Covers for Circuits

SIMERJOT KAUR - Oct 11, 2023, 10:17 PM CDT

Title: 3D Printing Covers for Circuit

Date: 2023/10/11

Content by: Simmi

Goals: Learn about different kinds of materials that can be used to 3d print covers

Source: P. Ghosal *et al.*, "3D printed materials in water treatment applications," *Advanced Sustainable Systems*, vol. 6, no. 3, 2021. doi:10.1002/adsu.202100282

Content:

PLA (Polylactic Acid): PLA is a commonly used 3D printing material. While it's not waterproof, it can provide some protection against splashes and light moisture. For better waterproofing, you can post-process PLA prints with sealants or coatings.

ABS (Acrylonitrile Butadiene Styrene): ABS is more durable than PLA and has better resistance to moisture. It can be sealed with acetone vapor to make it more water-resistant. PETG (Polyethylene Terephthalate Glycol):

PETG is a popular choice for 3D printing protective covers. It has good water resistance and is more robust than PLA.

Nylon: Nylon is a strong and durable material with decent water resistance. It can be further improved with coatings or sealants.

ASA (Acrylonitrile Styrene Acrylate): ASA is similar to ABS but offers better UV resistance and is more water-resistant. It's a good choice for outdoor applications.

TPE (Thermoplastic Elastomer): TPE is flexible and rubber-like, which can be beneficial if you need a seal or gasket along with the cover for a watertight seal.

TPU (Thermoplastic Polyurethane): TPU is another flexible material that provides good resistance to moisture and impact. It's commonly used for gaskets and seals.

Resin: If you have access to a high-quality SLA or DLP resin printer, you can use resin to create waterproof enclosures. Resins like Epoxy-based resins or castable resins can offer excellent waterproofing properties. Specialized Waterproof Filaments: Some filaments are designed explicitly for waterproofing, such as Taulman T-Glase or Taulman Bridge Nylon, which offer enhanced moisture resistance.

Ensuring a proper fit and seal, and potentially using additional methods like gaskets, O-rings, or sealing compounds, is crucial to achieving a truly waterproof enclosure for electronics. Additionally, if your application requires a high degree of water resistance, you may need to consider IP (Ingress Protection) ratings and professional sealing methods.

Conclusions/action items: From the above information, PETG seems like best option as it is cheapest and most commonly used so it will most likely be available at the Makerspace.

2023/10/11 Ergometer and Watt Bike for Rowing Assessment

SIMERJOT KAUR - Oct 11, 2023, 10:42 PM CDT

Title: Ergometer and Watt Bike for Rowing Assessment

Date: 10/11/2023

Content by: Simmi

Source: J. R. Lindenthaler, A. J. Rice, N. G. Versey, A. J. McKune, and M. Welvaert, "Differences in physiological responses during rowing and cycle ergometry in elite male rowers," *Frontiers in Physiology*, vol. 9, 2018. doi:10.3389/fphys.2018.01010

Goals: Learn about how ergometer and watt bike can be used to asses rowing technique and improve form.

Content:

Ergometers, commonly known as "ergs," are stationary rowing machines used for indoor rowing training and fitness testing. They are commonly employed for improving rowing technique, measuring performance, and providing structured training for rowers.

One specific type of ergometer designed for rowing is the "Wattbike," a stationary bike specifically adapted for rowing training and assessment.

Ergometers for Rowing Technique: Ergometers, especially those designed for rowing, like the Concept2 rowing machine or similar models, are valuable tools for detecting and improving rowing technique in several ways.

Performance Metrics: Ergometers provide real-time data on various performance metrics such as stroke rate, split time (time to complete 500 meters), power output (in watts), and heart rate (if a heart rate monitor is used). Athletes can use this data to assess and adjust their technique. Video Analysis: Many rowing facilities and athletes combine ergometer training with video analysis. This allows athletes and coaches to examine their rowing technique in detail, identifying areas that need improvement.

Force Curve Analysis: Some ergometers provide force curve data, which represents how the force is applied during each stroke. Analyzing the force curve can reveal imbalances and inefficiencies in technique. Power Curve: The power output data can be used to assess the power applied throughout the stroke. A consistent and efficient power curve is indicative of good technique.

Training Programs: Ergometers often offer various training programs and interval workouts that help athletes work on specific aspects of their rowing technique and fitness.

Frequency of Use: The frequency of ergometer usage varies among athletes and depends on their goals and the competitive season. However, many rowers, especially those in training or preparing for regattas, use ergometers regularly.

The frequency of use:

Off-Season Training: Athletes may use ergometers intensively during the off-season to build and maintain their fitness and work on technical aspects.

In-Season Maintenance: During the competitive season, rowers might continue to use ergometers for maintenance workouts to complement on-water training. Assessment: Athletes often use ergometers for periodic fitness assessments, which can help track progress and set training goals.

Recovery and Warm-Up: Ergometers can be used for low-intensity warm-up and cool-down sessions. The frequency and intensity of ergometer use are tailored to individual training plans and goals.

Conclusions/action items: Both ergometer and watt bike have been used mainly for off season training but aren't used to frequently during the in season. The rowing tank is great practice for off and on season due to its resemblance in rowing so our design will be used frequently.

2023/10/31 Patent on Load Cell Circuit

Title: Patent on Load Cell Circuit

Date: 10/31/2023

Content by: Simmi

Goals: Learn about existing load cell circuit and how they designed the circuit for their purpose

Content:

Their load cell circuit was used for weight detection.

-A weight detection circuit for a load cell scale which connects an operational amplifier directly to an-output of a bridge circuit of a load cell which simplifies a conventional differential amplifier, thereby enabling simplification of the overall weight detection circuit to result in a low manufacturing cost.

-A bias resistance is connected directly to the bridge circuit for the load cell to simplify the bias circuit which leads to lower manufacturing cost

FIG.2
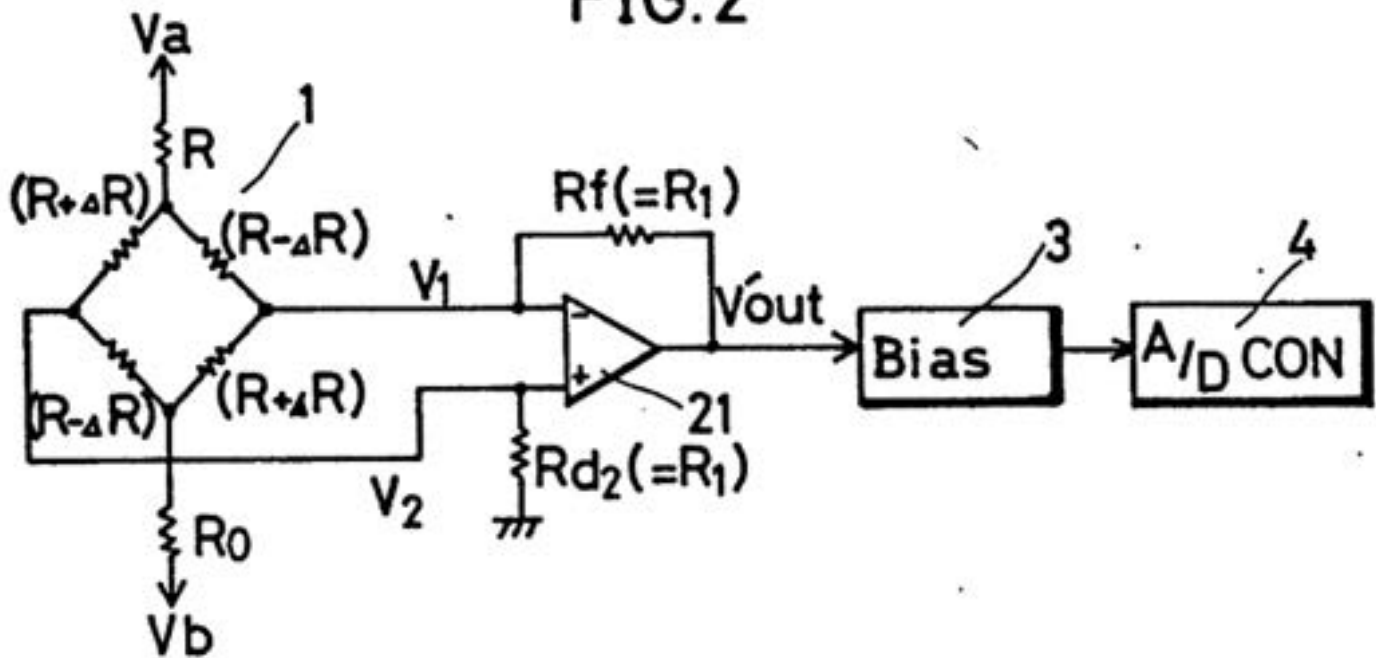
Conclusions/action items:

2023/09/23 Load Cell Design

SIMERJOT KAUR - Sep 29, 2023, 11:05 AM CDT

Title: Load Cell Design

Date: 9/23/2023

Content by: Simmi

Goals: Create a design that effectively mounts load cells to the row tank footplates.

Content:
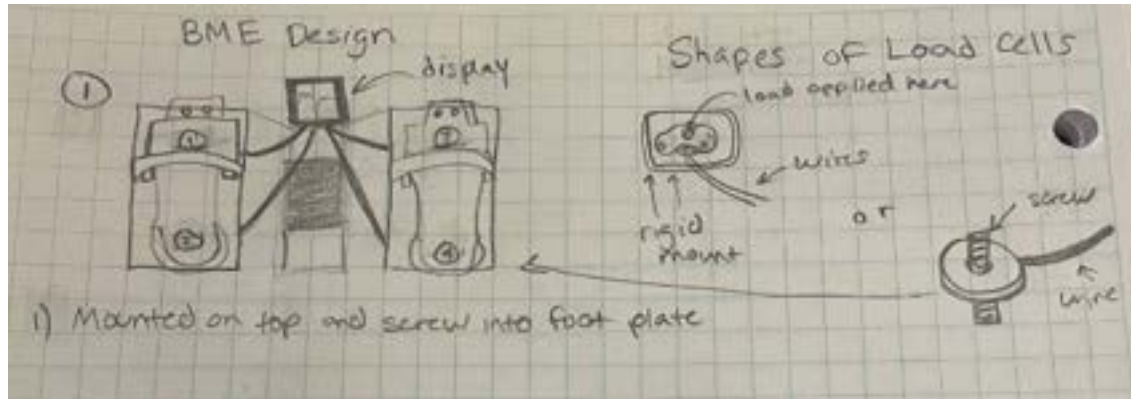
From my research into load cell vendors, I have noticed there are various types of load cell configurations. The ones I thought were the most functional with the footplates were the square shaped load cells that could mount on through some metal glue or screw in. The other type of load cell design I found was a thread in load cell that could easily be embedded onto the footplate. My design idea is to place two load cells into each foot, one at the toe region and the other at the heel. The load cells in each foot plate will connected to one processor and microcontroller which ultimately will be connected to a display that will be perched in the ledge between the two foot plates. The main problem with this design is we will have to modify the foot plates by drilling holes in the them. However the design will be comfortable for the rowers to place their feet onto and it won't impede on their rowing technique.

Conclusions/action items: Present to team and get feedback on how to improve the design.

2023/10/11 EEPROM Code

SIMERJOT KAUR - Oct 11, 2023, 10:06 PM CDT

Title: EEPROM Code

Date: 10/11/2023

Content by: Simmi

Goals: Find a good template to start the EEPROM code for the force resistor

Source:

> [1] codebender_cc and Instructables, "How to use a force sensitive resistor - arduino tutorial," Instructables, https://www.instructables.com/How-to-use-a-Force-Sensitive-Resistor-Arduino-Tuto/ (accessed Oct. 11, 2023).

Content:

- Read analog value from flex sensor :: value=analogRead(sensorPin)
- Map analog values 0-1023 to PWM values 0-255 :: value = map(value, 0, 1023, 0, 255)
- Send pwm value to led :: analogWrite(ledPin, value)
- FSR - Force Sensitive Resistor with Arduino to fade an LED. At a certain pressure applied, the led will light up

```
const int ledPin = 3;     //pin 3 has PWM funtion
const int sensorPin = A0; //pin A0 to read analog input

//Variables:
int value; //save analog value


void setup(){

  pinMode(ledPin, OUTPUT);  //Set pin 3 as 'output'
  Serial.begin(9600);       //Begin serial communication

}

void loop(){

  value = analogRead(sensorPin);      //Read and save analog value from potentiometer
  Serial.println(value);            //Print value
  value = map(value, 0, 1023, 0, 255); //Map value 0-1023 to 0-255 (PWM)
  analogWrite(ledPin, value);         //Send PWM value to led
  delay(100);                         //Small delay
```

Conclusions/action items: This code gives a good idea of using LED lights to alert athletes if they are asymmetrical and is a good starting point for force sensitive resistor data.

2023/10/22 Load Cell Circuit Design

Title: Load Cell Circuit Design

Date: 10/27/2023

Content by: Simmi

Source:

info@shopea. cz SHOPEA.cz, "Load cell electrical circuit.," Utilcell, https://www.utilcell.com/en/load-cell-electrical-circuit-/#:~:text=A%20load%20cell%20is%20based%20on%20an%20electrical%20circuit%20called%20Wheatstone%20bridge.&text=(mV%3Dmilivolts).&text=strain%20gauges%20placed%20in%20the,%2C%20R2%2C%20R3%20and%20R4.&text=obtains%20an%20output%20signal%20proportional%20to%20the%2 (accessed Oct. 27, 2023).

Goals: Find an effective load cell circuit design

Content:

-Basic circuit for a load cell involves a wheatstone bridge and strain gauges.

-Strain gauges are deformation sensors that are glued to the elastic body of the load cells. Applied force deforms the gauge will produce a change resistance values. This small resistance cha is magnified by the resistive imbalance produced in the Wheatstone bridge and thus obtains an output signal proportional to the applied force.

-Being Vin the power supply of the bridge or input excitation (V=Volts) and Vout the output signal (mV=milivolts)

-it is necessary to add additional circuitry to the strain gauges, dedicated to the fine adjustment of the output signal at different loads

-When the load cell has no load, the four gauges are at rest and have the same ohmic value, the nominal value of the strain gauge Rg: R1=R2=R3=R4=Rg

-When loading the load cell, the strain gauges changes its resistance value in a very small ratio ΔR: R1=Rg-ΔR ; R2=Rg+ΔR ; R3=Rg-ΔR ; R4=Rg+ΔR
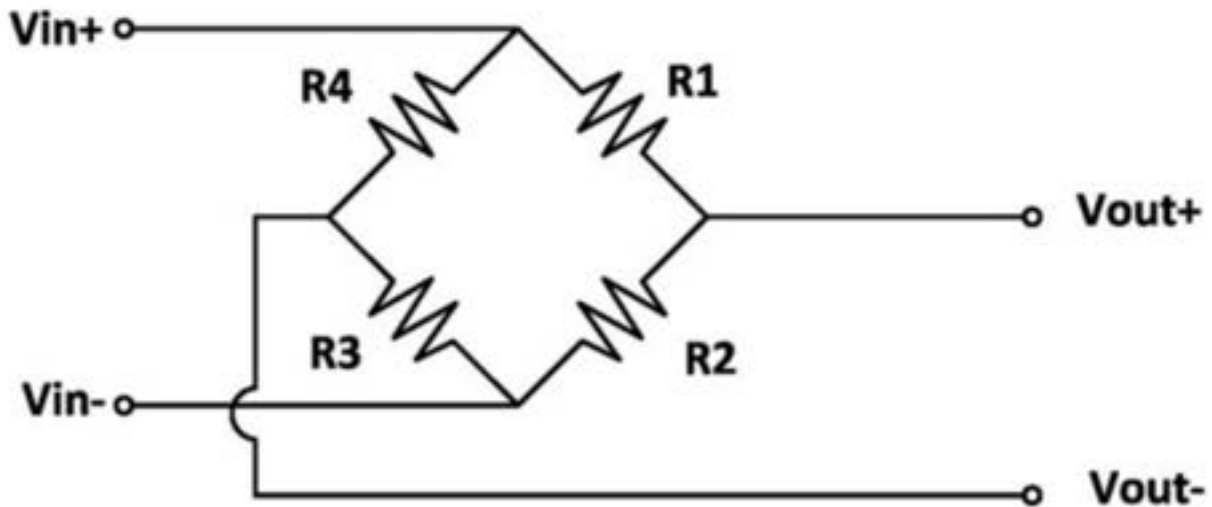
Conclusions/action items:

Action times are to look at tutorials on to create a wheatstone bridge for the load cells as it has proven to be the most effective method.

2023/10/23 FSR Circuit Design

Title: FSR Circuit Design

Date: 10/23/2023

Content by: Simmi

Goals: Find an effective force resistor sensor design

Source:

How to build a simple force sensing resistor (FSR) circuit, https://www.learningaboutelectronics.com/Articles/Force-sensing-resistor-FSR-circuit.php (accessed Oct. 27, 2023).

Content:
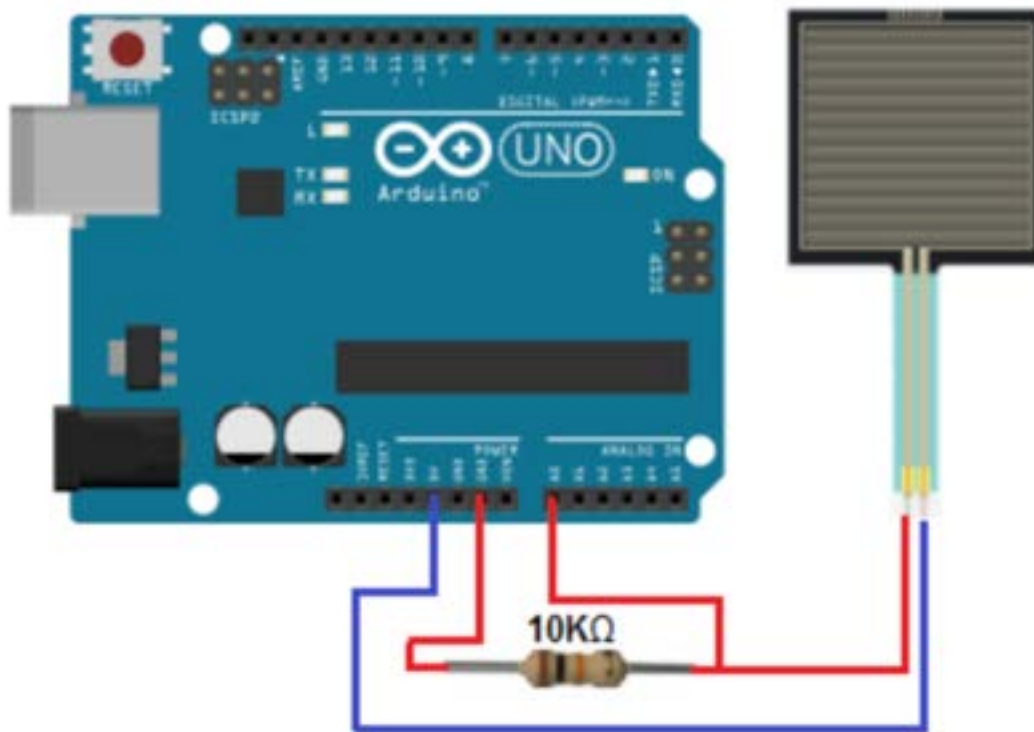
For our preliminary design, this is a useful design because it requires a minimal amount of materials and can be used to mainly test the accuracy of a force resistor and can be compared to our load cell circuit design.

We will wire an FSR to an arduino board. We wire a 10KΩ resistor in series with the force sensing resistor in order to create a voltage divider. One terminal of the FSR will connect to the 5-volt voltage supply of the arduino board and the other terminal will connect to ground. The 5 volts of voltage will be divided based on the resistance of the fixed resistor and the FSR. The fixed resistor will always stay 10KΩ. However, the FSR serves as the variable resistor. It will change resistance based on the pressure applied to its surface. When there is no pressure applied, its resistance is very high, so most of the voltage falls across it rather than the 10KΩ resistor. When it is pressed against with maximum pressure, its resistance falls to near 200Ω, so most of the voltage falls across the 10KΩ resistor and not the FSR.

Conclusions/action items: Action items are to create a voltage divider circuit and look up resistors that would pair well with our FSR.

2023/11/07 Load Cell Summing

SIMERJOT KAUR - Nov 20, 2023, 8:02 PM CST

Title: Load Cell Summing

Date: 11/07/2023

Content by: Simmi

Goals: Establish methods to combine multiple load cells into one arduino and amplifier.

Source:

"Load cell summing: Junction boxes, signal trim, and excitation trim," Tacuna Systems, https://tacunasystems.com/knowledge-base/load-sell-summing-junction-boxes-signal-trim-and-excitation-trim/#:~:text=In%20multi%2Dcell%20applications%2C%20load,generate%20quality%20data%20for%20operators. (accessed Nov. 20, 2023).

Content:

-In multi-cell applications, load cells or sensors are physically wired to the junction box in parallel, which instantaneously sums the data.

-Large-scale and complex weighing systems require the use of multiple load cell devices to produce accurate measurements. Load cell summing and junction boxes properly combine their multiple signals into a useful digital output to display, store, or control complex systems.

-If there is an even number of load cells, they can be trimmed in pairs. The process is similar to that of trimming individual load cells described above. To trim your system this way, follow the procedure below, referring to the figure.

-To ensure the quality of load cell measurement data delivered to operators, the individual load cells must be properly trimmed.

-The trimming process equalizes the output from multiple individual load cells into a single, accurate, output. Load cell trimming guarantees the correct measurements, regardless of where the weight is on the scale.

Conclusions/action items:

Action items are to find models that match the weight capacity of our application (able to withstand rowing force). In addition, find a amplifier that matches the load cell.

2023/11/08 4-Wire Load Cell Design

SIMERJOT KAUR - Nov 20, 2023, 7:45 PM CST

Title: 4 Wire Load Cell Design

Date: 11/08/2023

Content by: Simmi

Goals: Learn how to put a 4 wire load cells into one circuit and interface

Source:

 "Load cell summing: Junction boxes, signal trim, and excitation trim," Tacuna Systems, https://tacunasystems.com/knowledge-base/load-sell-summing-junction-boxes-signal-trim-and-excitation-trim/#:~:text=In%20multi%2Dcell%20applications%2C%20load,generate%20quality%20data%20for%20operators. (accessed Nov. 20, 2023).

