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UNIVERSITY OF WISCONSIN–MADISON

Force Sensors to Reduce Lower Limb Asymmetry in Rowers

Clients:
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Ms. Sarah Navin

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The Clients

Figure 1.

Tricia De Souza

UW Athletic Trainer

[1]

Figure 2.

Jill Thein-Nissenbaum

UW Athletics Physical Therapist

[2]

Figure 3.

Sarah Navin

PT Student

Former UW Crew

[3]

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Overview

- Problem Statement
- Background Research
- Competing Designs
- Product Design Specifications
- Preliminary Designs
- Design Matrices
- Conclusion and Future Work
- Acknowledgements
- References

Figure 4. UW-Madison Rowing [4]

Problem Statement

- Rowing athletes, particularly women, are susceptible to lower back or hip injuries
  - Asymmetric weight distributions on each leg while rowing

- Current methods
  - Studies outside of the environment
  - Real-time data is hard to obtain on the water

- Sensor system to collect biomechanical data from rowers' lower extremities
  - Capture load distribution during time of use in the rowboat

- User-friendly interface
  - Assess lower extremity asymmetry
  - Improve both performance and safeguarding against injuries

Background

What is sculling vs sweeping?

UW Madison's Crew Team primarily scull row with 8 for races

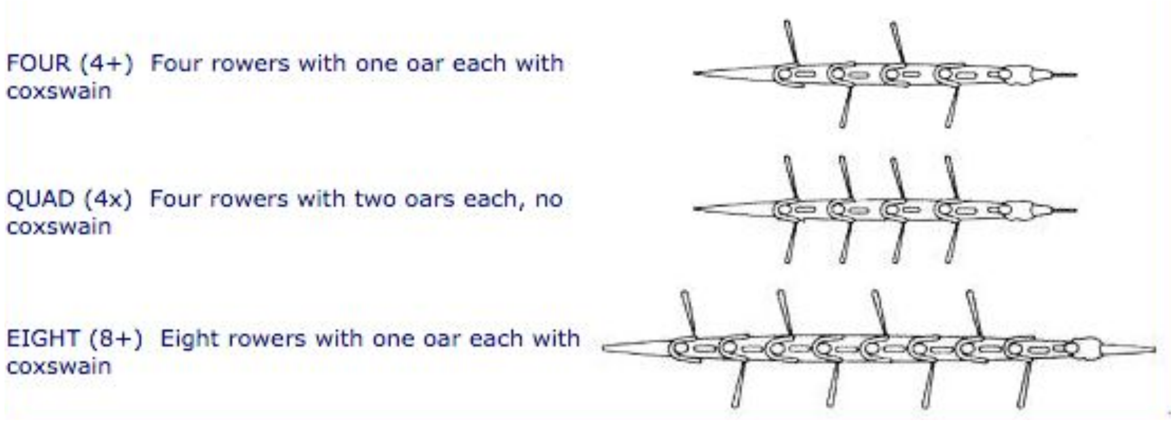

Figure 5. Rowing Terminology [5]

- When rowing, legs do the most work [6]
- Only having one oar can cause differences in force exertion through each foot based on which side the oar is
- The UW Madison Porter Boathouse has ergometers but with sweep rowing configuration

Competing Designs

- BioRow 2D Stretcher [7]
  - Load cells utilize strain gauges
  - Senses horizontal and vertical force components
  - Two load cells per foot
- Bertec Force Plate [8]
  - Load cells on each corner
  - Collects forces in all three directions
  - Designed for gait, balance, and performance analysis

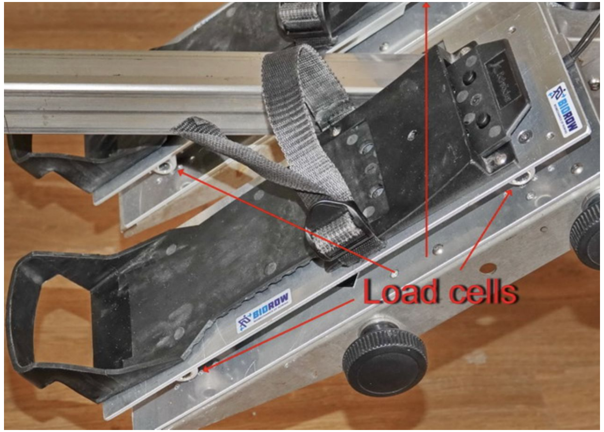

Figure 6. BioRow 2D Stretcher [7]