Content:

-Each wire connects to a corner of the Wheatstone bridge that is embedded into the load cell.

-The first thing you need to do is to identify the opposing corners of the Wheatstone bridge. You can do that with a multimeter by measuring the resistance between the wires. In my case, the opposing wires are red-black pair and green-white pair. The resistance between both of those pairs is about 1k ohm.
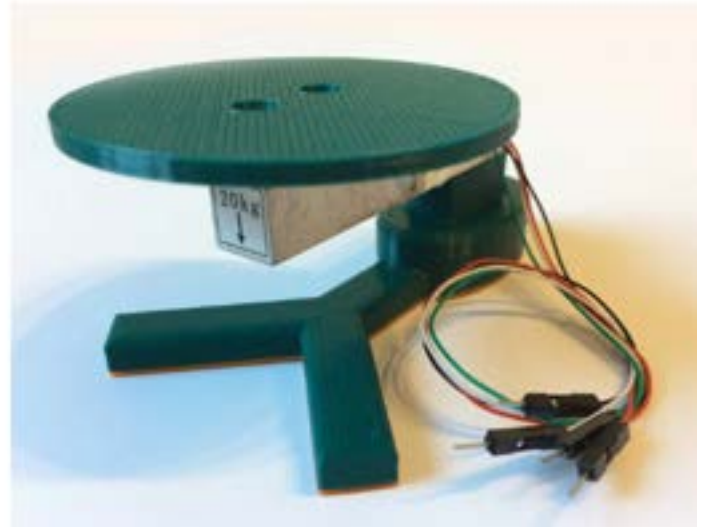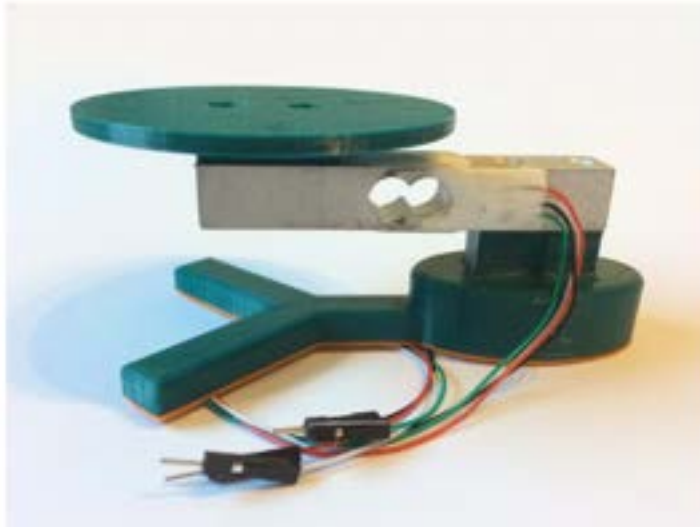
Can create a base plate like this to measure compression accurately

To calibrate, can use a filled water glass. The person in the article used a kitchen scale to compare results

1. Download the "HX711_ADC" library: https://github.com/olkal/HX711_ADC

2. Open up the calibration from the example

3. Load example code into Arduino

4. Open Arduino Serial Monitor

Conclusions/action items:

In conclusion, the load cell directions are very similar to the sparkfun kit. Action items are to look into creating a load cell base on SolidWorks and figure out code for 4 load cells.

9/14/2023 - Force Plate Pictures

Title: Force Plate Images

Date: 9/14/2023

Content by: Emily

Present: N/A

Goals: Have a picture of plates to show teammates

Content:

Took a picture of the force plates I use at pt to for jump tests. Made the observation that they are wired to the computer. Am unsure if all force plates need to be hooked up to relay information. Pt person told us to look into Bertec because it's a good brand.
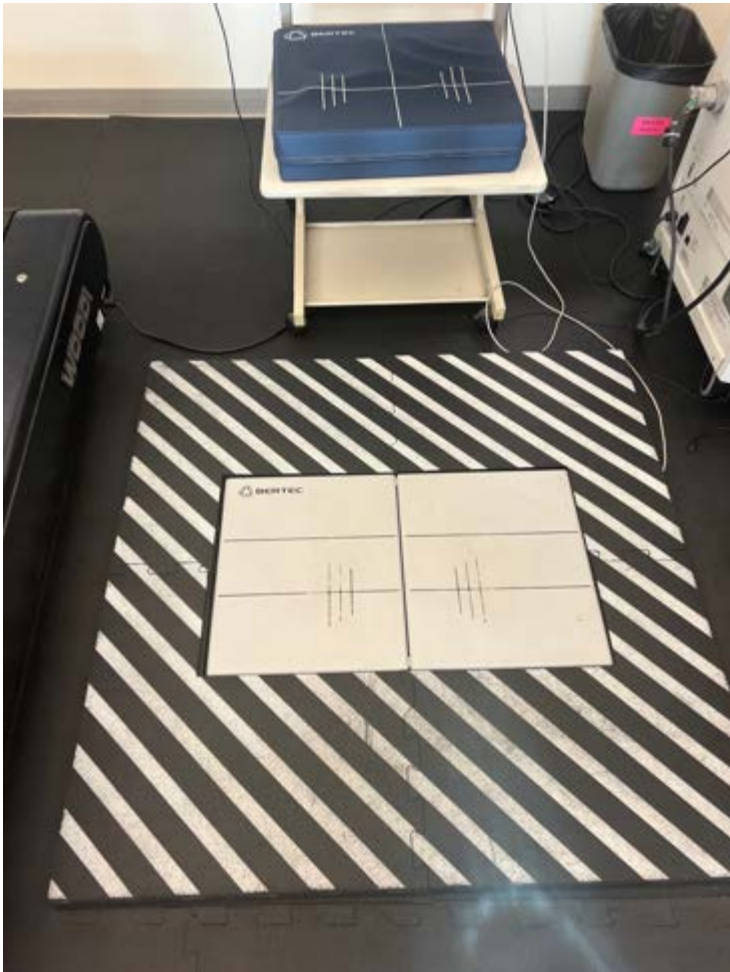
Conclusions/action items:

Show them to teammates, talk about how they are used.

9/14/2023 - Back Pain in Rowers

EMILY WADZINSKI - Sep 17, 2023, 8:18 PM CDT

Title: Reasons for Lower Back Pain

Date: 9/14/2023

Content by: Emily

Present: N/A

Goals: Learn more about where the pain stems from when rowing

Link: https://www.performancehealth.com/articles/lower-back-pain-relief-for-rowers

Content

- often cause by muscle strain

- 30-50% of rowers experience some lower back pain based on research

- proper rowing form and specific core exercises can alleviate soreness

Main causes:

1. rowing posture - rowers are mostly in flexed position, which puts strain on the back
2. repetition - the body can gain hypermobility and cause damage to the vertebrae or tissue
3. genetic predisposition, too long of ergometer trainings, and more

How to alleviate:

- pre season screenings: helps to find issues that may cause problems further down the line

- practice/coaching

- medication/gel/ice

- proper rowing form: athletes should be moving from hips, not back. Spine should be a smooth arch. Need high range of hip motion

- core strengthening exercises

Conclusion:

Since incorrect technique is the main cause of lower back pain in rowers, the force plates would be most beneficial in helping to correct form then other options like medication

9/14/2023 - Rehab with Force Plates

Title: How force plates are implemented in rehab for lower extremity injuries

Date: 9/14/2023

Content by: Emily

Present: N/A

Goals: Better understand the use of force plates

Link: https://www.technogym.com/us/newsroom/force-plate-benefits-sport-rehabilitation/

Content:

- Force plates detect the force exerted on the ground on the x, y, and z axes through several sensors.

- used to analyze athletes' thrusts

- can measure direction, acceleration, reaction time, power, and loading in each limb
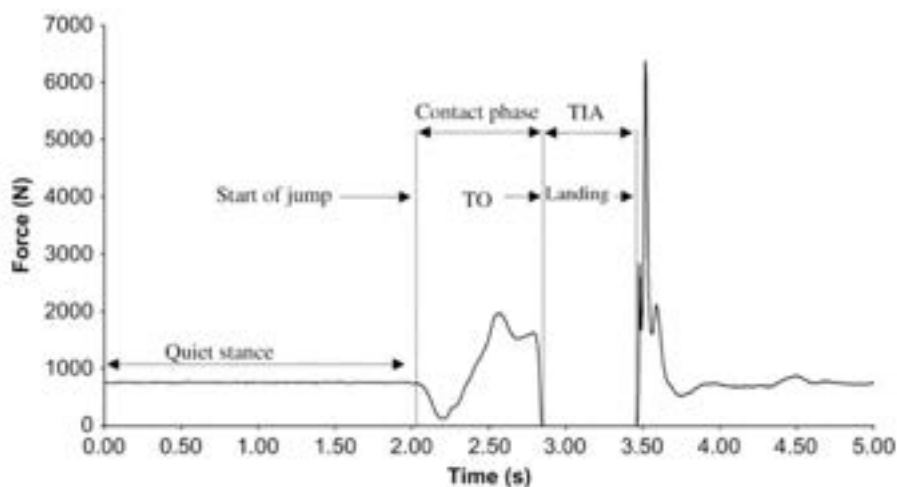
Graph of force plate data for one leg

- uses of platform: injury prevention and athletic performance

- jumping tests on the plates are a primary use of them, as they are repeatable and easy

- the tests involve jumping a couple times on both legs and each leg individually, then the graphs are compared

- can't cheat a force plate (it catches everything)

- useful for sports to observe "stresses related to posture, jumping, and levers."

- applied in gait analysis: if plates make up a path, they can calculate the pressure of each foot, the gait, and direction of step (helps determine load distribution and symmetry)

- also expensive and limited to certain sport/medical facilities

Conclusion:

Force plates are a good way to measure our clients' data goals

9/19/2023 - UW Porter Boathouse

EMILY WADZINSKI - Sep 27, 2023, 10:25 PM CDT

Title: Porter Boathouse Facility

Date: 9/19/2023

Content by: Emily

Goals: Research what the Boathouse all has quantity-wise for PDS section

Link: https://uwbadgers.com/sports/2015/8/21/GEN_2014010131.aspx

Content:

Looking at the website, they have:

- Storage space for more than 100 boats in five boat bays and a boat repair bay.
- Moving water rowing tank for 24

The client hoped that eventually each rower could have sensor for their 8 person boats, but if we go with the indoor tank, that's up to 24 sensors that we could make. Additionally, if they want to expand our project with additional funds/resources, they could one in each spot of each boat (which is a lot).

Conclusion:

Note that there's 24 (not 16) spots for the tank in the PDS

9/21/2023 - Rowing Terms

Title: Crew Terminology

Date: 9/21/2023

Content by: Emily

Goals: Learn more about rowing terms and the correct uses of them

Link: https://www.dallasunitedcrew.org/rowingglossary#:~:text=Octuple%20(8x)%3A%20A%20shell,rowers%20with%20two%20oars%20each.

Content:

sweep - each rower has one oar

Sculling - Rowing with two oars, one in each hand (an oar rigged on each side of the boat).

shell - crew boat

crew - competitive rowing

erging - using the Ergometer (rowing machine)

sweep - each rower has one oar

shell - boat

scull oar - oar for one hand

Collar - A ring around the oar sleeve, designed to position the oar and prevent slippage.

Gate - A bar across the oarlock that keeps the oar in place.

Lightweight - class weight limits = 150 pounds for boys and 130 pounds for girls

#numbers in boats: 8, 4, or 2 at UW

Eight: A shell with 8 rowers. "Along with the single scull, it is traditionally considered to be the blue ribbon event." Has a coxswain

Four: A shell with 4 rowers. "Coxless fours (4-) are often referred to as straight fours, and are commonly used by lightweight and elite crews and are raced at the Olympics. In club and school rowing, one more frequently sees a coxed four (4+) which is easier to row, and has a coxswain to steer."

Conclusion:

Use terminology for greater professionalism moving forward

9/25/2023 - Load Cell Circuit

Title: Load Cell Circuit

Date: 9/25/2023

Content by: Emily

Goals: Gain understanding on load cell circuits and amplifiers for designing

Link: https://www.futek.com/load-cell-circuit

Content:

load cell = force transducer

- converts an input mech force like load, weight, tension, compression, or pressure into another variable
- ex) can be changed into an electrical output signal (resistance) that can be measured, converted and standardized. (what we will probably do)
- "As the force applied to the force sensor increases, the electrical signal changes proportionally."

How does a Load Cell Circuit work?

Firstly, we need to understand the underlying physics and material science behind the strain gauge load cell working principle, which is the strain gauge (sometimes referred to as Strain gage). Metal foil strain gage is a sensor whose electrical resistance varies with applied force. In other words, it converts (or transduces) force, pressure (i.e. pressure sensor), tension, compression, torque, weight, etc... into a change in electrical resistance, which can then be measured.

Strain gauges are electrical conductors tightly attached to a film in a zigzag shape. When this film is pulled, it – and the conductors – stretches and elongates. When it is pushed, it is contracted and gets shorter. This change in shape causes the resistance in the electrical conductors to also change. The strain applied in the load cell can be determined based on this principle, as strain gauge resistance increases with applied strain and diminishes with contraction. This same concept is also utilized in weight sensors.

These strain gauges are arranged in what is called a Load Cell Signal Conditioner Circuit (aka Load Cell Amplifier). This means that four strain gages are interconnected as a loop circuit and the measuring grid of the force being measured is aligned accordingly.

The **strain gauge bridge amplifiers** (or strain gauge amplifiers) provide **regulated excitation voltage** to the load cell amplifier circuit and convert the mv/V output signal into another form of signal that is more useful to the user, for example a 4-20ma load cell analog output or a digital USB load cell output. The signal generated by the strain gage bridge is low strength signal and may not work with other components of the system, such as PLC, data acquisition modules (DAQ), computers, or microprocessors. For some applications, it may be needed a local signal readout, also known as a load cell indicator. Thus, force sensor signal conditioner functions **include excitation voltage, noise filtering or attenuation, signal amplification, and output signal conversion.**

Furthermore, the change in the amplifier voltage output is calibrated to be linearly proportional to the Newtonian force applied to the flexure, which can be calculated via the **load cell circuit voltage equation.**
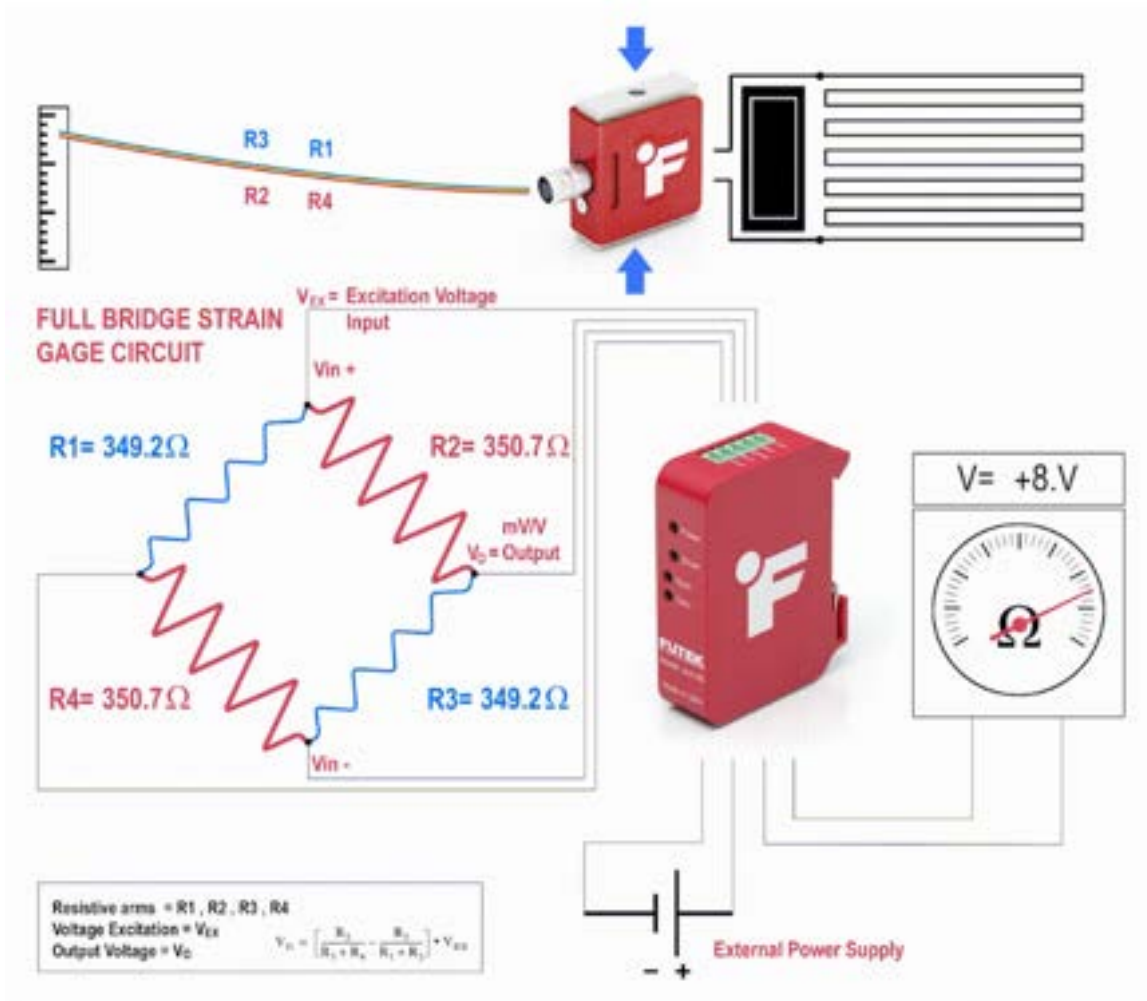
Conclusion:

Add amplifier to design, discuss with team members for design matrix

10/3/2023 - Boat Geometry and Rowing Phases

Title: Eight (8+)

Date: 10/3/2023

Content by: Emily

Goals: Understand a shell layout

Source: Provided by Client (Printed)

Content:

- collegiate crew teams typically race in an eight person shell by sweep rowing. There are different positions and force exertions throughout the rowing phases.

- this document provided by Jill does a great way of showing the layout of the boat that our design should ultimately end up in and the boats we saw during the morning practice we attending.

THE OAR

THE BOAT

STERN

STARBOARD

PORT

COXSWAIN

STROKE (8)

7 SEAT

6 SEAT

RIGGER

5 SEAT

4 SEAT

BACK STAY

3 SEAT

2 SEAT

BOW SEAT (1)

BOAT DIRECTION

bow ball

-BLADE

GATE

PIN

OAR LOCK

RIGGER

-SHAFT

SLEEVE

-BUTTON/COLLAR

-HANDLE

DRIVE

ARMS ONLY   ARMS+BODY   ½ SLIDE   THE CATCH

LINNEA ANDERSON
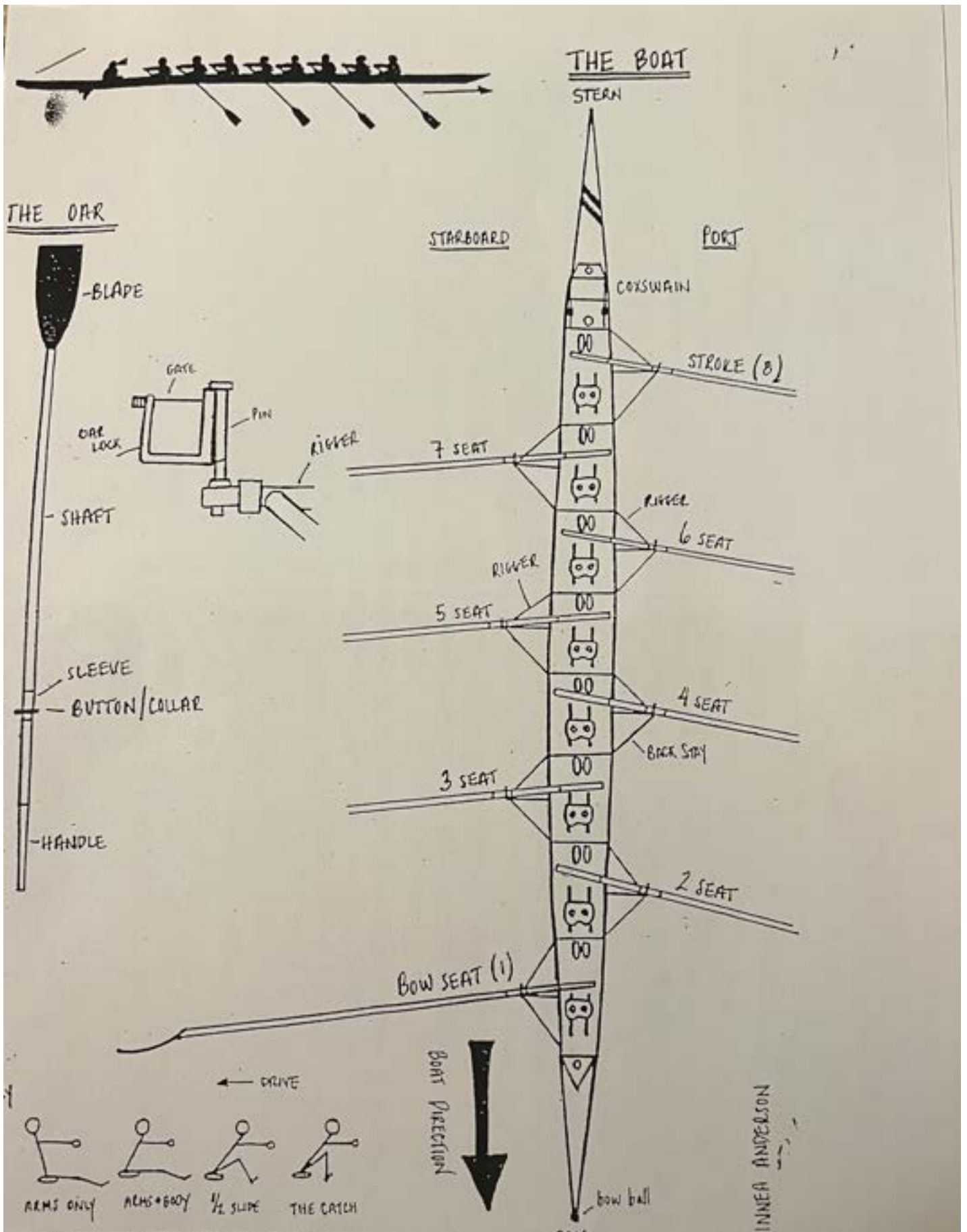
Conclusion:

Find a similar image to put on the preliminary presentation slide that I will present, as well as a section to define sweep/scull.

10/9/2023 - Force Sensitive Resistor

Title: FSR

Date: 10/9/2023

Content by: Emily

Goals: Learn more about our chosen design

Link: https://learn.adafruit.com/force-sensitive-resistor-fsr/overview

Content:

- FSRs are sensors that detect physical pressure or weight

- FSRs have two layers with a space in between

- As the pressure increases, the resistance decreases

- The sensors have ranges of responses, so they are less accurate. However, accurate measurements are not a high priority from our client

- The force range of the resistors in the article can take 0-20lbs, so the one used in our design would have to have a higher capacity

- We can use any power supply for it

- The data makes a slight curve in a graph as resistance is not exactly linear

As we've said, the FSR's resistance changes as more pressure is applied. When there is no pressure, the sensor looks like an infinite resistor (open circuit), as the pressure increases, the resistance goes down. This graph indicates approximately the resistance of the sensor at different force measurements. (Note that force is not measured in grams and what they really mean is Newtons * 100!)
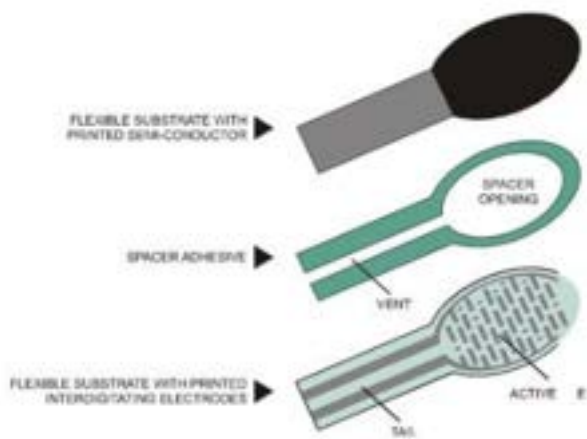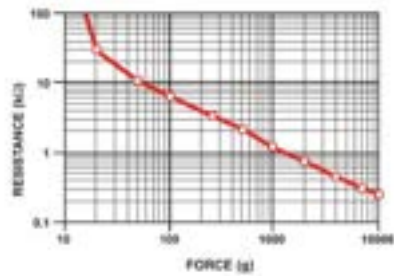
Conclusion:

Research more about circuits to discuss with Dr. N

11/15/2023 - Concept 2 Ergometer Schematics

Title: Footplate Schematic

Date: 11/15/2023

Content by: Emily

Goals: Try to find CAD files of footplate dimensions to solidworks the load cell plate

Link: https://shop.concept2.com/parts/87-flexfoot-gray.html

Content:

To begin modeling a heel and toe part to embed the load cells, I tried to see if there were CAD files posted online of the concept 2 footplates. They sell all the parts individually, however, I was unsuccessful in locating specific dimension files. Schematics of each ergometer model is available to see what parts are needed in case of replacement. Visuals of the footplate are helpful in case we need to reassemble when embedding our design. Some general weights and lengths were found of the entire machine.

concept 2
MODEL C SCHEMATIC
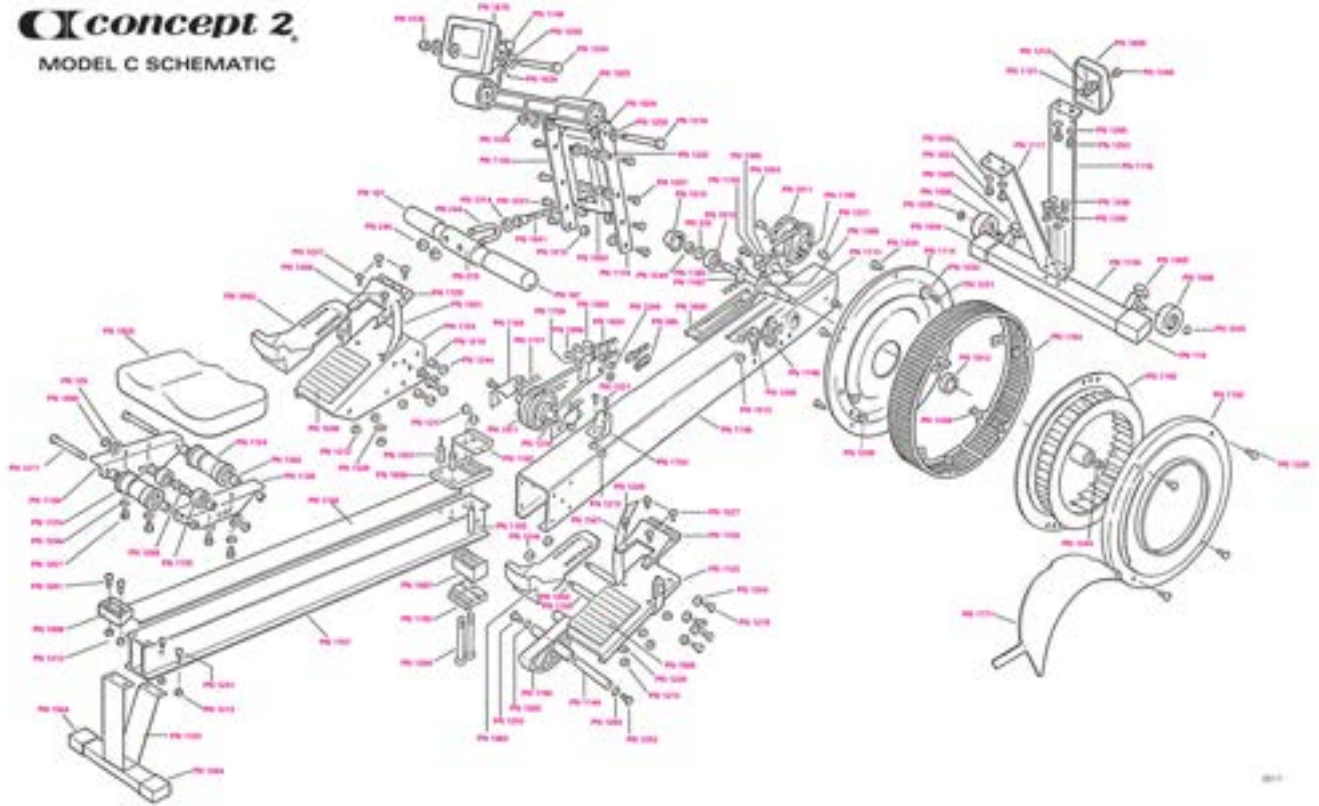
Footplate/Flex Foot Assembly

For all Model E Indoor Rowers and Model D
Indoor Rowers purchased after July 31, 2006

Cover Foot Stretcher - Left
PN 1055 - 6 hole
PN 2016 - 7 hole

Footstrap w/Buckle PN 1517 (1 per side)

Cover Foot stretcher - Right
PN 1054 - 6 hole
PN 2015 - 7 hole

Flex Foot PN 1063

Belly Right Foot Stretcher
PN 1056 - 6 hole
PN 2017 - 7 hole

PN 1241
(6 per side)

Belly Left Foot Stretcher
PN 1057 - 6 hole
PN 2018 - 7 hole

PN 1243 (2 per side)

PN 1242 (2)

Compression Member PN 1037 (1)

Reinforcing Bracket PN 1139 (2 per side)

RowERG

With Standard Legs

The RowErg with the standard legs (giving a 14" seat height) is our best-selling machine. This is our most affordable option and provides everything you need for a great workout.

PMS Performance Monitor

Integrated device holder fits a wide range of mobile devices.

Adjustable monitor arm

Low-maintenance, nickel-plated chain

Ergonomic handle allows for natural arm and hand positions.

Aluminum rail capped with a stainless-steel track allows the seat to move smoothly and facilitates full leg involvement in the rowing stroke.

Frame lock enables easy separation for transport and storage

14 inch (36 cm) seat height

Spiral damper controls airflow to the flywheel, allowing users to choose the feel of the stroke

Flexfoot™ footrests adjust for quick and easy sizing

Caster wheels make it mobile

Separates easily into two parts for storage

Length	Width	Seat Height	Weight	Space Recommended For Use	Stored Dimensions	Weight Capacity
96 in	24 in	14 in	57 lb	9 ft x 4 ft	25 in x 33 in x 54 in H	500 lb
244 cm	61 cm	36 cm	26 kg	274 cm x 122 cm	63.5 cm x 83.8 cm x 137.2 cm H	227 kg

Conclusion:

Remeasure the footplate myself before final plate is designed

9/14/2023 - Force Plate Sizes

Title: Sizes of Plates

Date: 9/14/2023

Content by: Emily

Present: N/A

Goals: Look up the smallest sizes on the market

Link: https://www.bertec.com/products/force-plates

Content:

model	width mm (in)	length mm (in)	height mm (in)	weight kg (lb)	load capacity 1000 lb (5000 N)	load capacity 2000 lb (10000 N)	load capacity 4000 lb (20000 N)	spec sheet
				Portable (USB or standard output directly from force plate)				
4060-05	400 (15.75)	600 (23.62)	50 (1.97)	8 (18)	✓	✓		download
5060-06	500 (19.68)	600 (23.62)	60 (2.36)	13 (28)		✓		download
6090-06	600 (23.62)	900 (35.42)	60 (2.36)	23 (50)		✓		download
				Fixed				
4060-07	400 (15.75)	600 (23.62)	75 (2.95)	38 (84)	✓	✓	✓	download
4060-08	400 (15.75)	600 (23.62)	83 (3.25)	38 (84)	✓	✓	✓	download
4060-10	400 (15.75)	600 (23.62)	100 (3.94)	30 (66)	✓	✓	✓	download
4060-15	400 (15.75)	600 (23.62)	150 (5.91)	21 (46)	✓	✓	✓	download
4550-08	**464 (18.25)**	**508 (20)**	**83 (3.25)**	**38 (84)**	✓	✓	✓	download
6012-15	600 (23.62)	1200 (47.24)	150 (5.91)	62 (137)	✓	✓	✓	download
6090-15	600 (23.62)	900 (35.43)	150 (5.91)	45 (99)	✓	✓	✓	download
9090-15	900 (35.43)	900 (35.43)	150 (5.91)	65 (143)	✓	✓	✓	download

One of the leading force plate brands is Bertec, often used clinically. On Bertec's website, the have a variety of plates. It looks like the smallest we could get to go under the foot is a 16in by 23in or a 18in by 20in, which would extend out quite more than someone's foot. In order to fit it in the boat, it looks like we might have to find another brand that has smaller ones, or make due with Bertec's.

These are some of Bertec's specifications listed on their website that would be beneficial for our project:

- Utilize with any motion capture system including camera-based systems using passive or active markers

- Simultaneously measures three force components and three moment components about the x, y, and z axes for a total of six outputs which are used to compute the Center of Pressure (CoP)

- Force plate signal is fed into your choice of amplifier - digital, analog or dual digital/analog output

- Digital signal output from the portable force plate can be directly plugged into a standard USB port

- Digital acquisition software enables the user to collect data quickly

- Mounted and portable force plates available

- Portable force plates allow data collection in more natural environments

Conclusions/action items:

Discuss chart with team members.

9/20/2023 - Competing Force Plate Designs

EMILY WADZINSKI - Sep 27, 2023, 10:45 PM CDT

Title: Competing Force Plate Designs and Costs

Date: 9/20/2023

Content by: Emily

Goals: Compare costs and qualities between plates

Link: https://www.comparesportstech.com/compare-force-plates

Content:

While the plates seem similar in size and usage, the name brands can cost up to $40,000! Most of the plates were similar to this picture below. The cheapest this website gave was $4,050 by ForceDecks for their lite model.

Upon further investigation, I noticed that the software to process these plates' data is also quite costly. That is another consideration my group would have to take into account even if we found a cheap force plate. Lastly, the smallest the ones given would go is around 2 feet in length, which is too big for the boat or Ergometer. The force plate needs to be around one foot in order to fit under the foot comfortably/unnoticeably.

Conclusion:

Bring up in PDS and to advisor

9/20/2023 - BioRow Stretcher 2D

Title: How force plates are implemented in rehab for lower extremity injuries

Date: 9/20/2023

Content by: Emily

Goals: Look at alternatives to force plates

Link: https://biorow.com/index.php?route=product/product&path=61_115&product_id=109

Content:

After previous research, it seems like force plates are too expensive. Alternatively, Neha found this product from BioRow that is made up of load cells instead. This product has "two for each foot to measure toes and heels force components, which gives four data channels." Out of curiosity, I went to this website to see the prices of load cells to talk about it in my PDS to see if it was cheaper, and the product actually costs about $2183.73. Therefore, the cells can be just as expensive, however it seems that they are still on a plate, making it more similar to a force plate.
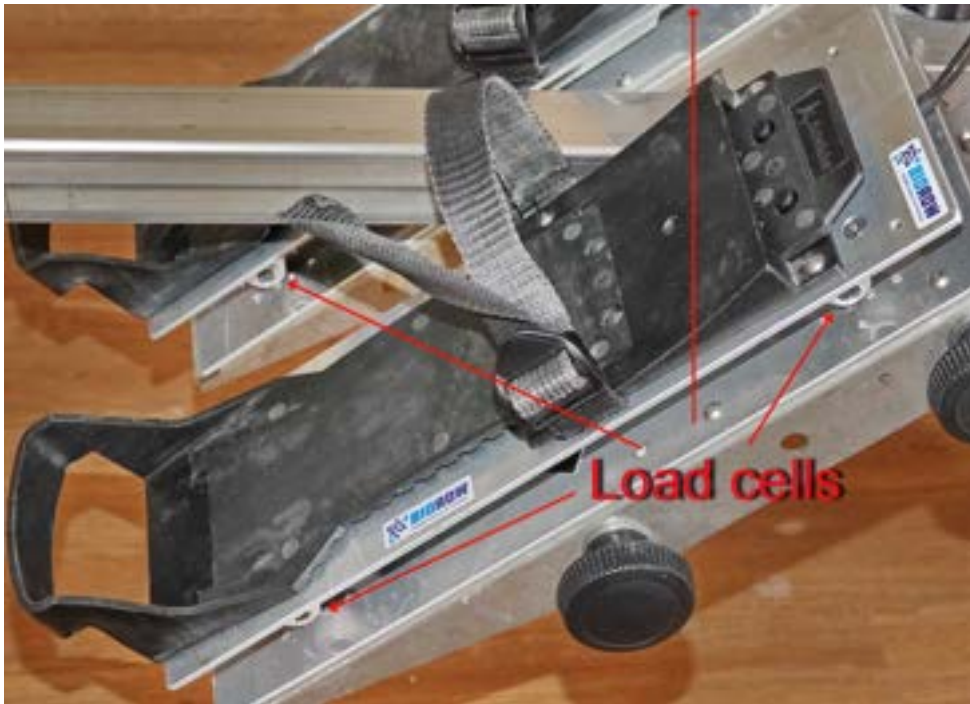
Variable	Whole stretcher sensor
Measured force range	From -800N to +3200N
Dimensions of each plate	345mm (W) 120mm (W) 30mm (H)
Weight	2.0 kg
Length of the cable	1.6m
Interface	analogue 0 – 5V
Number of data channels	4

Conclusion:

Mention in my PDS section

 9/25/2023 - Competing Load Cells

<div align="right">EMILY WADZINSKI - Sep 27, 2023, 11:53 PM CDT</div>

Title: 3 Axis Load Cell Purchase Site

Date: 9/25/2023

Content by: Emily

Goals: Compare load cell prices for design matrix

Link: https://www.alibaba.com/showroom/3-axis-load-cell.html

Content:

The single point cells are cheaper than the multi point ones (obviously), however, the more the axes the better the data collection for the rowers. Multi load cells can take data in the x, y, and z axes, similar to a force plate. When observing the costs on this website, most are within the $500 budget. The average cost seemed to be around $250 and up, but that's per cell, and we'd need at least two (one per foot). The product pictured here is one example of the many you can buy on this site. This product is more costly, but most of them look like this cell, either circular or square in shape.

For my design to present to the group for our design matrix, I'm thinking of finding a cheaper one so I could put two on each foot, for a total of four cells. All of the cells on the website are wired, so we'd have to include an Arduino or something that connects to the load cells and relays data to a monitor.

Conclusion:

Draw up design, conduct further research on circuits/software for load cells.

10/8/2023 - ATO Compression Load Cell

Title: Miniature Compression Load Cells Specs

Date: 10/8/2023

Content by: Emily

Goals: Find specific for cells used for design

Link: https://www.amazon.com/dp/B0BX1Z3VSB/ref=emc_b_5_i?th=1

Content:

The load cell chosen by Bryan for the design included in the Preliminary Report is sold on amazon. If we were to make this design, we'd pick the option with that can read the highest force, so the 100kg option. They each cost $135, so one per foot would amount to a total of $270, well within our budget.

Some of the specs include:

- capacity of almost 1000 N

- sensitivity of 2+-10%mV/V

- made out of stainless steel

- diameter = 13mm, height 7mm, cable length 2m to connect to circuit

- 0.5% F.S accuracy

The bottom of the page also states:

After purchasing ATO load cell

Use with a special digital panel meter to obtain readings directly, or a transmitter to output standard signal to PLC, DCS and other systems. Customized output signal is 0-5V, 0-10V, or 4-20mA or RS485

- therefore, we'd have to look at specific meters/systems

Conclusion:

Add to my section of the Preliminary Report

9/27/2023 - Personal Design for Matrix

EMILY WADZINSKI - Sep 27, 2023, 10:34 PM CDT

Title: Design Idea for Design Matrix Group Meeting

Date: 9/27/2023

Content by: Emily

Goals: Come up with idea to share with group when we decide three

Content:

My design uses load cells instead of a force plate, as we discovered the plates are too costly. The load cells can also be costly, so I limited the design down to two cells on each foot.

Conclusions/action items:

Combine ideas with Simmi and Bryan and put in matrix

EMILY WADZINSKI - Sep 27, 2023, 10:34 PM CDT
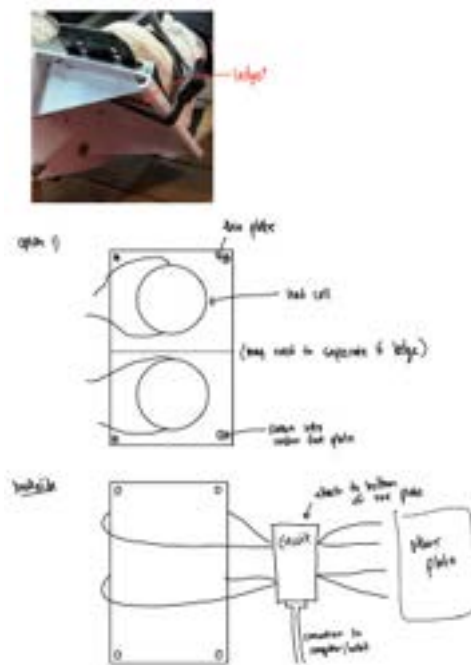
[Download](#)

300_personal_design_matrix_idea.pdf (4.61 MB)

10/10/2023 - Interfacing Force Sensing Resistor (FSR) with Arduino

EMILY WADZINSKI - Oct 11, 2023, 10:52 PM CDT

Title: FSR to Arduino

Date: 10/10/2023

Content by: Emily

Goals: Figure out how to make circuit

Link: https://lastminuteengineers.com/fsr-arduino-tutorial/#:~:text=It%20is%20quite%20easy%20to,down%20resistor%20and%20the%20FSR.

Content:

"The simplest way to read the FSR is to combine it with a static resistor to form a voltage divider, which produces a variable voltage that can be read by the analog-to-digital converter of a microcontroller."
   - Works since we were planning to do an Arduino

"output voltage you measure is the voltage drop across the pull-down resistor, not the voltage drop across the FSR."