Figure 7. Bertec Force Plate [8]

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Product Design Specifications

Must be compatible with Concept2 RowErg:

Figure 8. RowErgs in the boathouse tank

Figure 9. Foot stretcher on Concept2 RowErg

Figure 10. Concept2 RowErg [12]

- Transferable and reproducible in boat
- Measure force magnitude within 5% error [9]
- Life in service of 10-12 years [10]
- Withstand temperatures from 8.3° C to 22.2° C [11]

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Force-Sensitive Resistor

- Thin sensors that detect pressure through compression
- Changes its resistive value (in ohms Ω) depending on how much it is pressed
- Water resistant and low cost
- Can be directly taped on the footplate allowing easy fabrication

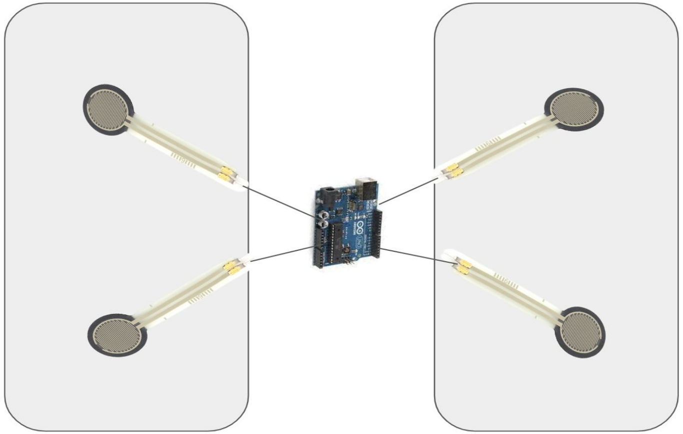

Figure 12: Force-Sensitive Resistor Design

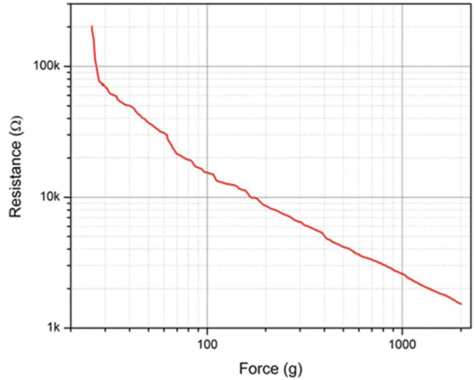

Figure 13: Sample Force-Resistance curve of a Force-Sensitive Resistor [13]

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Silicone-Magnetic Force Sensor

- Many market-brand force cells/sensors are over the group budget
- Magnetic sensors involve the "Hall effect" [14]
    - Combining usage of electric currents and magnetic fields
- Utilizes either high-end sensors or cheaper chips
- An existing experiment tested *compression* [15], which would align directly with the client's wishes
- Sensors would be fabricated directly by the team, cutting down immensely on costs

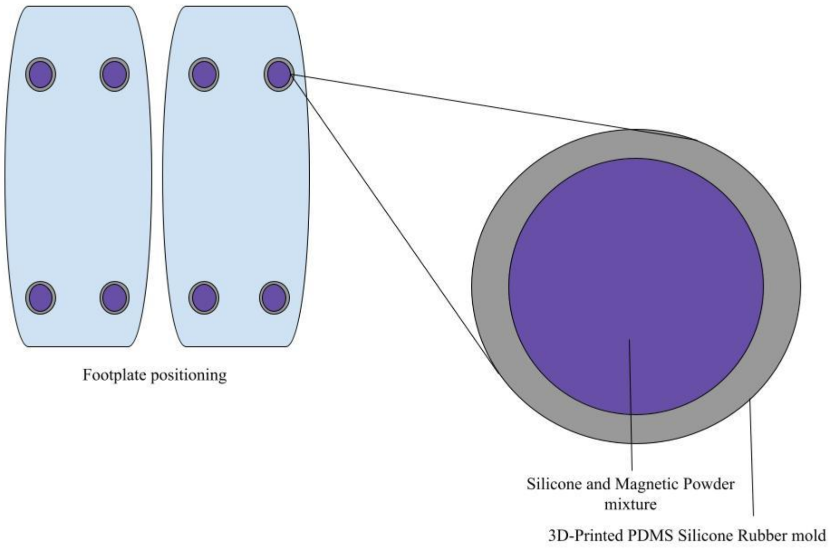


Figure 13. A Google sketch of the shape and placement of this design.