Equation to code in Arduino:

$$V_O = V_{CC} \frac{R}{R + FSR}$$

Steps for circuit building:

- 10kΩ pull-down resistor in series with the FSR to create a voltage divider circuit.
- A0 ADC input of an Arduino is wired to the junction of the pull-down resistor and the FSR.
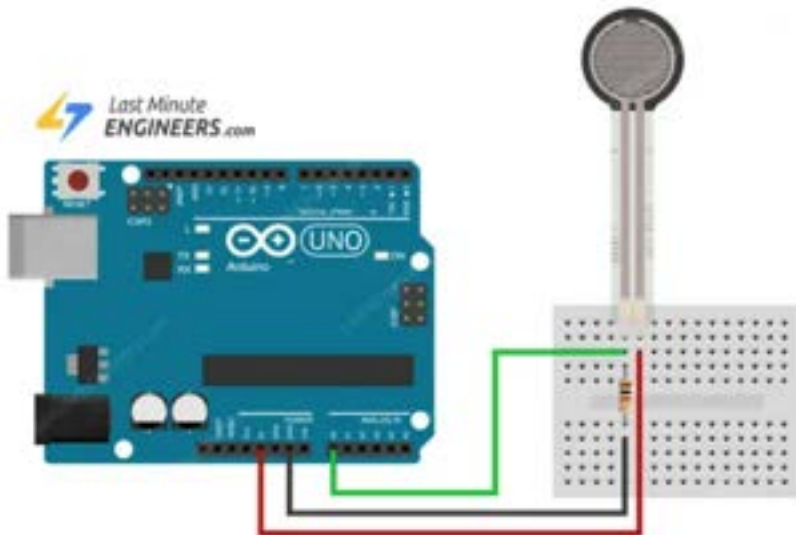
Possible code wee can use from article:

```
int fsrPin = 0;        // the FSR and 10K pulldown are connected to a0
int fsrReading;        // the analog reading from the FSR resistor divider

void setup(void) {
  Serial.begin(9600);
}

void loop(void) {
  fsrReading = analogRead(fsrPin);

  Serial.print("Analog reading = ");
  Serial.print(fsrReading);      // print the raw analog reading

  if (fsrReading < 10) {
    Serial.println(" - No pressure");
  } else if (fsrReading < 200) {
    Serial.println(" - Light touch");
  } else if (fsrReading < 500) {
    Serial.println(" - Light squeeze");
  } else if (fsrReading < 800) {
    Serial.println(" - Medium squeeze");
  } else {
    Serial.println(" - Big squeeze");
  }
  delay(1000);

}
```

Option 2 code:

```
int fsrPin = 0;        // the FSR and 10K pulldown are connected to a0
int fsrReading;        // the analog reading from the FSR resistor divider
int fsrVoltage;        // the analog reading converted to voltage
unsigned long fsrResistance;  // The voltage converted to resistance
unsigned long fsrConductance;
long fsrForce;          // Finally, the resistance converted to force

void setup(void) {
  Serial.begin(9600);   // We'll send debugging information via the Serial monitor
}

void loop(void) {
  fsrReading = analogRead(fsrPin);
  Serial.print("Analog reading = ");
  Serial.println(fsrReading);

  // analog voltage reading ranges from about 0 to 1023 which maps to 0V to 5V (= 5000mV)
  fsrVoltage = map(fsrReading, 0, 1023, 0, 5000);
  Serial.print("Voltage reading in mV = ");
  Serial.println(fsrVoltage);

  if (fsrVoltage == 0) {
    Serial.println("No pressure");
```

```
  } else {
    // The voltage = Vcc * R / (R + FSR) where R = 10K and Vcc = 5V
    // so FSR = ((Vcc - V) * R) / V        yay math!
    fsrResistance = 5000 - fsrVoltage;     // fsrVoltage is in millivolts so 5V = 5000mV
    fsrResistance *= 10000;                // 10K resistor
    fsrResistance /= fsrVoltage;
    Serial.print("FSR resistance in ohms = ");
    Serial.println(fsrResistance);

    fsrConductance = 1000000;             // we measure in micromhos so
    fsrConductance /= fsrResistance;
    Serial.print("Conductance in microMhos: ");
    Serial.println(fsrConductance);

    // Use the two FSR guide graphs to approximate the force
    if (fsrConductance <= 1000) {
      fsrForce = fsrConductance / 80;
      Serial.print("Force in Newtons: ");
      Serial.println(fsrForce);
    } else {
      fsrForce = fsrConductance - 1000;
      fsrForce /= 30;
      Serial.print("Force in Newtons: ");
      Serial.println(fsrForce);
    }
  }
  Serial.println("--------------------");
  delay(1000);
}
```

Conclusion:

Discuss in circuit meeting with teammates and Dr. N

11/1/2023 - Load Cell Circuit Diagram

Title: Load Cell Circuit Diagram

Date: 11/1/2023

Content by: Emily

Goals: Figure out circuit configurations

Link: https://learn.sparkfun.com/tutorials/load-cell-amplifier-hx711-breakout-hookup-guide?_gl=1

Content:

- Both load cells that we ordered can be interfaced with the same amplifier. The set up is the same with the arduino and wires as well since they're both disk-type cells

- Usually another plate with a hole is used to make sure whatever you are measuring is hitting the same spot on the load cell each time, but it is not necessary. We will try to make this in solidworks

- Finding the gage size will be needed if we decide to screw in the final load cell when embedding

- The amplifier we ordered matches up with each wire color

- Amplifier is already soldered
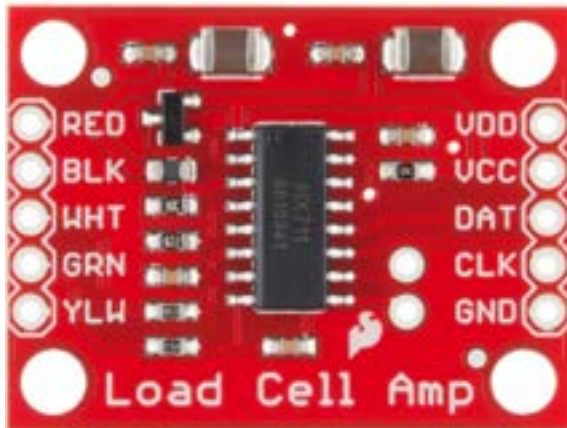
Wiring:

- each cell has four strain gauges that are hooked up in a **wheatstone bridge** formation.

LOAD CELL WIRING
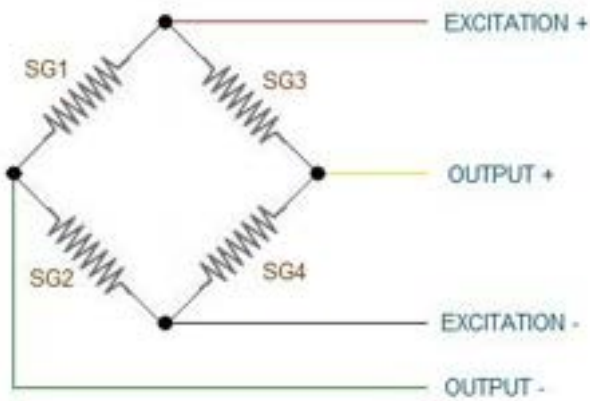
The four wires coming out from the wheatstone bridge on the load cell are "usually":

Wheatstone Bridge Node	"Typical" Wire Color
Excitation+ (E+) or VCC	RED
Excitation- (E-) or GND	BLACK or YELLOW
Output- (O-), Signal- (S-), or Amplifier- (A-)	WHITE
O+, S+, or A+	GREEN or BLUE

- "If the readings from the HX711 are opposite of what you are expect (for example the values decrease as you increase weight) simply reverse the O+/O- wires."

- "hook up VDD, VCC, DAT, CLK, and GND to a microcontroller such as a RedBoard or Arduino board."
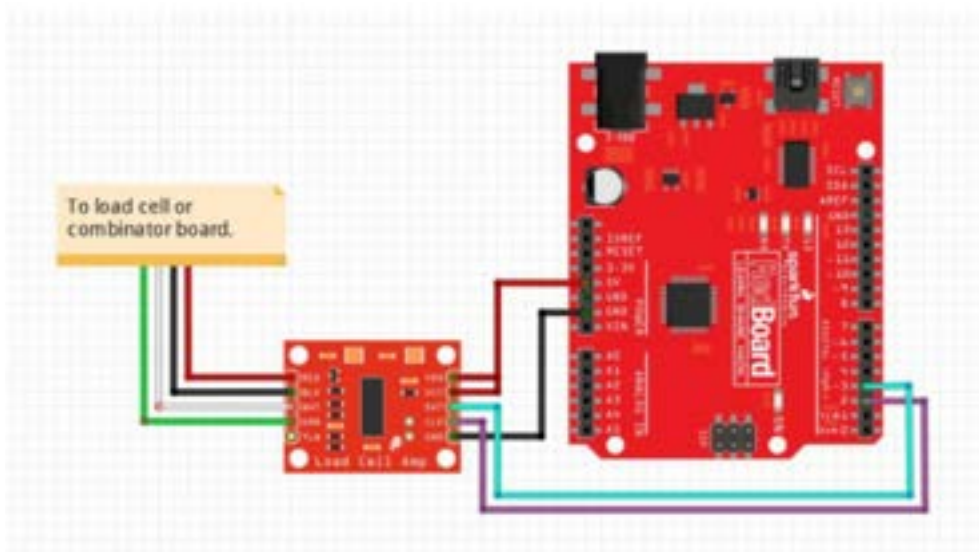
Fritzing diagram of HX711 amplifier connected to a RedBoard

Conclusion:

Make sure to add circuit schematics to final report

11/1/2023 - Arduino Code for Load Cell

Title: Load Cell Code

Date: 11/1/2023

Content by: Emily

Goals: Find Arduino code

Link: **https://learn.sparkfun.com/tutorials/load-cell-amplifier-hx711-breakout-hookup-guide?_gl=1**

Content:

Calibration code:

```
This is the calibration sketch. Use it to determine the calibration_factor that the main example uses. It also
 outputs the zero_factor useful for projects that have a permanent mass on the scale in between power cycles.

 Setup your scale and start the sketch WITHOUT a weight on the scale
 Once readings are displayed place the weight on the scale
 Press +/- or a/z to adjust the calibration_factor until the output readings match the known weight
 Use this calibration_factor on the example sketch
```

```cpp
#include "HX711.h"

#define DOUT  3
#define CLK  2

HX711 scale;

float calibration_factor = -7050; //-7050 worked for my 440lb max scale setup

void setup() {
  Serial.begin(9600);
  Serial.println("HX711 calibration sketch");
  Serial.println("Remove all weight from scale");
  Serial.println("After readings begin, place known weight on scale");
  Serial.println("Press + or a to increase calibration factor");
  Serial.println("Press - or z to decrease calibration factor");

  scale.begin(DOUT, CLK);
```

simple scale output example code:

```cpp
#include "HX711.h"

#define calibration_factor -7050.0 //This value is obtained using the SparkFun_HX711_Calibration sketch

#define DOUT  3
#define CLK  2

HX711 scale;

void setup() {
```

```
  Serial.begin(9600);
  Serial.println("HX711 scale demo");

  scale.begin(DOUT, CLK);
  scale.set_scale(calibration_factor); //This value is obtained by using the SparkFun_HX711_Calibration
 sketch
  scale.tare(); //Assuming there is no weight on the scale at start up, reset the scale to 0
```

Conclusion:

Copy code for initial setup

11/3/2023 - Load Cell Embedding Ideas

EMILY WADZINSKI - Dec 02, 2023, 6:48 PM CST

Title: Embedding Brainstorm

Date: 11/3/23

Content by: Emily

Present: All

Goals:

Content:

During our group meeting, we brainstormed the best way to embed the cell into the footplate with our client.

As we discussed I drew down these ideas and shared with the group.

Orla then redrew my thoughts into a more concise design in which we shared with the others.

Conclusion:

Think more about how'd we cut into the footplate.

EMILY WADZINSKI - Dec 02, 2023, 6:49 PM CST
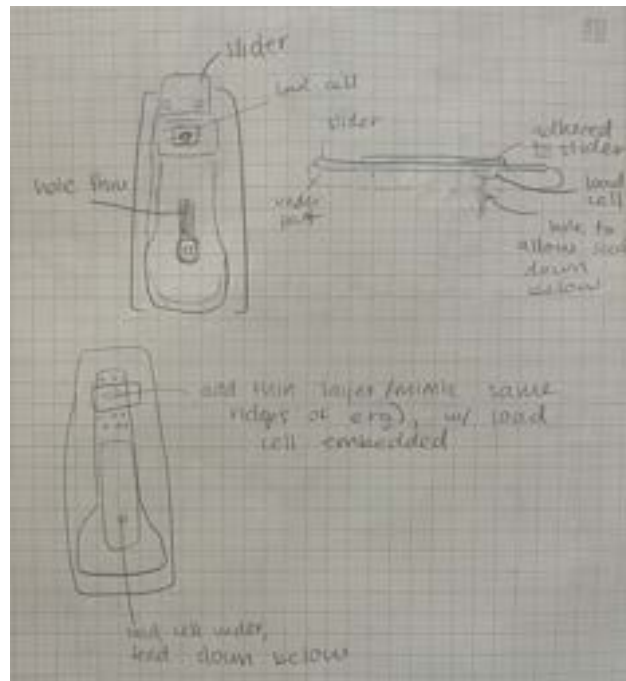
[Download](#)

IMG_5759.jpg (1.23 MB)
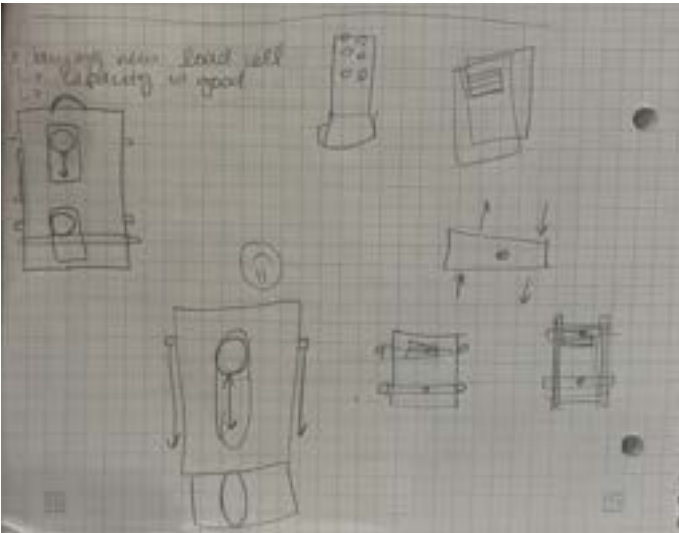
Download

IMG_5760.jpg (1.04 MB)

11/18/2023 - Prelim Solidworks Image

EMILY WADZINSKI - Nov 29, 2023, 2:16 PM CST

Title: Heel Plate Model

Date: 11/18/2023

Content by: Emily

Goals: Start brainstorming what the 3D prints will be

Content:

Picture attached below. The load cell for the heel will be placed in a center, and a cut is extruded for the load cell's wire. The 3D print will be placed upon the adjustable foot piece.

Conclusion:

Measure dimensions and edit model

EMILY WADZINSKI - Nov 28, 2023, 8:17 PM CST

Download

preliminary_bottom_footplate_pic_1_.JPG.jpg (18.1 kB)

11/28/2023 - Solidworks Hand Drawings

EMILY WADZINSKI - Nov 29, 2023, 2:15 PM CST

Title: Solidworks Dimensions

Date: 11/28/2023

Content by: Emily

Goals: Draw out design with measurements to help when modeling on software

Content:

picture attached

Conclusion:

Save as STL file

EMILY WADZINSKI - Nov 29, 2023, 2:16 PM CST
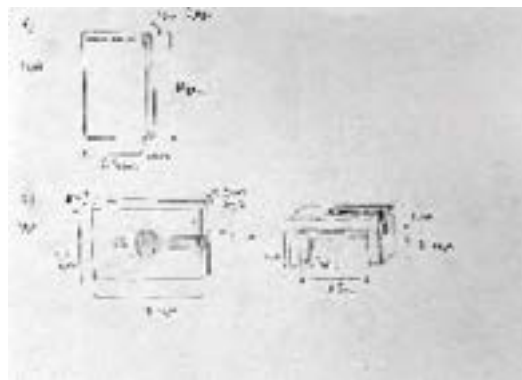
Download

Solid_works_drawing29_2023.pdf (233 kB)

11/28/2023 SolidWorks 3D Models

EMILY WADZINSKI - Dec 15, 2023, 2:10 AM CST

Title: Solidworks 3D Print

Date: 11/28/2023

Content by: Emily

Goals: Design parts to print

Content:

attached

Conclusion:

3D print

EMILY WADZINSKI - Dec 15, 2023, 2:09 AM CST
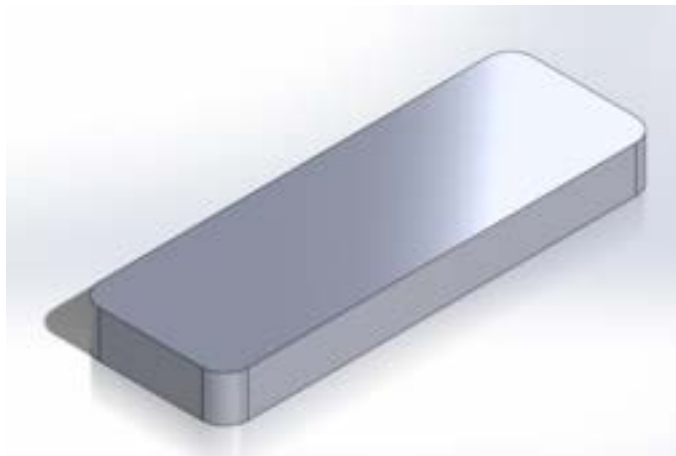
Download

3D_print_heel.png (223 kB)
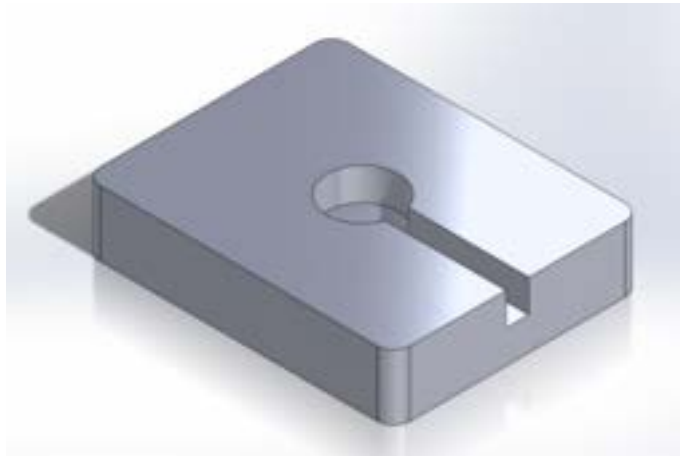
Download

3D_print_toe.png (262 kB)

12/01/2023 - 3D Prints

Title: 3D Prints of Footplate Add-ons

Date: 11/30/23

Content by: Emily

Present: N/A

Goals: Analyze print

Content:

The 3D print keeps getting delayed. Considering that testing will be done with rower on Monday, 12/4, a different load cell housing must be made by then.

Conclusion:

Go to the Team Lab and fabricate a new design. New SolidWorks designs are included in the Fabrication section of Team Activities in the Notebook.

Edit

The 3D print was ultimately delayed until 12/7/2023. The print was delayed every day and restarted twice. Considering the fact that presentations were on 12/8, it was a good idea that we fabricated something else. In addition the prints were heavy and the heel block is warped/melted???

2023/09/27 - Green Pass

EMILY WADZINSKI - Mar 11, 2023, 8:02 PM CST

Title: Green Pass Documentation

Date: 3/4/2023

Content by: Emily

Present: N/A

Goals: Show completion of pass

Content:

Displayed below:

Conclusions/action items:

Ready to use the shop

EMILY WADZINSKI - Mar 11, 2023, 8:04 PM CST

[Download](#)

green_pass.pdf (1.17 MB)

2023/09/27 - Biosafety and Chemical Safety Documentation

EMILY WADZINSKI - Jan 28, 2023, 1:16 PM CST

Title: Training Documentation

Date: 1/28/2023

Content by: Emily

Present: N/A

Goals: Show documentation of lab training

Content:

 Linked below:

Conclusions/action items:

Ready to be in the lab!

EMILY WADZINSKI - Jan 28, 2023, 1:16 PM CST

[Download](#)

Training_Information_Lookup_Tool.pdf (92.8 kB)

Forces Involved in Rowing - Boat and Body

Title: Forces Involved in Rowing - Boat and Body

Date: 9/13/2023

Content by: Simret

Present: Simret

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Link: https://www.searowing.wales/2020/05/04/biomechanics-of-rowing/

Citation:

[1 S. Says, "Biomechanics Of Rowing | Welsh Sea Rowing," May 04, 2020. https://www.searowing.wales/2020/05/04/biomechanics-of-rowing/
] (accessed Sep. 13, 2023).

Content:

External Biomechanical Factors of Rowing:

- Propulsion
    - dependent on Newton's 3rd law
    - oar moves the water one way and the boat moves the opposite way
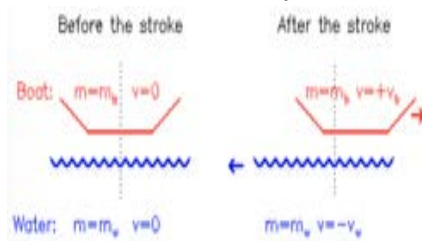
- Resistance
    - skin drag
        - friction between boat and water
            - smoother surface = less drag
    - form drag
        - dependent on shape of boat
            - a sleeker shape that will cut through water easily = less drag
    - wake drag
        - force needed to create wake as boat is propelled forward

Forces affecting the oar

- The stroke of the oar is the rower putting energy into the oar and transferring it to the water causing it to move

Muscles involved in Rowing

- Catch
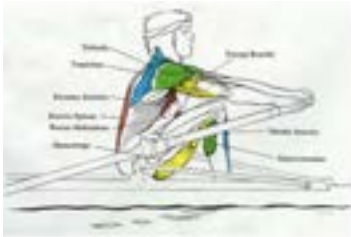
Joint	Movement	Muscles
Knee	Flexion	Hamstrings, gastrocnemius, and quads although should be noted rectus femoris in allowing hip flexion
Hip	Flexion	Psoas major and minor, iliacus. Rectus femoris contributes to this
Ankles	Dorsi flexion	Tibialis anterior
Elbow	Extension	Triceps brachii
Shoulder	Stabilization	Deltoid and trapezius

- Drive
  - Leg Emphasis

Joint	Movement	Muscles
Knee	Extends	Quadriceps
Hip	Extends	Hamstrings and gluteus
Feet	Planter flexion	Soleus and gastrocnemius
Back	Stabilization	Erector spinae
Shoulder	Contraction	Deltoid, supra and infraspinatus, subscapularis, teres major and minor, biceps brachii
Scapula	Stabilization	Serratus anterior and trapezius

  - Body Swing Emphasis

The Drive (Body Swing Emphasis)

Joint	Movement	Muscles
Knee	Extension	Quadriceps
Hip	Extension	Hamstrings and gluteus
Back	Extension	Erector spinae
Elbow	Extension	Biceps, brachialis and brachioradialis
Scapula	Stabilization	Serratus anterior and trapezius

  - Arm Pull Through Emphasis

Joint	Movement	Muscles
Knee	Maximal Extension	Quadriceps
Hip	Extension	Hamstrings and gluteus
Ankles	Planter flexion	Soleus and gastrocnemius
Back	Extension	Erector spinae
Shoulder	Full force contraction	Deltoid, supra and infraspinatus, subscapularis, teres major and minor, biceps brachii
Upper arm	Rotation	Latissimus dorsi, pectoralis major
Elbow	Flexion	Elbow flexors
Forearm	Stabilization and adduction	Flexor and extensor muscles
Scapula	Rotated downwards	Pectoralis minor
Scapula	Drawn backwards	Trapezius and rhomboid

- Finish

Joint	Movement	Muscles
Knee	Maximal Extension	Quadriceps
Hip	Extension	Hamstrings and gluteus
Ankles	Planter flexion	Soleus and gastrocnemius
Back	Extension	Erector spinae
Shoulder	Contraction	Deltoid, supra and infraspinatus, subscapularis, teres major and minor, biceps brachii
Upper arm	Internal Rotation	Latissimus dorsi, pectoralis major
Elbow	Extension	Triceps
Forearm	Stabilization and adduction	Flexor and extensor muscles
Scapula	Rotated downwards	Pectoralis minor
Scapula	Drawn backwards	Trapezius and rhomboid

- Recovery

Conclusions/action items: Use the knowledge of forces to help understand the biomechanics of rowing and applying it to our project.

Force Plates Function and Use

SIMRET BHATIA - Sep 24, 2023, 6:36 PM CDT

Title: Force Plates Function and Uses

Date: 9/14/23

Content by: Simret

Present: Simret

Goals: Learn the functions of force plates and what data they can provide.

Link: https://www.scienceforsport.com/force-plates-what-are-they-and-what-insights-do-they-provide-coaches/

Citation:

[1 W. Ambler, "Force Plates: What are they and what insights do they provide coaches?," *Science for Sport*, Jan. 25, 2022.
] https://www.scienceforsport.com/force-plates-what-are-they-and-what-insights-do-they-provide-coaches/ (accessed Sep. 14, 2023).

Content:

- force plates are used to measure the force that is produced by a certain activity
    - specifically analyze an athletes ground reaction force
- force plates can be used to study power, posture, and position
    - this data can be combined to find an athlete's movement efficiency
    - data can be used to find "body symmetry, rehabilitation effectiveness, running/walking gait, balance, and changes of pressure" [1]
- tests: strength test and jump test
    - can be used to measure peak force output, rate of force development, and limb asymmetry
        - these are very important factors affecting an athlete's performance
- training interventions with force plates
    - Dynamic Strength Index (DSI) - shows an athlete's maximal vs explosive strength capacity
    - Eccentric Utilisation Ratio (EUR) - shows the lower-extremity stretch-shortening cycle
        - jump height can also be an indicator

Conclusions/action items: This knowledge can help us determine how to use the force plates in our prototyping. It is important to keep in mind the types of data we can learn from force plates and then how to implement into our project.

Force Plates User Manual - Voltage

Title: Force Plates User Manual - Voltage

Date: 9/24/23

Content by: Simret

Present: Simret

Goals: Determine the safe voltage to plug a force plate into for PDS.

Link: file:///C:/Users/simre/Downloads/ForcePlateManual.pdf; https://simtk-confluence.stanford.edu:8443/

Citation: [1]"Site Home - Global Site," *Stanford.edu*, 2017. https://simtk-confluence.stanford.edu:8443/ (accessed Sep. 22, 2023).

Content:

- force plate needs to be plugged into an outlet with standard voltage of 120 V

Conclusions/action items:

The force plate should be plugged into a regular outlet in our product.

Cleaning Force Plates

Title: Cleaning Force Plates

Date: 9/24/23

Content by: Simret

Present: Simret

Goals: Determine the best way to clean force plates between uses for PDS.

Link: https://success.spartascience.com/en/knowledge/how-should-i-clean-or-disinfect-the-force-plate

Citation:

[1] "How should I clean or disinfect the Force Plate?," *success.spartascience.com*. https://success.spartascience.com/en/knowledge/how-should-i-clean-or-disinfect-the-force-plate (accessed Sep. 22, 2023)

Content:

ways to clean a force plate:

- alcohol based solution
- soap and water

Do not clean force plate with hydrogen peroxide or bleach because it can cause discoloration.

Conclusions/action items:

Include in the PDS that the force plate should be cleaned with an alcohol-based solution or soap and water.

Force Plate Accuracy

SIMRET BHATIA - Sep 24, 2023, 6:58 PM CDT

Title: Force Plate Accuracy

Date: 9/24/23

Content by: Simret

Present: Simret

Goals: Determine how accurate the force plate is for PDS.

Link: https://ieeexplore.ieee.org/document/10011703

Citation:

[1] Q. Liu, Y. Dai, M. Li, B. Yao, Y. Xin and J. Zhang, "Real-time processing of force sensor signals based on LSTM-RNN," *2022 IEEE International Conference on Robotics and Biomimetics (ROBIO)*, Jinghong, China, 2022, pp. 167-171, doi: 10.1109/ROBIO55434.2022.10011703.

Content:

The force plates have high accuracy as outlined in the data below. The researchers used a variety of tests to accurately measure the accuracy of the force plates.

Method	Signal amplification factor	ME(V)	AE(V)	ME/Ideal Output	AE/Ideal Output
LSTM-RNN	3200	0.0121	0.0028	1.21%	0.30%
	12800	0.0405	0.0134	1.74%	0.57%
RNN	3200	0.0459	0.0306	2.66%	2.06%
	12800	0.0725	0.0534	3.80%	3.99%

Conclusions/action items: The data shows that the accuracy for force plates is between 1 and 4 percent. In the PDS we have given ourselves a 5% range for accuracy because our clients do not need very high accuracy for the data.

10/09/2023 - Asymmetry caused by rowing

SIMRET BHATIA - Oct 09, 2023, 4:46 PM CDT

Title: Asymmetry caused by rowing

Date: 10/9/23

Content by: Simret

Present: Simret

Goals: Determine potential causes of asymmetry caused by rowing

Link: https://batlogic.net/wp-content/uploads/2017/08/Row360-Issue-008-Symmetry-of-Sweep.pdf

Content:

- some people think that switching force between feet is a better way to gain speed
- some argue that keeping symmetry in force is better
- causes of asymmetry
    - the lumbar spine (bottom portion of spine) only allows for 1.2-1.7 degrees of rotational movement
    - most rotation happens in the mid spine
    - this rotation in the mid spine worsens asymmetry in the legs and causes stress on the lumbar spine

Conclusions/action items:

Use findings to outline background information in the preliminary report.

![Preliminary Design logo] **Preliminary Design**

SIMRET BHATIA - Sep 26, 2023, 6:58 PM CDT

Title: Preliminary Design

Date: 9/26/23

Content by: Simret

Present: Simret

Goals: Create a preliminary design

Content:

Made a preliminary design for our product using the photos we took from our visit to rowing practice. I decided to use load cells for my design. I placed one load cell on the top to capture any data from the top of the foot. I placed this under the foot adjusting piece to ensure that the load cell would remain in a static, stable place while gathering data. The bottom of the foot has two load cells because this is where most of the motion is done and most of the data will be gathered.

Conclusions/action items:

Present and discuss preliminary designs with team.

10/25/23 - Fabrication

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

11/28/23 - Building/Calibration

SIMRET BHATIA - Dec 01, 2023, 12:47 PM CST

Title: Calibration and Final Poster

Date: 11/28/23

Content by: Simret Bhatia

Present: All team members

Goals: Finish circuit and calibrate load cell.

Content:

Helped finish the load cell circuit.

Started testing and calibrating the load cell. Ran into issues with the load cell because there is a node on the load cell where the weight should be concentrated. This made it hard to balance weights on the load cell. We had to problem-solve and obtain a disc to place around the node to help balance weights on top of it.

Conclusions/action items:

Finished load cell circuit and began calibration.

12/1/23 - Calibration and Final Poster

Title: Calibration and Final Poster

Date: 12/1/23

Content by: Simret Bhatia

Present: All team members

Goals: Finish load cell calibration and work on final poster.

Content:

Helped calibrate the load cell by testing different weights. Adjusted the calibration factor until readings were correct, indicating the load cell was correctly calibrated.

Started working on the final poster. Split up sections between team members to be more efficient. I worked on background for the poster.

We checked on our 3D print.

Conclusions/action items:

Calibrated load cell and finished final poster.

12/4/23 - Testing with client

SIMRET BHATIA - Dec 04, 2023, 5:57 PM CST

Title: Testing with Client

Date: 12/4/23

Content by: Simret Bhatia

Present: All team members

Goals: test and fix the prototype

Content:

Tested with client standing and balancing on the load cell. We were able to obtain a weight value from the load cell which was approximately the same as her actual weight. This indicated our load cell calibration is accurate.

Next we put the prototype on the erg and had client row to determine the accuracy of our design. We modified our design a little by adding velcro for easy detachment and movement of the load cell and to make it more user friendly.

Conclusions/action items:

The prototype works decently well. We will analyze data to get more concrete evidence.

2023/09/11-Study on Common Rowing Injuries

ORLA RYAN - Sep 11, 2023, 2:51 PM CDT

Title: Initial Biological Research on Injuries Common in Rowers

Date: 9/11/2023

Content by: Orla Ryan

Present: N/A

Goals:

- to begin developing an understanding of the client's need

- accumulating necessary background information in terms of physical/biological project aspects

Content:

- LUMBAR SPINE injuries are the most common

- once an injury occurs, lower back pain (LBP) is frequently recurrent

- analysis of movements overall, angles in joints, and forces generated in the feet are all processes undertaken to understand biomechanical movements in rowing

- 3D motion capture analysis lends more awareness (see reference below)

- problems stem from foot force when it becomes asymmetrical upon application and an improper ratio of toe-to-heel is used

- "late heel engagement" precedes injury and also creates sub-optimal performance

- rowers should be tested for flexibility, explosiveness capability, and endurance (foot force included)

- lumbar injuries can require up to 3/4 months of rest

- Reference: S, Arumugam, et al. "Rowing Injuries in Elite Athletes: A Review of Incidence with Risk Factors and the Role of Biomechanics in Its Management." *Indian Journal of Orthopaedics*, vol. 54, no. 3, Jan. 2020. *pubmed.ncbi.nlm.nih.gov*, https://doi.org/10.1007/s43465-020-00044-3.

Conclusions/action items:

Lower spine injuries are very common in the sport of rowing, as many biomechanical factors come into play. Analyzing the forces extended through rowers' feet is an essential contribution to kinetic analysis, as rowers with poor heel engagement and asymmetric application of foot force are more injury prone.

2023/09/11-Study on Efficient Rowing Technique

ORLA RYAN - Sep 11, 2023, 3:12 PM CDT

Title: Biomechanical Determinants of Elite Rowing Technique

Date: 9/11/2023

Content by: Orla Ryan

Present: N/a

Goals: To improve my comprehension of the encouraged techniques used in rowing and what physical demands those techniques entail.

Content:

- large, symmetrical foot forces are key to a higher velocity

    - rowers aim to create an effective transfer of power throughout the body

- "Multiple regression analyses identified hip kinematics as a key predictor of foot force output ($R2 = 0.48$), whereas knee and lumbar-pelvic kinematics were the main determinants in optimizing the horizontal foot force component ($R2 = .41$)" (Buckeridge)

- uneven application of force on footplates can then extend up to other joints like knees, hips, and pelvis (thus affecting more aspects of the whole-body movement)
- angles at the ankle, knee, hip, etc. were studied

- a lot of interconnections between greater hip flexibility and greater resultant foot forces

- Reference: Buckeridge, E. M., et al. "Biomechanical Determinants of Elite Rowing Technique and Performance: Rowing Technique and Performance." *Scandinavian Journal of Medicine & Science in Sports*, vol. 25, no. 2, Apr. 2015, pp. e176–83. *DOI.org (Crossref)*, https://doi.org/10.1111/sms.12264.

Conclusions/action items:

Rowing is a full-body movement that involves optimizing a transfer of power from the feet to the trunk. As described in this study, large and symmetrical foot forces result in higher velocities for rowers. Foot forces are also connected to other joints throughout the body, especially the hips; this is an important biological feature to note.

2023/09/21- Concept2 Ergometer Specification Notes

ORLA RYAN - Sep 21, 2023, 10:11 PM CDT

Title: Ergometer Specification Determinations

Date: 9/21/23

Content by: Orla Ryan

Present: n/a

Goals: To document physical measurements and visual characteristics of the UW boathouse ergometers to compare to possible finishings for our device.

Content:

- overall length of erg: 96 in

- width of erg: 24 in (including footrest?? take note)

- chain of erg is nickel-plated

- legs are made of various metals, eg. iron and steel

- finish is called a "powder coat" (look to replicate in our device)

- parts can be separated --> look to attach sensors/plates to *footrests*

Reference:

[1] david, "RowErg," *Concept2*, May 09, 2012. https://www.concept2.com/indoor-rowers/concept2-rowerg (accessed Sep. 21, 2023).

Conclusions/action items:

Share my findings with the group and update the current PDS to match my findings.

2023/09/22-Sensor Waterproofing Research

ORLA RYAN - Sep 22, 2023, 9:58 AM CDT

Title: Potential Waterproof Methods for Sensors

Date: 9/22/23

Content by: Orla Ryan

Present: n/a

Goals: To conduct research on waterproofing methods to provide for our initial PDS.

Content:

- this article discusses "wearable electronic devices", meaning sensors in the size range that we are looking at

- essentially, sensors are fabricated in "flexible substrates"

- what does this mean? -->

> - "Silver nanoparticles conductive circuits were simultaneously synthesized and patterned inside PDMS films by laser direct writing to form a waterproof sensor"

- thus, the device can withstand humid and overall wet environments with a high level of functionality still possible

- "silver ink" is what was used to create the barrier

- would this be within realm of possibility for our team to use? (expenses, availability, etc)

- the method is called "laser direct writing"

> - explore further, determine if possible with other materials (that are possibly more available at UW)

Reference:

[1] W. Zhou, Y. Yu, S. Bai, and A. Hu, "Laser direct writing of waterproof sensors inside flexible substrates for wearable electronics," *Optics & Laser Technology*, vol. 135, p. 106694, Mar. 2021, doi: 10.1016/j.optlastec.2020.106694.

Conclusions/action items:

Share my findings with my group, and conduct further research into more examples of the laser direct writing technique.

2023/09/16- Rival Patent to Determine Measurements

ORLA RYAN - Sep 16, 2023, 10:04 PM CDT

Title: Research on a Rival Patent

Date: 9/16/23

Content by: Orla Ryan

Present: N/A

Goals: I will be examining a patent of a possibly competing design to get inspiration for starting measurements, materials, and design elements.

Content:

- this design describes a more full-body measuring experience

- similar lower extremity force plates, but more focus on analysis throughout the rest of the body (mentions leg supports, etc)

- user instead steps on force plate

- mentions using both a "footrest sensor" and a "load sensor" ... consider sharing with team or examining difference between the two

- unfortunately, no mention of specific measurements or materials --> not a fruitful search

Reference:

Sang Hoon, K. (n.d.). *LOWER EXTREMITY REHABILITATION EXERCISE SYSTEM AND LOWER EXTREMITY EXERCISE EVALUATION*

METHOD USING SAME. Retrieved September 16, 2023, from

https://worldwide.espacenet.com/patent/search/family/086772962/publication/WO2023113240A1?q=foot%20forceplate

Conclusions/action items:

I can consider the possible difference between the sensors mentioned in this patent, and thus bring the potential decision to the group; however, I will have to continue my search for existing patents for a better idea of specific materials and measurements.

2023/09/27-Design Matrix Assigned Writing

ORLA RYAN - Sep 27, 2023, 3:00 PM CDT

Title: Justification of Sensor in Design Matrix

Date: 9/27/23

Content by: Orla Ryan

Present: n/a

Goals: I will be writing a justification for my imagined design for our preliminary design matrix.

Content:

The Silicone-Magnetic Force Sensor scored highest in Ease of Use, Compatibility, and Functionality. Due to its projected smaller size, it would not be likely to interfere with the rowers' technique and would fit in and be transferred between all of the considered locations quite easily. Thus, it scored a 4/5 in both Ease of Use and Compatibility. It would also involve use of sensors and communicating results through a microcontroller to a display, which is a process that would not be overly complex, allowing it to also score a 4/5 in Functionality. It received middling scores, 3/5, in both Cost and Safety, as the current cost of production and logistics of installation and use are unknown. Finally, considering that this design would involve constructing our own magnetic sensors, a novel process, it received a 3/5 in Reproducibility. This design therefore scored the lowest of the three.

Conclusions/action items:

I will add this to the team's design matrix Google Doc so that it can be turned in on Friday.

Orla Ryan/Research Notes/Competing Designs/2023/10/02- Work on Prelim. Presentation

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2023/10/02- Work on Prelim. Presentation

ORLA RYAN - Oct 02, 2023, 3:33 PM CDT

Title: Preliminary Presentation Assignment

Date: 10/2/23

Content by: Orla

Present: n/a

Goals: To complete/get work done on my assigned slide for this week's preliminary presentation.

Content:

I reformatted and (in some cases) copy and pasted my notes from my research on 9/23/23 to create my slide. Since I was assigned the slide to discuss my idea for a design, I was able to draw inspiration from my previous research. Finally, I also created a Google drawing to have a clean-cut/more professional image to depict my brainstormed sketch. I will attach that below.

Conclusions/action items:

I will practice discussing my slide and fitting in seamlessly with the group's presentation.

ORLA RYAN - Oct 02, 2023, 3:33 PM CDT
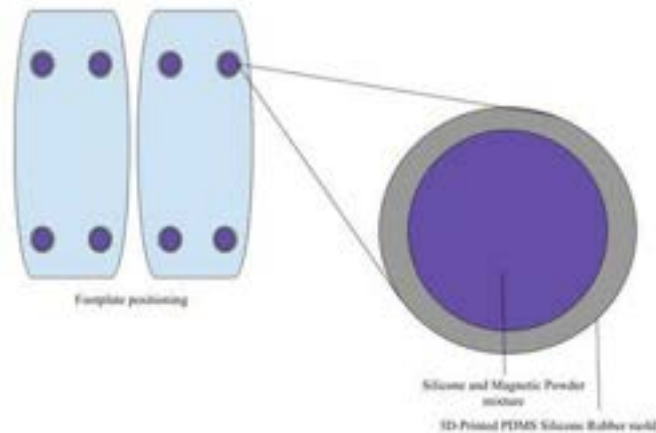
[Download](#)

Silicone-Magnetic_Sensor.jpg (38.7 kB) A Google drawing of my Silicone-Magnet Force Sensor design!

Orla Ryan/Research Notes/Competing Designs/2023/10/06 - Prelim. Report work

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2023/10/06 - Prelim. Report work

Orla Ryan/Research Notes/Competing Designs/2023/10/06 - Prelim. Report work

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Title: Preliminary Report Section work (Client Info, Design Specifications, Silicone-Magnetic Force Sensor)

Date: 10/06/2023

Content by: Orla Ryan

Present: n/a

Goals: To begin working on my assigned section for one of the team's first deliverables: the preliminary report.

Content:

Client Information (taking inspiration/drawing from past descriptions or mentions):

- in reality, I mostly conducted my own research/created a short description of each of our clients (Dr. Jill Thein-Nissenbaum, Ms. Tricia De Souza, and Ms. Sarah Navin)

- I will list the references below.

- final paragraph (for this draft):

The clients that the team is working with include Dr. Jill Thein-Nissenbaum, Ms. Tricia De Souza, and Ms. Sarah Navin. All three work with and are representing the University of Wisconsin-Madison (UW Madison) women's rowing team. Dr. Jill Thein-Nissenbaum is a professor in the UW Madison Physical Therapy Program, and is the staff physical therapist for Badger sports medicine. She provides consultation and rehabilitation services for all UW Madison sports and works in the Badger Athletic Performance Center analyzing athletic testing performed on UW Madison athletes (1). Ms. De Souza is a UW Madison athletic trainer; in particular, she provides athletic training services for both the Badgers men's and women's rowing teams (2). Finally, Ms. Sarah Navin is a UW Madison Physical Therapy student. She attended UW Madison for undergraduate school and was previously on the Badger women's rowing team.

Design Specifications (using Preliminary Presentation):

- essentially took inspiration from Preliminary Presentation (Neha assembled a lot of information and sources that I could work with)

- paragraph not finished, but I am trying to touch on importance of compatibility with Concept2 RowErg(3)

- transferable into different locations

- reproduce to get readings on 8 rowers at once

- accuracy

- temperature range (Wisconsin weather, etc.)

- longevity

Silicone-Magnetic Force Sensor (using my own research and Preliminary Presentation):

- once again, constructed with a lot of help from my preliminary presentation slide.

- also used resources I found during my original searches for the design.

- final paragraph:

The Silicone-Magnetic Force Sensor preliminary design is centered around a set of handmade force sensors; that is, fabrication of said sensors would be completed by the team. These small sensors would gather data through the Hall effect, by both generating a magnetic field and an electric current (4). Once the devices' magnetic field was disturbed, the electric current would be disrupted and the sensors would generate a reading to be processed by an Arduino and subsequently pictured on a display screen for rowing athletes. Given the ability of Hall-effect chips and sensors to measure compressive force, these sensors would hypothetically present accurate, helpful data (5). The fabrication process would include 3D printing a PDMS silicone and rubber mold, filling the mold with a silicone and magnetic powder mixture that comprises the magnet upon setting, and aligning the constructed magnet via existing permanent magnets (6). Once formed, the force sensors would be adhered to the ergometer's footplates – one on each corner of each footplate – and likewise connected to the processing Arduino through wires or a similar creation.

Conclusions/action items:

To continue editing my section and asking for feedback from my group members.

References:

[1] "Jill Thein-Nissenbaum, Physical Therapy (PT) Program," UW School of Medicine and Public Health. Accessed: Oct. 06, 2023. [Online]. Available: https://www.med.wisc.edu/education/physical-therapy-program/faculty-and-staff/jill-thein-nissenbaum/

[2] "Tricia De Souza | Women's Rowing Coach," Wisconsin Badgers. Accessed: Oct. 06, 2023. [Online]. Available: https://uwbadgers.com/sports/womens-rowing/roster/coaches/tricia-de-souza/1617

[3] david, "RowErg," Concept2. Accessed: Oct. 05, 2023. [Online]. Available: https://www.concept2.com/indoor-rowers/concept2-rowerg

[4] "How Hall effect sensors and probes work," Explain that Stuff, Jul. 29, 2009. http://www.explainthatstuff.com/hall-effect-sensors.html (accessed Sep. 23, 2023).

[5] J. D. Miller, D. Cabarkapa, M. J. Hermes, A. C. Fry, and C. J. Berkland, "Soft Magnetic Composites as Quantitative 3D Compression Sensors for Wearable Technology," Advanced Materials Technologies, vol. 7, no. 3, p. 2100784, 2022, doi: 10.1002/admt.202100784

[6] J. D. Miller et al., "Novel 3D Force Sensors for a Cost-Effective 3D Force Plate for Biomechanical Analysis," Sensors (Basel), vol. 23, no. 9, p. 4437, May 2023, doi: 10.3390/s23094437.