Miniature Compression Load Cells

Figure 14: A miniature compression load cell [16]

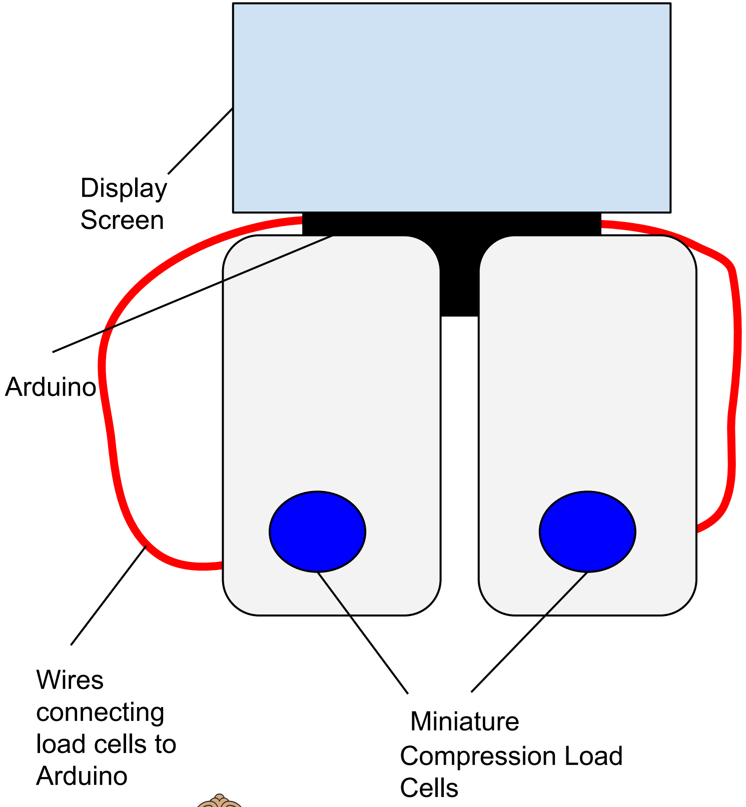
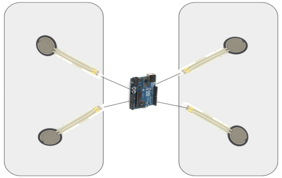


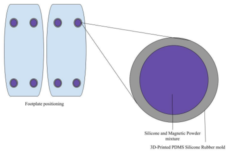
Figure 15: A sketch of the Miniature Compression Load Cell Design

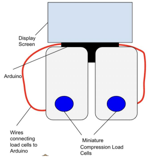
- Miniature Compression Load Cells
  - Cost effective, small, minimize interference
- Wires connect load cells to Arduino
- Arduino connects to display screen
- Load cells under heels

Design Matrix - Force Sensor Designs

Table 1: Design matrix for the evaluation of 3 proposed designs for the device.







		Force-Sensitive Resistor		**Silicone-Magnetic Force Sensor**		**Miniature Compression Load Cells**	
Criteria	**Weight**	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score
Functionality	25	4	20	4	20	5	25
Ease of Use	20	4	16	4	16	5	20
Cost	15	5	15	3	9	2	6
Safety	15	3	9	3	9	4	12
Compatibility	15	5	15	4	12	4	12
Reproducibility	10	4	8	3	6	3	6
Sum	**100**	**Sum**	**83**	**Sum**	**72**	**Sum**	**81**

Design Matrix - Location of Device

Table 2: Design matrix for the evaluation of 3 proposed locations for the device.

		Ergometer 		Boat 		Tank 	
Criteria	**Weight**	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score	Score (5 max)	Weighted Score
Resemblance	30	0	0	5	30	5	30
Compatibility	25	1	5	3	15	4	20
Complexity	20	3	12	2	8	4	16
Safety	15	3	9	4	12	4	12
Cost	10	3	6	3	6	3	6
Sum	**100**	**Sum**	**32**	**Sum**	**71**	**Sum**	**84**

Future Work

- Improving Design
  - Integrate design into an 8 person row boat
  - Waterproofing
- Build Prototype
  - Challenges: placement of circuit, software
- System for measuring accuracy→ testing

Figure 16: Picture of rowing shoes mounted onto footplate of boat

Acknowledgements

- Dr. Jill Thein-Nissenbaum
- Ms. Tricia De Souza
- Ms. Sarah Navin
- Dr. Joshua Brockman
- Ms. Adrienne Kisting
- UW Rowing Team Staff and Athletes

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Questions?