2023/10/09- Force Sensitive Resistor Research

ORLA RYAN - Oct 09, 2023, 11:45 AM CDT

Title: Force Sensitive Resistors -- How They Work and Examples

Date: 10/9/23

Content by: Orla Ryan

Present: n/a

Goals: To learn more about force sensitive resistors and get a clearer picture on the installation/fabrication plan.

Content:

How-to (in my own words):

- resistor will need to be connected to power source and a "fixed pulldown resistor" [1]

- microcontroller acts as midpoint

- resistor itself can detect pressure, then increases the electric current which (via the code input into Arduino/other microcontroller) can generate qualitative readings or other output like light

- some can measure approximate Newton force (can be used to calibrate expected forces)

- lot of effort will go into the coding, creating an easy-to-read (or interpret) display of results

Examples:

- on website, a few links to experiments using these force sensitive resistors included a thumb wrestling set up and a more simple lights display (that would activate upon pressing on the resistor)

- both included microprocessors as described (group's best bet is likely an Arduino)

Conclusions/action items:

Attend the team's meeting with Dr. Nimunkar on Thursday and ask any questions that arise.

References:

[1 "Force Sensitive Resistor (FSR)," Adafruit Learning System. Accessed: Oct. 09, 2023. [Online]. Available: https://learn.adafruit.com/force-
  ] sensitive-resistor-fsr/using-an-fsr

2023/10/26- Force Measurement through Electromagnetics

ORLA RYAN - Oct 26, 2023, 10:56 AM CDT

Title: Force Sensors via Electromechanical Systems

Date: 10/26/23

Content by: Orla

Present: n/a

Goals: To expand my understanding of electromechanical circuitry prior to beginning work on prototype.

Content:

- refers to circuit sensors as dielectric-capitance based

- "The working principle of such a sensor is a change in capacitance as a result of an acting force" [1]

- seems to be essentially the transformation of force sensing into an output display

- discusses both wiring and wireless options (might be too complicated for team)

- communication occurs between transducer, essentially the sensing element, and electronic part of the sensor (circuitry/Arduino)

- as we are learning, article discusses rising demand for smaller sizes (indicating more usability/flexibility)

- for this semester, might not be possible to create a "micro electromechanical system" [1], as that would be too advanced/time consuming for the team

- potential for future groups to expand upon, however

Reference:

[1 R. Hartansky *et al.*, "Towards a MEMS Force Sensor via the Electromagnetic Principle," *Sensors (Basel)*, vol. 23, no. 3, p. 1241, Jan. 2023,
 ] doi: 10.3390/s23031241.

Conclusions/action items:

Work with group to assemble our beginner load cells and force sensitive resistor circuits.

2023/12/10 - Types of Load Cells research

ORLA RYAN - Dec 10, 2023, 8:51 PM CST

Title: Types of Load Cells research

Date: 12/10/23

Content by: Orla

Present: n/a

Goals: Look at uses for different kinds of load cells to properly add to the final report.

Content:

- Point load cells used when measuring a "one directional force component"

- We have to be conscious of multiple force angles (given the diagonal of the footplate)

- also need to take possible moments/bending into account

- We used a disc shaped load cell, so likely read only a one dimensional force

- Better choices?

  - Planar beam load cells, potentially

  - Don't take up too much room and would better measure the variety of forces presented

[1] "Choosing the Right Load Cell for Your Job," Tacuna Systems. Accessed: Dec. 10, 2023. [Online]. Available: https://tacunasystems.com/knowledge-base/choosing-the-right-load-cell-for-your-job/

Conclusions/action items:

Complete my final report sections and assist the group in turning it in before Wednesday evening.

2023/09/17-Potential Usable 3D Force Plate

ORLA RYAN - Oct 06, 2023, 8:33 PM CDT

Title: Research on Affordable 3D Force Plate

Date: 9/17/23

Content by: Orla Ryan

Present: N/A

Goals: To conduct research on relevant and existing force plate documentation for comparison and inspiration for the team's PDS.

Content:

- authors acknowledged the great cost of many high-quality force plates on the market at this moment (upwards of 10,000 USD)

- goal was to investigate a cheaper alternative

- "A force plate prototype was constructed using aluminum plates and four of the novel magnetic 3D force sensors"

- sensors (possibly more relevant to us) constructed of PDMS silicone rubber elastomer

- also involved magnetic particles

- attached to pad of pure silicone (group could potentially invest in a smaller size to apply to our project)

- total cost was under 300 USD (based on our thus far limited budget, this idea shows potential)

- has a great load capacity

- "he silicone-magnetic sensors used in the experimental force plate within this study are made of biocompatible and soft yet mechanically robust silicones. This enables the potential to use this 3D force sensor platform in wearable technologies such as shoe insoles and helmets [14] as well as in other medical technologies."

[1] J. D. Miller *et al.*, "Novel 3D Force Sensors for a Cost-Effective 3D Force Plate for Biomechanical Analysis," *Sensors (Basel)*, vol. 23, no. 9, p. 4437, May 2023, doi: 10.3390/s23094437.

Conclusions/action items:

I will share my findings with the group and consider looking into purchasing Force Plates of this nature for a prototype.

2023/09/23- Hall Effect Sensor & Magnet initial thoughts

ORLA RYAN - Sep 23, 2023, 5:41 PM CDT

Title: Research on the Hall Effect and Practicality

Date: 9/23/23

Content by: Orla Ryan

Present: n/a

Goals: To come up with a preliminary design idea by drawing on previous research (see 9/17/23).

Content:

- our team has already run into several issues with the overall potential cost of our design

- market-brand force cells/sensors all seem over-budget

    - thus, I wanted to try and explore a simpler/cheaper/hand-made alternative (still with the same design principles in mind)

- I began researching magnetic sensors (based on a scientific experiment I discovered last week), which immediately prompted me to look into the "Hall effect" [1] given how many times it was brought up in an article I found [2]

- the "Hall effect" combines the ideas of electric currents and magnetic fields, allowing for applications towards sensing things like movement, tactile force, and speed [1]

    - utilizes either high-end sensors or cheaper chips (already found many affordable versions by running a quick search which the team can explore later

- in article I found, which was another experiment with "soft magnetic composites", authors tested *compression*, which I believe could perfectly apply to our needs (if sensors are put in footplates like we had originally thought, compression would occur as force is applied)

- essentially involves building sensors (will paste in fabrication description here):

"All sensors were 10 mm diameter by 5 mm height cylinders composed of PDMS silicone rubber elastomer (Sylgard 184, 20:1 base to curing agent ratio, Dow Chemical Company; Pevely, MO, USA), with a discreet cylindrical or conical portion of the construct composed of a silicone-magnetic powder composite. The magnetic powder used in the composite was a neodymium iron boron alloy with an average particle size <10 μm (American Elements, Los Angeles, CA, USA). The geometry of this magnetic element was variable, as the most efficacious geometry for the magnetic element of the sensor was a primary question of the investigation. Sensors were fabricated with cylindrical magnetic elements with diameters of 2, 3, 4, and 5 mm, and heights of 2, 3, and 4 mm, and with conical magnetic elements with base diameters of 3, 4, and 5 mm and heights of 3, and 4 mm" [2]

- molds are 3D printed, then a mix of the PDMS silicone and magnetic powder is poured in, to then be aligned using strong permanent magnets

- exact prices are still unknown, but I would guess that composing our own sensors has the potential to be a more feasible option, if we can successfully execute the fabrication

- before making a sketch to present to my group, I will be thinking about a next step beyond creating the sensors (how will they be connected? covered? etc)

References:

[1] "How Hall effect sensors and probes work," *Explain that Stuff*, Jul. 29, 2009. http://www.explainthatstuff.com/hall-effect-sensors.html (accessed Sep. 23, 2023).

[2] J. D. Miller, D. Cabarkapa, M. J. Hermes, A. C. Fry, and C. J. Berkland, "Soft Magnetic Composites as Quantitative 3D Compression Sensors for Wearable Technology," *Advanced Materials Technologies*, vol. 7, no. 3, p. 2100784, 2022, doi: 10.1002/admt.202100784.

Conclusions/action items:

Translate my research and brainstorming ideas into a sketch to present to my group on Tuesday.

2023/09/24-Hall Effect Sensor p2 (sketch)

ORLA RYAN - Sep 24, 2023, 9:28 PM CDT

Title: Preliminary Design sketch

Date: 9/24/23

Content by: Orla Ryan

Present: n/a

Goals: To upload a copy of my sketched design described previously.

Content:

See the attached PDF below! If needed, a more accurate/detailed sketch can be drawn later.

Conclusions/action items:

I will share this design with my team at our meeting on Tuesday.

ORLA RYAN - Sep 24, 2023, 9:29 PM CDT
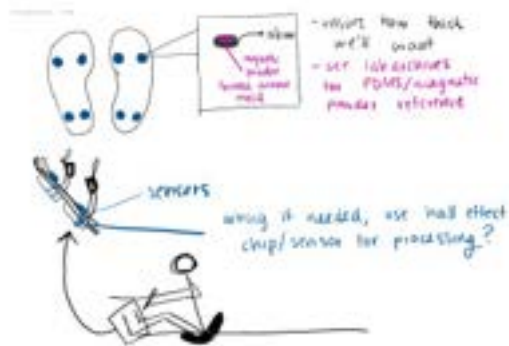
Download

orla_design.pdf (1.15 MB)

2023/10/11- Updated Design Drawing (measurements added)

ORLA RYAN - Oct 11, 2023, 10:04 AM CDT

Title: Upload of Silicone-Magnetic Force Sensor Design, including measurements

Date: 10/11/23

Content by: Orla

Present: n/a

Goals: To upload an updated version of my Google Drawing for the preliminary design titled "Silicone-Magnetic Force Sensor".

Content:

In this drawing, I made sure to include measurements as this will be necessary for our Preliminary Report. See attached pdf below!

Conclusions/action items:

Upload this drawing to our Preliminary Report to gain a more accurate idea of data/measurements for this design.

ORLA RYAN - Oct 11, 2023, 10:05 AM CDT

Download

Silicone-Magnetic_Sensor-_Updated.pdf (33.3 kB)

2023/10/12-Takeaways from Dr. Nimunkar

ORLA RYAN - Oct 12, 2023, 11:33 AM CDT

Title: Personal Takeaways from Dr. Nimunkar meeting

Date: 10/12/23

Content by: Orla
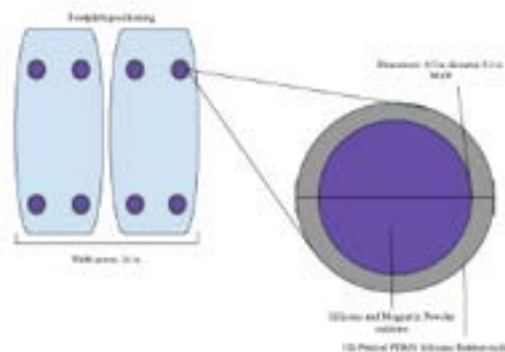
Present: Orla, Neha, Simmi, Emily, Simret

Goals: To absorb knowledge from Dr. Nimunkar and take his advice into account, putting it in my own words.

Content:

- focused mainly on force sensor load cells (finding affordable options)

- looked at DigiKey

- unsure about using force sensitive resistors

    - might be unable to find resistor with force measuring capabilities

    - ideally force will be concentrated at center of these resistors

    - have to ensure shoes of rowers will have direct contact with resistors (might have difficulty)

    - all force will need to be placed onto that resistor (in one single point/small area)

- would entail adding an extra piece in between to focus that force onto the sensor

- can start with cheaper resistor (for testing, before buying more expensive options)

- good idea to divide and conquer (one group focuses on coding/resistor, one on load cells)

- use amplifier, (sparkfun, digikey should have supply options for us)

Conclusions/action items:

As the team reevaluates our design and testing process, keep Dr. Nimunkar's advice in mind: consider load cells *and* resistor circuits (remain flexible and openminded)!

2023/10/18- Arduino Review

ORLA RYAN - Oct 18, 2023, 1:07 PM CDT

Title: Review of Arduino Methods

Date: 10/18/23

Content by: Orla

Present: n/a

Goals: To review concepts associated with using an Arduino, as well as typical approaches to efficiently getting results.

Content:

- Arduino hardware is low-cost and very flexible in terms of usage

- users must build the systems themselves, as well as writing the proper software

- data logger shields are often used to allow for good connection of sensors

- more general code that can be configured for our specific purpose will be difficult to find online

- sensor(s) that we connect to the Arduino have several standards of measurement:

    - robustness

    - response time (we'll want real-time, for example)

    - replicability

    - calibration setup

- software in the Arduino is structured so users will be able to define sensor type, connector position, and the method that the data must be processed in a certain sampling period (we'll want force v time)

- software generates a CSV file in which measurements are stored

Reference:

[1] E. Hernández-Rodríguez *et al.*, "Reliability Testing of a Low-Cost, Multi-Purpose Arduino-Based Data Logger Deployed in Several Applications Such as Outdoor Air Quality, Human Activity, Motion, and Exhaust Gas Monitoring," *Sensors (Basel)*, vol. 23, no. 17, p. 7412, Aug. 2023, doi: 10.3390/s23177412.

Conclusions/action items:

I will approach the group's work with an Arduino microcontroller with a more solid base of knowledge.

2023/10/30 - Standard for Testing a Force-Measuring Device

ORLA RYAN - Oct 30, 2023, 12:33 PM CDT

Title: Standard for Calibrating/Testing Force-Measuring Device

Date: 10/30/23

Content by: Orla

Present: n/a

Goals: To get an idea of industry standards for testing as we approach the creation of our first prototype.

Content:

- overall goal is to ensure that the amount of force applied translates to an accurate reading consistent with the International System of Units (SI)

- methods include:

    - standard weights

    - equal-arm balances and standard weights
    - elastic force (less likely to apply to our design)

- these measurements/methods must be used for verifying/calibrating force-machine (INCLUDING the device's display), from the load cells/sensors to the laptop display in our case

- values from either SI or inch-pound must be used, not combined

- "As a result, a testing machine verified using these practices may produce a deviation from the true force greater than ±1.0 % when the force measurement error is combined with the measurement uncertainty" [1]

- this fits within our goal force accuracy, so should be doable

Reference:

[1] "Standard Practices for Force Calibration and Verification of Testing Machines." Accessed: Oct. 30, 2023. [Online]. Available: https://www.astm.org/e0004-21.html

Conclusions/action items:

I will keep these practices in mind as the team creates our first product version(s) and moves into the initial testing phase.

2023/11/01 - Assembling Initial Arduino

ORLA RYAN - Nov 01, 2023, 8:44 PM CDT

Title: Initial Assembling of Arduino construction

Date: 11/1/23

Content by: Orla

Present: Orla, Neha, Emily, Simmi

Goals: Construct an Arduino circuit/learn from juniors

Content:

- Helped to connect the small wires between different ports for the Arduino set up

- Learned about various tools (alligator clips, cord connecting laptop and Arduino circuit board) that are necessary for proper construction

- Arduino has its own coding language

- Can download examples/templates from various sites to build off of

- Troubleshooting is important for a successful final product (team had to undergo a few rounds of this to make a running/functioning beginner circuit)

- Found the calibration factor (learned that they can be negative)

- We tested the mechanism/circuit by using an object with a known weight (iPhone 12 Pro)

Conclusions/action items:

I will work with the group later in the week to present our initial prototype at the Show and Tell. I can also hopefully apply some small details I've learned to BME 201!

2023/11/06-Method to Install Load Cell

ORLA RYAN - Nov 06, 2023, 3:53 PM CST

Title: Best Method to Install a Load Cell

Date: 11/6/23

Content by: Orla

Present: n/a

Goals: I am conducting research to aid the team in coming to a decision on load cell placement/installation.

Content:

- After last week's show and tell, the team is deciding on the best way to adhere the load cell to the ergometer's footplate(s)

- Several ideas were presented to us, such as making it into a wearable device, placing it within the footplate, or replacing the overall footplate with a construction of our own

- In an online resource I found below (1), I found tips for installing load cells (with highest accuracy in mind) that I thought could be relevant to this decision

- We must observe the loading applications of our specific load cell, primarily, to avoid reducing its life in service

- We should provide a rigid design for the support structure since our load cell is measuring compressive force

    - this involves an even contact surface

    - distributes tension properly

- Rigid base plate will ensure even load transfer

- Protections for the load cell may be necessary (shield cables, avoid pliable designs that may impede the device's abilities)

- Overall, I think that this helps to rule out the accuracy of a wearable device (would be difficult to create a strong support without disrupting the wearer's rowing technique)

- Seems that the team should either construct a kind of footplate of our own, or adhere it within the existing ergometer's design

Reference:

[1] "Installing a Load Cell: Best Practices," https://www.omega.com/en-us/. Accessed: Nov. 06, 2023. [Online]. Available: https://www.omega.com/en-us/resources/load-cell-installation

Conclusions/action items:

I will share my findings with the team and participate in upcoming meetings to continue fabricating our prototype.

2023/11/09- Ideas for Load Cell materials

ORLA RYAN - Nov 09, 2023, 11:26 AM CST

Title: Research on Load Cell materials

Date: 11/9/23

Content by: Orla

Present: n/a

Goals: I'm hoping to contribute to the team's materials order and come up with an idea for shape/style of load cell and amplifier.

Content:

I don't have really any experience with load cell types/amplifiers, but will be looking on sites such as Digikey and Sparkfun to find possible materials.

I didn't find anything promising on Digikey, as all the applicable sensors seemed to be sold out. Looking at Sparkfun, and applying a max load force filter, I found one possible option: a 200kg load cell (about 65 dollars each), and an associating simple amplifier (11 each). I will have to consult with my group, but right now I am assuming we need two of each. Overall, this would be definitively pricier, at around $152. Given our lack of high spending up until this point, it could still be a promising option.

Reference to chosen materials:

[1] "Load Cell - 200kg, S-Type (TAS501) - SEN-14282 - SparkFun Electronics." Accessed: Nov. 09, 2023. [Online]. Available: https://www.sparkfun.com/products/14282

Conclusions/action items:

I will share these links with my group to discuss the next time we meet, finalizing our product order.

2023/11/15- Solidworks for Footplate work

ORLA RYAN - Nov 15, 2023, 7:58 PM CST

Title: Working on Solidworks for Footplate

Date: 11/15/23

Content by: Orla

Present: Orla, Emily

Goals: Make some headway on finding a previous CAD model or constructing our own for the footplate.

Content:

- began searching for premade models online

- created rudimentary 3D sketch of footplate design (will be difficult to do from scratch given the strange shape of the footplate)

- Emily started from scratch, estimating some dimensions

- I will be working on downloading SolidWorks on my own laptop to help out further/get more practice in the future

- I looked at various sites like BiblioCAD and GrabCAD, trying to find a reference/example that we could use or even build off of

- the closest helpful image that I found was a schematic of the Flex Foot (footplate) through the Concept2 Erg website (will attach the image below)

Conclusions/action items:

Share our findings with the group and continue to assist in overall fabrication.

ORLA RYAN - Nov 15, 2023, 7:59 PM CST
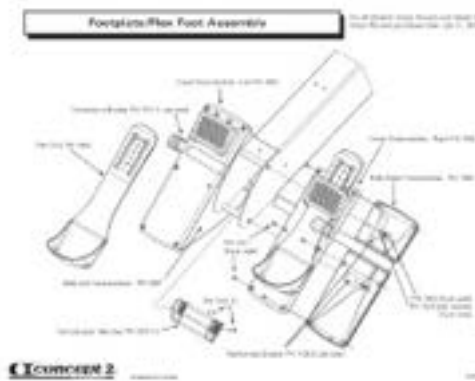
Download

D_E_Footplate_Flexfoot_Assembly.pdf (9.08 MB) The piece that we are looking to recreate is titled "Flex Foot PN 1063".

2023/11/30 - Testing Standard, Known Weight

ORLA RYAN - Nov 30, 2023, 11:56 AM CST

Title: Standardizing Weights used in Testing

Date: 11/30/23

Content by: Orla

Present: n/a

Goals: To document a relevant standard on testing with weights, should the team deide to use known weights to measure reliability of the load cell.

Content:

- Standards exist for both weights and mass

- Typical to use laboratory weights (will we have access to any?)

- weight manufacturers are especially expected to adhere to these standards and produce reliable, accurate measurements for the weights that they produce

- "Maximum permissible error" must be low to ensure confidence

- Take surface area and design/shape into account too! (especially in this case since we are using a small load cell, distribution of weight/pressure is important to consider)

- Cleaning the weights before use would technically be best practice, to ensure no added weight (no matter how small)

Reference:

[1] "E617 Standard Specification for Laboratory Weights and Precision Mass Standards." Accessed: Nov. 30, 2023. [Online]. Available: https://www.astm.org/e0617-23.html[1]

Conclusions/action items:

I will use this knowledge when helping the team complete testing and gather data for our final presentation.

2023/10/18- Documenting completion of "Intro to Machinery"

Title: Documentation for Completion of Intro to Machinery

Date: 10/18/23

Content by: Orla

Present: n/a

Goals: Sharing evidence of my completion of the Intro to Machinery training last week, thus indicating proficiency on the lathe and the mill.

Content:

My Memberships

Membership Type	Start Date	Expiry Date	Renew
Machining	Sun, Jan 1 2023	Permanent	Not Renewab

Conclusions/action items:

I will have to wait to see if my Intro to Machinery training will be needed for fabrication of this semester's product.

2023/12/01 - Calibration, Quantifying Data, and Poster Work

ORLA RYAN - Dec 01, 2023, 12:51 PM CST

Title: Calibration, Quantifying Data, and Poster Work

Date: 12/1/23

Content by: Orla

Present: All

Goals: Work with team to calibrate our design and make headway on our final poster.

Content:

- helped edit the team's final poster

    - I made aesthetic edits like regulating font size across the poster and formatting the title, and edited the "Future Work" section

- contributed to calibrating the load cell

- took a few turns with different weights and balancing them with minimal pressure applied

- team realized that 3D print will not be completed until tomorrow

Conclusions/action items:

Meet with group on Monday to conduct testing, then finalize poster and data by Wednesday.

2023/12/04 - Testing Session

ORLA RYAN - Dec 04, 2023, 5:04 PM CST

Title: Prototype Testing with Sarah

Date: 12/4/23

Content by: Orla

Present: All

Goals: Test the current prototype when attached to erg.

Content:

- We met with Sarah and Jill in the ECB and assembled our ergometer for testing

- Only one circuit was tested, we will get the other assembled by Friday

- Load cell construction involves duct tape and scrap material from the TeamLabs

- With fluctuating balance, Sarah's reported weight ranged from 130lbs to 215lbs (Sarah's actual weight was somewhere around 175 lbs)

- The output was within a close range of her actual weight, and would change every time she shifted (as to be expected)

- Duct tape allowed the device to slide slightly (fastenings could be improved in future, like velcro or a similar adhesive material)

- Moved the load cell block down further to align more with the ball of foot/joint where force is output from

- considered adding velcro to sides/beneath device

- Overall, we were decently happy with information that the device collected and will try and get a second load cell working by Friday

Conclusions/action items:

We will format our collected data and notes to make changes to our poster presentation. The team plans to meet either tomorrow or Wednesday to run through the presentation before Friday.

2023/09/11 - Basic Fundamentals of Force Plates and How They Are Used in Athletics

Title: Basic Fundamentals and Operation of Force Plates for Athletics

Date: 9/11/2023

Content By: Bryan Topercer

Present: n/a

Goals: To further understand how force plates are used for athletics and what their purposes can be.

Content:

First Source

-Force plates help determine abnormalities in force distribution in an athlete that physical therapists may not be able to catch

-These plates can be used not just to determine maximum force output, but different stages of an explosive movement such as the loading phase or landing phase.

-Can also help determine when an athlete is at rest the distribution of force between either extremity.

-Can also be useful for injured athletes in recovery, can help aim for certain force outputs or track progress in rehabilitation.

Second Source

-This visual shows how force plates were used to determine the difference in the usage of right and left legs in participants who did vertical jumps. High percent deviation will correlate to higher risk of injury.

-Athletes can use this data to track if they favorite a certain side of their body and therefore try to correct this to avoid injury.
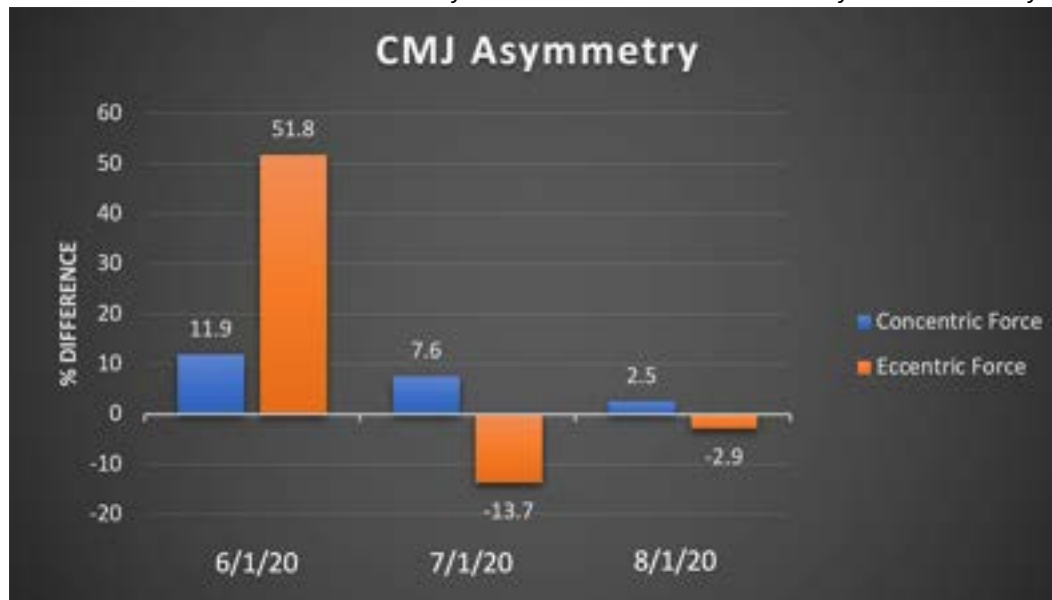
-Certain percent difference deviations help physical therapists determine injury risk and can help select exercises or part of the body that need work in order to help the athlete avoid injury.

Citation: "Force Plates Provide Data for Sports Medicine Team - LMH." *LMH Health*, 25 June 2022, www.lmh.org/news/2022-news/force-plates-provide-data-for-sports-medicine-team/.

"The Force Plates – Using Science Instead of Speculation." *Kinetic Sports Performance*, 3 Dec. 2020,
kineticsportsperformance.com/the-force-plates-using-science-instead-of-speculation/.

Conclusions/Action Items:

Force plates are very useful in athletic setting for determining injury risks and also monitoring athletic performance in
athletes. They can monitor certain aspects of performance such as percent different in force output during different
portions of an athletic movement, or also natural movements. These readings can help a physical therapist or
trainer look for abnormalities and overall improve the athlete.

-I must continue research on competing designs

2023/09/11 - Studies Done on Force Plates for Athletics

Title: Studies Conducted on Force Plates and Their Impact for Athletic Performance

Date: 09/11/23

Content By: Bryan Topercer

Present: n/a

Goals: To gain further knowledge on force plates and how they have been studied in the past. This will help me gain an understanding of more of their functions and how they can study certain biological factors of an athlete.

Content:

Study One

-Force plates helped determine coaches figure out weaknesses of their 100m sprinters, whether it was power in the drive phase or stride frequency, and allowed them to coach to these needs
-They also used these force plates in 3 dimensions to determine force output in different directions to help an athlete optimize their output in the correct direction.
-Jump forces have been previously known to directly correlate to sprint speed
-Many factors were kept controlled such as diet and time of testing, athletes had to do vertical jump, 60m sprint, and 150m sprint.
-Force plates were used for jumping tests, while photocells were used for sprinting tests.
-Force plates helped determine a nearly direct correlation between force output in jumps and sprint speed performance in olympic athletes

Study Two

-Force plates were used to determine postural sway in athletes to determine concussional abnormalities and assess their health
-Females were tested with their eyes closed, none of these athletes were previously concussed to eliminate this from affecting results.
-The force plates were used to determine if while their eyes were closed, the athletes had any unnatural swaying movement and detecting abnormalities in their posture.
-This study found that force plates could detect swaying motions and abnormalities in posture, which could be used to further explain concussions or brain injuries in the future. The force plates are used as a risk test.

Citations:

Loturco, Irineu, et al. "Portable Force Plates: A Viable and Practical Alternative to Rapidly and Accurately Monitor Elite Sprint Performance." *Sports (Basel, Switzerland)*, U.S. National Library of Medicine, 12 July 2018, www.ncbi.nlm.nih.gov/pmc/articles/PMC6162417/.

Quatman-Yates, Catherine C, et al. "Test-Retest Consistency of a Postural Sway Assessment Protocol for Adolescent Athletes Measured with a Force Plate." *International Journal of Sports Physical Therapy*, U.S. National Library of Medicine, Dec. 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3867067/.

Conclusions/Action Items:

Force plates have been used in a variety of ways to test different traits and performance factors of athletes. Studies conducted on athletic performance found that force plate test results can predict and have a direct correlation with performance. In terms of injuries and concussions, force plates can find natural tendencies and help predict risk of injury.

-I will need to do research on competing designs.

10/08/2023 - How Asymmetry in Rowing Leads to Back Injury

BRYAN TOPERCER - Oct 10, 2023, 9:44 PM CDT

Title: How Asymmetry in Rowing Leads to Back Injury

Date: 10/08/2023

Content by: Bryan Topercer

Present: n/a

Goals: Gain a further understanding of the physiology of rowing and how asymmetry can cause injury.

Content:

-The study focused on how an ergometer is symmetrical and will not cause rowing injuries, but how actual rowing is not and causes injury.

-Load cells were used on many different athletes and multiple different quantities were measured such as pelvic twist and external power.

-Hip and knee range of motion was seen as very asymmetrical, and they focused more on how hip range of motion can cause injuries in the lower back.

-The study concluded that hip range of motion is a lead indicator in rowing of why lower back injuries develop.

-This should translate to our design and find how asymmetries in force can lead to lower back injury.

Citations:

A;, Buckeridge E;Hislop S;Bull A;McGregor. "Kinematic Asymmetries of the Lower Limbs during Ergometer Rowing." *Medicine and Science in Sports and Exercise*, U.S. National Library of Medicine, pubmed.ncbi.nlm.nih.gov/22677926/. Accessed 10 Oct. 2023.

Conclusions/action items:

 -Begin looking at purchasing materials and finishing up important deliverables

10/18/2023 - Force Sensitive Resistor Function

BRYAN TOPERCER - Oct 19, 2023, 1:18 PM CDT

Title: Force Sensitive Resistor Function

Date: 10/18/2023

Content by: Bryan Topercer

Present: n/a

Goals: To get a better understanding of the device we will be using to prototype and be familiar with certain aspects of the resistor when we physically have it.

Content:

-Resistor value changes in response to change in pressure or force applied

-Contains conductive layer and resistive layer, applied forces cause particles to move closer and allow for more electrical current

-As this current changes, voltage changes, and from voltage applied force can be determined

-Can be sensitive to environmental factors and have more room for error.

-Relationship between force and resistance is nonlinear, can make calculations difficult.

Conclusions/action items:

Matan. "Force-Sensitive Resistor (FSR): How It Works, Application & Advantages." *Electricity*, 11 June 2023, www.electricity-magnetism.org/force-sensitive-resistor-fsr/.

09/14/2023 - Forces Applied on Ergometer Study

Title: Study of Analyzing Force on an Ergometer - UCLA

Date: 09/14/2023

Content By: Bryan Topercer

Present: n/a

Goals:

-The aim is to gain an understanding of how force plates have been used in a similar context or similar design. This will help us gain a better understanding of how we can use force plates to track an athletic movement such as rowing. This study in particular highlights how force has been tracked on an ergometer, exactly what we are going to be using.

Content:

-The group conducting this study used force plates on the feet for the lower extremities, and had other force monitoring devices where points of contact with the ergometer were made.

-A 3D motion analysis system was used for the overall movement, which tracked the rowers overall full body movement.

-For the lower extremities, three axis force plates were used: two for the legs, and one for the seat.

-My thoughts were that I would rather focus on the foot force plates used here, so I will focus on these results and what they indicated. The pushing off and recovery phase both indicated different force values, and they found the peak forces during which part of each movement (propulsion and recovery).

-Overall this study looked at how force plates were used on an ergometer to track the usage of force throughout different portions of a movement for a rower. Although they did not use this data to look at injury, this data could be used to determine force output in each leg, and produced graphs for the entire movement.

-We could use a similar strategy to print a graph of each pushing and recovery motion to also show how quickly or evenly distributed an athlete's force output is, and how that contributes to injury.

Citation:

Forces Applied on Rowing Ergometer Concept2®: A Kinetic ... - UCLA, UCLA, bionics.seas.ucla.edu/education/Rowing/Biomechanics_2008_01.pdf. Accessed 16 Sept. 2023.

Conclusions/Action Items:

-Force plates can successfully be used on an ergometer to track force distribution in lower extremities.

-Data can be graphed throughout the entire movement using force plates, if it proves useful.

-Will need to begin working on PDS document.

09/25/2023 - Miniature Compression Load Cell

BRYAN TOPERCER - Oct 04, 2023, 10:49 AM CDT

Title: Miniature Compression Load Cell Research

Date: 09/25/2023

**Content by:** Bryan Topercer

Present: n/a

Goals: To do further research on types of load cells that are more cost effective and space efficient.

Content:

 -Miniature compression load cells are a much smaller version of a load cell that could much be easier to adapt to the space available between the rowing shoes and the flat surface.

-These range in price from around $70-150, a much cheaper alternative.

-They have multiple ranges of the forces of which they can withstand, around 50 N to 5000N of force
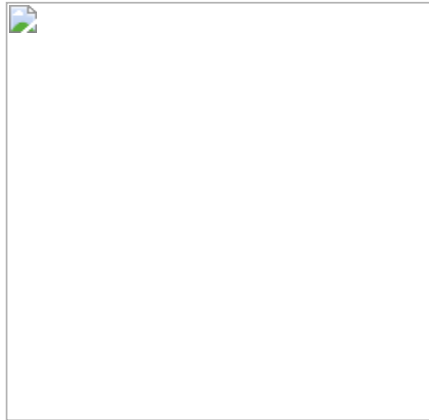
Citation:

ATO Compression Load Cell 5kg, Button Type, Weighing Mini Load Cell ..., www.amazon.com/Compression-Button-Weighing-Sensor-Miniature/dp/B0BWYCKYQQ. Accessed 29 Sept. 2023.

Conclusions/action items:

-Finish design matrix idea

-Discuss with group findings of mini load cells

10/08/2023 - Rowing Force Plates

BRYAN TOPERCER - Oct 10, 2023, 9:08 PM CDT

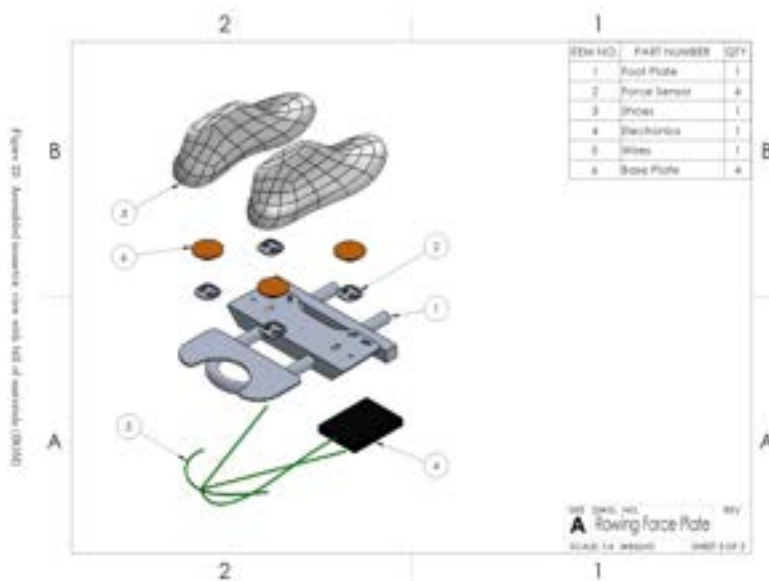**Title:** Rowing Force Plate Design

Date: 10/08/2023

Content by: Bryan Topercer

Present: n/a

Goals: To look at a prototype using similar methods that we were looking at and understand further how effective measuring force output can be for rowers.

Content:

 -The mechanical engineering department of Washington University St. Louis did a similar project to measure force output in rowers.

-The team used four load cell force sensors which connected to an Arduino, similar to one of our designs.

-The team struggled at first with getting accurate results in force output but fixed their circuitry and upgraded load cells and found accurate results.

-The design worked on a boat on the water.

Citation:

Hubel, Mae; Southwick, Taylor; and Petersen, Miles, "MEMS 411: Rowing Force Plate" (2021). *Mechanical Engineering Design Project Class*. 166.
https://openscholarship.wustl.edu/mems411/166

Conclusions/action items: Similar designs to ones we have brainstormed have been created and successfully worked.

-Look further into our chosen design, force resistors as well as look at code related to them.

09/26/2023 - Miniature Compression Load Cell Design

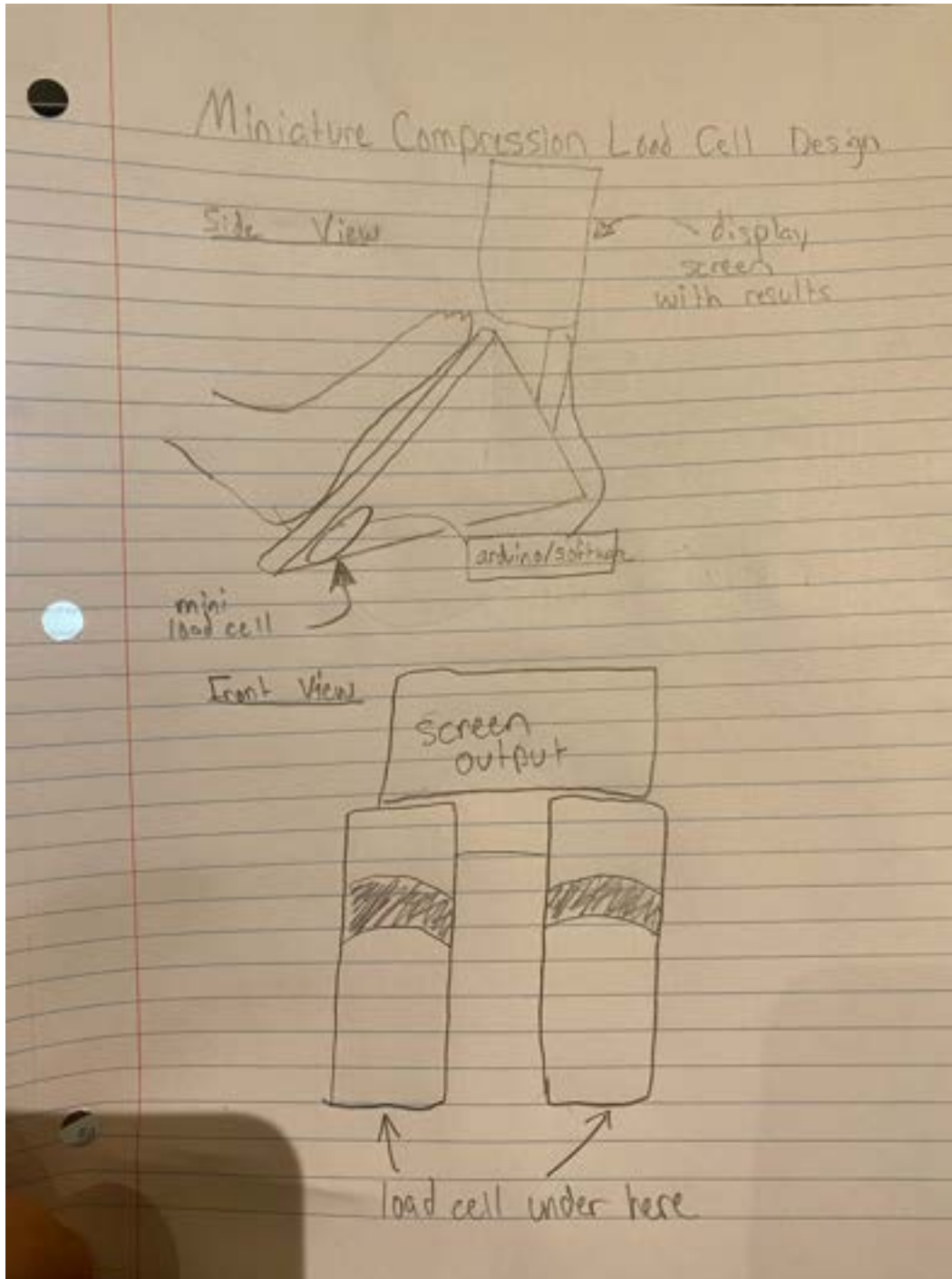**Title:** Miniature Compression Load Cell Design

Date: 09/26/2023

Content by: Bryan Topercer

Present: n/a

Goals: The goal is to create a design for the design matrix that can be analyzed and looked at as a potential prototype.

Content:

This design is simple, but effectively measures force output in the heels of rowers during their movements. The load cells in each heel will measure force output in each individual leg, and send that value to an intermediate device, such as an Arduino or microprocessor. This intermediate will then send data to a screen that will display force output in each foot, as well as a symmetrical value.

Conclusions/action items: This design is simple and cost effective, and uses the least amount of load cells possible to cooperate with the budget at hand. The screen is slightly more advanced and difficult to program, but will be much easier for rowers to get feedback and change their form.

09/28/2023 - Design Matrix Process

BRYAN TOPERCER - Sep 28, 2023, 10:11 AM CDT

Title: Design Matrix Process

Date: 09/28.2023

Content by: Bryan Topercer

Present: n/a

Goals: The goal is to be able to work with the team and create a design matrix that correctly evaluates both the best option for location of our device, and the best design.

Content:

 We sat down as a team and discussed all of our design and found three differing options that could be effective in different ways. Of those three designs, mine was one of which was considered for the final three designs, due to its simplicity and cost effectiveness. While creating the design matrix, I helped contribute to analyzing one of the locations for our design, the ergometer. Our process was very collaborative and we are ready for the next step of the design process.

Conclusions/action items:

I will have to begin helping find materials and prototyping our design, as well as prepare for the preliminary design presentation next week.

10/10/2023 - Force Sensitive Resistor Software

BRYAN TOPERCER - Oct 10, 2023, 9:29 PM CDT

Title: Force Sensitive Resistor Software

Date: 10/10/2023

Content by: Bryan

Present: n/a

Goals: The goal is to get an understanding of the software and coding involved with the force sensitive resistors. This will help me become more familiar with the prototyping process and get somewhat of a framework for how to code for force using resistors.

Content:

-The force sensitive resistor can take in pressure as an input and be able to understand its voltage. This can be converted into force.

-This simple coding takes pressure and outputs how much of a "squeeze" is applied. This is not what we will be doing, but is a sample for how levels of pressure can be outputted.

-An Arduino can be used to connect to the force sensitive resistor. We can be able to display a similar screen, however with force output instead of pressure. We also hope to be able to show force output in each leg, and create some sort of variable that can show the difference in force output (asymmetry) .

-This simple design used thresholds of pressure and corresponded them to light, medium, and big. We can do something similar for athletes so it is easier to interpret rather than reading numbers.

Citation:

Benne de BakkerBenne is professional Systems Engineer with a deep expertise in Arduino and a passion for DIY projects. "Force Sensing Resistor (FSR) Arduino Tutorial (3 Examples)." *Makerguides.Com*, 19 Aug. 2023, www.makerguides.com/fsr-arduino-tutorial/.

Conclusions/action items:

-Begin looking into purchasing materials and sensors needed to begin prototyping.

-Finish preliminary report

-Do additional research on competing designs.

10/26/2023 - Arduino Circuitry for Load Cells

Title: Arduino Circuitry for Load Cells

**Date:** 10/26/2023

Content by: Bryan Topercer

Present: n/a

Goals: To get a further understanding of how the Arduino code works when using a load cell, and how to circuitry will be assembled.

Content:

-Load cells can be used and programmed to measure force very accurately. This is done using a set of electrical resistances that respond to force applied and removed.

-This article in particular recommends an Arduino Uno 3 and HX711 amplifier to build the circuit. The amplifier is used to convert the very small load cell voltage readings into readable numbers that can be easily processed by the Arduino.

Step 4: Circuit
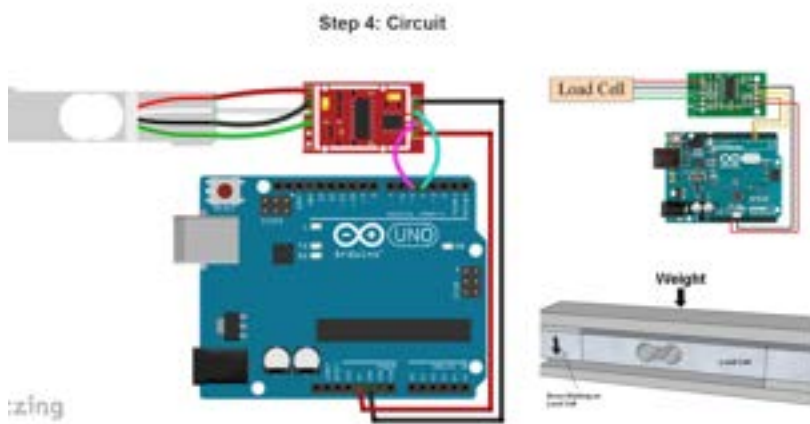
-This is an example circuit using the Arduino and a breadboard with wiring.

-When we receive the load cell, we must first calibrate it.

-The following is a sample for code that we can use to calibrate the load cell.

-We must then separately code the Arduino to be able to convert to force, this requires lots of software and coding that we will have to talk to the bioinstrumentation professor with.

Citation:

Electropeak, and Instructables. "Build a Digital Weight Scale & Force Guage W/ Arduino & Loadcell." *Instructables*, Instructables, 25 May 2019, www.instructables.com/Build-a-Build-a-Digital-Weight-Scale-Force-Guage/.

Conclusions/action items:

-The hardware for the Arduino circuit with the load cell is somewhat complicated, but Dr. Nimunkar can assist us during his office hours.

-I now have a general idea of what to expect when we work with Dr. Nimunkar, and am aware that code online can assist us in creating a successful circuit.

10/27/2023 - Load Cell Code

BRYAN TOPERCER - Oct 27, 2023, 5:51 PM CDT

Title: Load Cell Code/Software

Date: 10/27/2023

Content by: Bryan Topercer

Present: n/a

Goals: To understand the basics of the coding behind the load cells. Since we will be testing both the load cells and force sensitive resistors, it is important to understand both and have a basic knowledge of the software we will be building.

Content:

```
// Arduino with load cell

// Put two known loads on the sensor and take readings. Put those values
// here.
float aReading = 192.0;
float aLoad = 15.0; // lbs.
float bReading = 344.0;
float bLoad = 24.3; // lbs.

long time = 0;
int interval = 500; // Take a reading every 500 ms

void setup() {
  Serial.begin(9600);
}

void loop() {
  float newReading = analogRead(0);

  // Calculate load based on A and B readings above
  float load = ((bLoad - aLoad)/(bReading - aReading)) * (newReading - aReading) + aLoad;

  // millis returns the number of milliseconds since the board started the current program
  if(millis() > time + interval) {
    Serial.print("Reading: ");
    Serial.print(newReading,1); // 1 decimal place
    Serial.print("  Load: ");
    Serial.println(load,1);  // 1 decimal place, println adds a carriage return
    time = millis();
  }
}
```

-The following represents the code for the Arduino with reading a load cell. The load variables are already predetermined here, but our load variables should be coded and will be altered as a result of each applied load.

-This code is set up to take a reading every 0.5 seconds, and continues the process.

-The float load variable calculates the load using a simple formula.

-After the load has been calculated, simple print functions are written within an if statement. These will print out a reading of the load as well as the time between intervals.

-Dr. Nimunkar should be able to walk us through the software or at least give us a brief guideline on how to take an input from the load cell and output a force reading.

Citation:

Load Cell with an Arduino, edg.uchicago.edu/tutorials/load_cell/. Accessed 27 Oct. 2023.

Conclusions/action items:

-This software is not something we are going to completely copy, but helps me understand a brief outline of the process of taking in a load and outputting the load through Arduino code.

11/2/2023 - Embedding the Load Cell into Footplate

Title: Embedding Load Cell into Footplate

Date: 11/2/2023

Content by: Bryan Topercer

Present: n/a

Goals: As we have built our circuit, we now need to focus on how we are going to embed the load cell into the footplate without distracting a rower's movement.

Content:
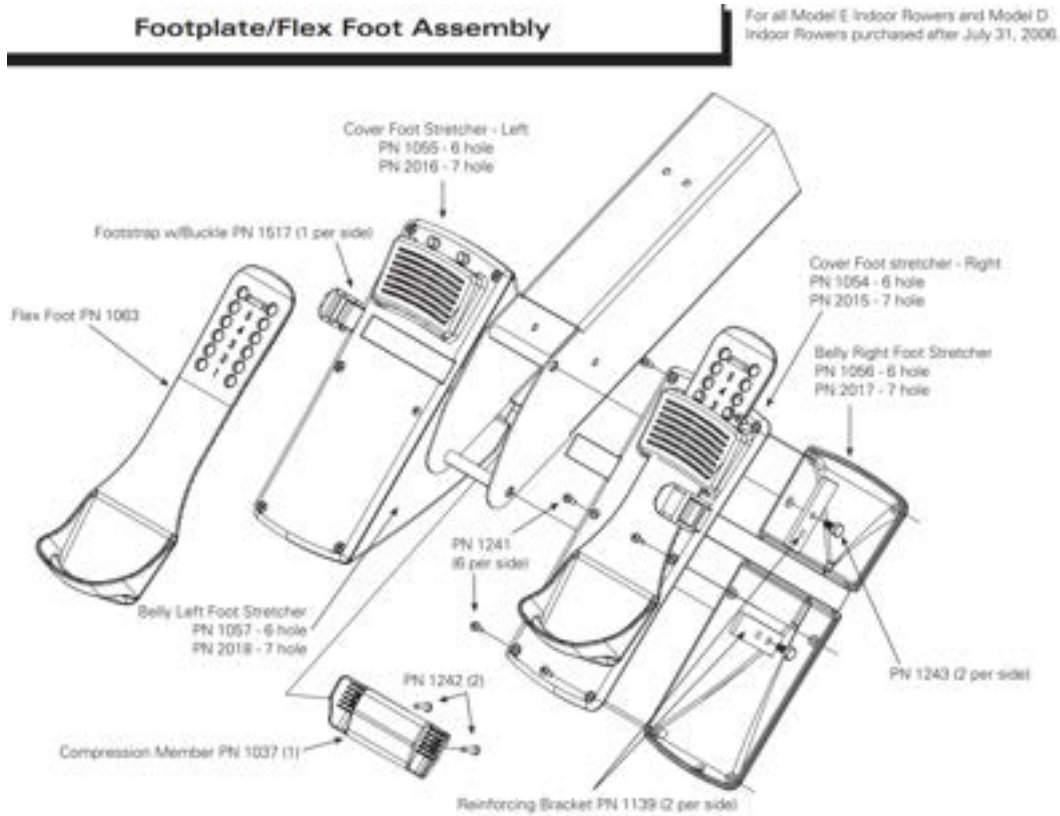
-This design is the footplate of an ergometer disassembled. Looking at the parts, the foot plate appears to be rigid and supported on top of a triangular shaped block.

-If the inside of this block is hollow, we can find a way to push the load cell as close to the bottom surface of the footplate as possible, we would just have to either 3D print or assemble a way to stabilize the load cell in place.

-
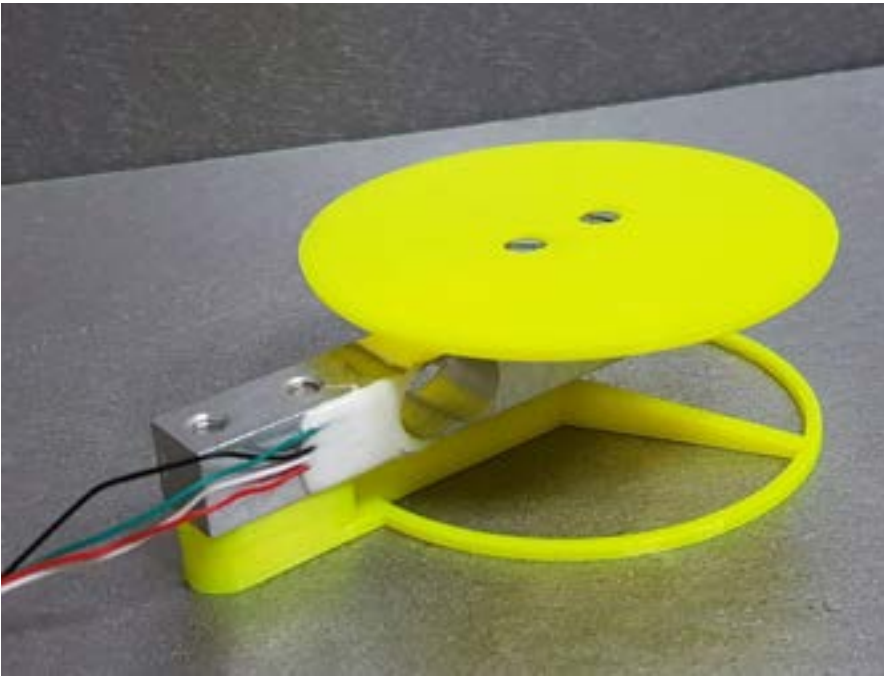
-Something similar to what is provided here could be a way to increase the area that an athlete can produce force over for the load cell. Additionally, this design stabilizes the load cell to the ground much more effectively.

-Depending on how high or low on the foot plate we plan to place the load cell, a similar mechanism to what is shown beneath the load cell can be used. We can just increase the height or add additional supports to stabilize the load cell at higher heights.

-We could also create a similarly shaped support to the triangular prism shape of the inside of the foot plate, and just place the load cell between the bottom of the footplate and the support we create. This would be stable, and if we 3D print at a high enough percentage, should be rigid enough to withstand strong forces and stay in place.

Citations:

Haseloff, Jim. "Weight Sensor - 1kg (HX711)." *Biomaker.Org*, Biomaker.org, 27 Jan. 2022, www.biomaker.org/block-catalogue/2021/12/17/weight-sensor-1kg-hx711.

Footplate/Flex Foot Assembly - Concept2, www.concept2.com/files/pdf/us/indoor-rowers/DE_FlexfootSchematic.pdf. Accessed 2 Nov. 2023.

Conclusions/action items:

-There are a variety of ways we can place the load cell inside the footplate, 3D printing will likely be the route we take unless we can find and use a different material such as a wood or metal.

-Prepare for show and tell, begin creating way to implement load cell into footplate.

11/2/2023 - Load Cell Embedding Drawings

Title: Load Cell Embedding Drawings

**Date:** 11/2/2023

Content by: Bryan Topercer

Present: n/a

Goals: I have already done research on ways to imbed the load cell using 3D printing, the goal of this entry is to create drawings for tentative ideas of how we are going to approach this.

Content:
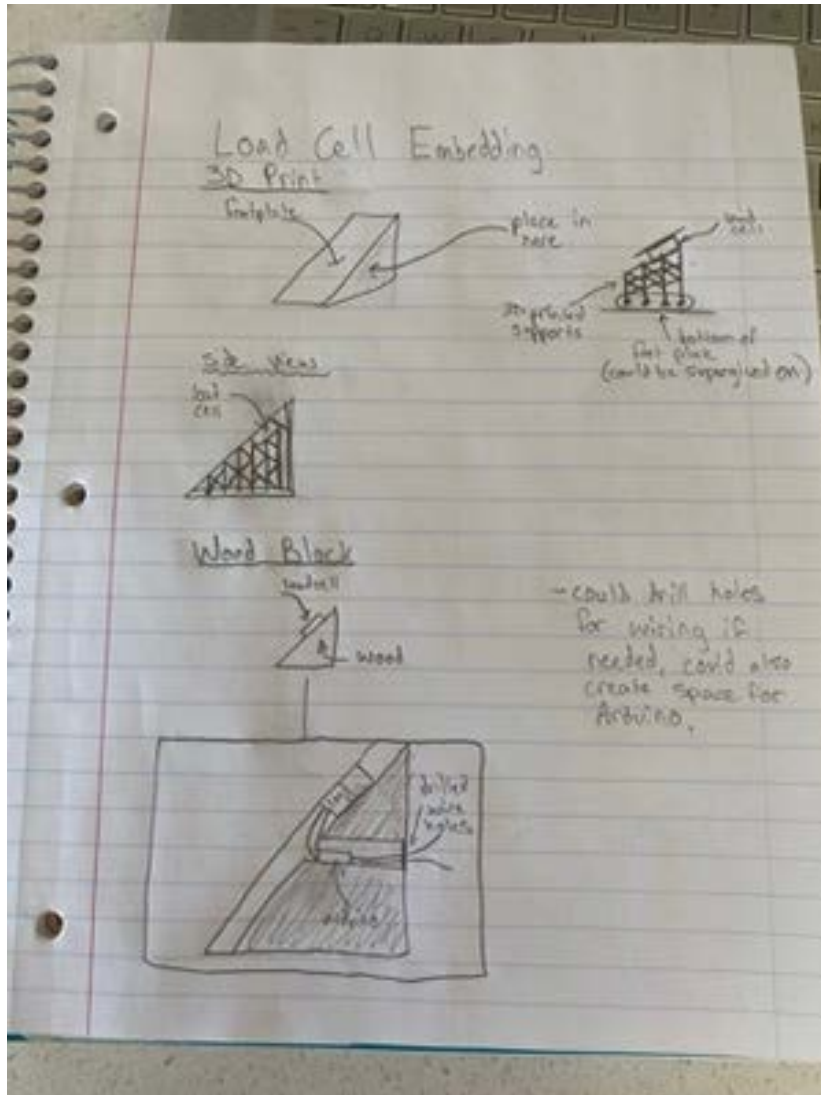
-The two designs above are made of different material with similar concepts, one made of 3D printing material, the other of solid wood. Both have their benefits and downsides in terms of fabrication or stability, but are viable options to plant our load cell into the foot plates, given a triangular shape.

-This design can be altered in any way to fit a different shape such as a rectangle.

Conclusions/action items:

-Prepare for show and tell and continue conducting any necessary research.

Conclusions/action items:

-Prepare for show and tell and continue conducting any necessary research.

10/4/23 - Creating Preliminary Design Presentation

BRYAN TOPERCER - Oct 10, 2023, 9:11 PM CDT

Title: Creating Preliminary Design Presentation

Date: 10/4/23

Content by: Bryan Topercer

Present: n/a

Goals: The goal is to add my slides to the preliminary design presentation and create somewhat of a script to base my presentation off of.

Content:

This week I have not had much new additional information researched, but have worked on many things such as the design matrix, presentation, and report. The force sensitive resistor is the design we have chosen, however may be somewhat difficult to prototype due to coding and software. I will need to do research on this in order to get a further understanding and effectively work on prototyping. In terms of the presentation, I have been working on the load cell compression slides and the design matrix. I will be presenting these slides, and am gaining an understanding of why certain designs had certain strengths and weaknesses.

Conclusions/action items:

-Overall the presentation process went smoothly, and slides were created well.

-Do more research on software for force sensitive resistors.

10/10/2023 - Preliminary Report Notes

BRYAN TOPERCER - Oct 10, 2023, 9:53 PM CDT

Title: Bryan Topercer

Date: 10/10/2023

Content by: Bryan Topercer

Present: n/a

Goals: To work on my assigned sections of the preliminary report and make notes/remarks on my writing process.

Content:

-I was assigned to work on the introduction portion of the preliminary report. This includes 3 sections: motivation, existing devices, and the problem statement.

1. Motivation

-For the motivation section I thought about what our first client meeting included and what the clients were really looking for. They had many athletes who were struggling with lower back pain and were more so looking for a way to be able to quantify asymmetry, and potentially gain more information for personal trainers.

2. Existing Devices

-I aimed to find 3 different existing devices and give a brief explanation of how they function, and what similarities they have to our project.

-The three devices I decided to include were the BioRow force plates, Concept2 Row Erg, and

-I simply stated how each device functions and what its purpose it, and included a citation for each.

3. Problem Statement

 -The problem statement included similar elements to the motivation, however also highlighted what the rowing team is looking for, and what they currently do not have. This essentially sets up for the rest of the report, and how we aim to tackle this problem and help the team find a way to quantify asymmetry in their rowers.

Conclusions/action items:

-Finish up working on notebook and adding all entries

-Begin looking into prototyping

10/27/23 - McClain Center Visit

Title: McClain Center Visit

Date: 10/27/2023

Content by: Bryan Topercer

Present: n/a

Goals: To be able to see the ergometer in person as well as get measurements for a prototype that we can create for show and tell, as well as a final product.

Content:

-We went near the weightroom of the McClain center and looked at the ergometer.

-We initially took pictures from different angles, these will be in our shared Google Drive.

-We took measurements of different parts of the footplates: the entire footplate itself, the flexible and moveable section, and the heel plate.

-We discussed with Tricia bringing an ergometer to show and tell, and are now prepared to begin prototyping and have full dimensions in SI units.

Conclusions/action items:

-We are prepared to begin prototyping for show and tell, as well as our actual final design.

-We are soon meeting with Dr. Nimunkar to build our circuit.

11/1/23 - Visit With Dr Nimunkar

Title: Office Hours with Dr. Numinkar

Date: 11/1/23

Content by: Bryan Topercer

Present: n/a

Goals: To get help from Dr. Nimunkar on assembling the load cell circuit and create a very rough prototype that we can use at show and tell, as well as for a proof of concept for our design later on.

Content:

 -We will need an amplifier to connect load cell to Arduino, this will increase the strength of signals going through the load cell and create more accurate values.

-Our current load cell is not the intended shape, but should be able to read compressive forces up to around 10 lb, this is just for proof of concept that an applied force is read on the display.

-The circuit setup is mainly online via websites or the load cell website itself, as well as the amplifier website has its details on connection to the Arduino as well.

Conclusions/action items:

-We will need to build the circuit ourselves, but Dr. Nimunkar helped clarify the process as well as showing us resources available to help create the circuit.

-We will need to find our own code for the real time display stats.

11/26/2023 - Calibration Factor and Solidworks Designs

BRYAN TOPERCER - Dec 03, 2023, 3:45 PM CST

Title: Calibration Factor and Solidworks Designs

Date: 11/26/2023

Content by: Bryan Topercer

Present: n/a

Goals: As we begin fabricating, we need to split into teams to accomplish two different goals: finding the calibration factor for our load cell that is accurate and consistent, and create solidworks designs that we can later 3D print for embedding the load cell into the foot plate.

Content:

-We will use known weights supplied by Dr. Puccinelli to calibrate the load cell.

-Calibration is done directly on the Arduino software; we will apply different known weights to the top of the load cell, and manually adjust the calibration factor until the real time data accurately reads the applied weight.

-We were able to find a calibration factor that was relatively accurate, however, the load cell has an oddly shaped point load at the top, which makes it nearly impossible to balance the weights without holding onto them with our hands for support. This may alter the overall accuracy of our data, but has shown to still be consistent and accurate.

-I worked on creating Solidworks designs with Emily for embedding our load cells. One of the designs was a simply shaped box with fillets for heel support, and the other design allowed the load cell to be placed inside and supported. These will be later 3D printed.

Conclusions/action items:

-We were able to get a relatively accurate calibration factor but are going to try another method during our next group meeting to ensure even more accuracy, if possible.

-We need to 3D print the Solidworks designs and create backup plans if these designs do not work as we intended.

-Begin working on final deliverables

12/1/2023 - Initial Testing and Poster Work

BRYAN TOPERCER - Dec 03, 2023, 3:55 PM CST

Title: Initial Testing of Calibration Factor and Poster Work

Date: 12/1/2023

Content by: Bryan Topercer

Present: n/a

Goals: We want to have quantitative data for our final poster and report, so we must test our load cell using its calibration factor and quantify this testing. We also want to begin working on our final poster as much as possible.

Content:

-To create testing data using our calibration factor, we conducted the following test:

-Every group member would balance the known weight on the load cell, and we would manually adjust the calibration factor accordingly. After all members have balanced the weight, we average the calibration factors, and the following calibration factor will be further tested.

-Once we have the average calibration factor, every group member will balance the known weight and we will get a corresponding reading. The known weight and weight read by the load cell will be compared in a data chart. This will be conducted multiple times per person to ensure accuracy.

-We then tested our bodyweight on the load cell, however ran into issues of the measured weight being very low. We figured this to be due to the rubber material of our shoes, which absorbed into the load cell and did not give our entire body weight as a result.

-After our testing was concluded, we worked on as much of the poster as possible, as our final prototype is not yet completed.

Conclusions/action items:

-Pick up 3D prints (assuming not delayed) and install

-Finalize poster for presentation.

-Test with client on Monday

12/4/2023 - Client Testing

BRYAN TOPERCER - Dec 04, 2023, 9:21 PM CST

Title: Client Testing

Date: 12/4/2023

Content by: Bryan Topercer

Present: n/a

Goals: Today we are having Sara test out our final prototype, using her rowing technique to collect data and results on the performance of our design.

Content:

-We finalized our prototype and prepared it for Sara to use. We have created a plate on top of the point load on the load cell and have installed a Velcro system to easily attach our load cell design to the erg.

-Sara tested the erg, and we were able to get good data; her push off motion created the largest force reading, and her catch motion produced the least, right around 0 force.

-We were able to identify asymmetries in her rowing; specifically, her left side produced less force than her right on average.

-We have copied data from the client testing trials and are converting them into readable data methods for the final poster.

Conclusions/action items:

-Our prototype seems to be successful based on client testing, and we have all data needed for the poster. We now need to complete the poster and prepare for the presentation.

-Finish other deliverables (report).

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: