Moviflex Stationary Rehabilitation Bike

Team 9

Jessica Hasson, Carder House, Sarah Lawson and Mihiri Rajapaksa

March 2nd, 2016

Heilmeier Hall (Towne 100)

ROADMAP

- Background and Problem Description
- Second Semester Progress
- Validation/Testing Plan
- Project Timeline

An Essential Need

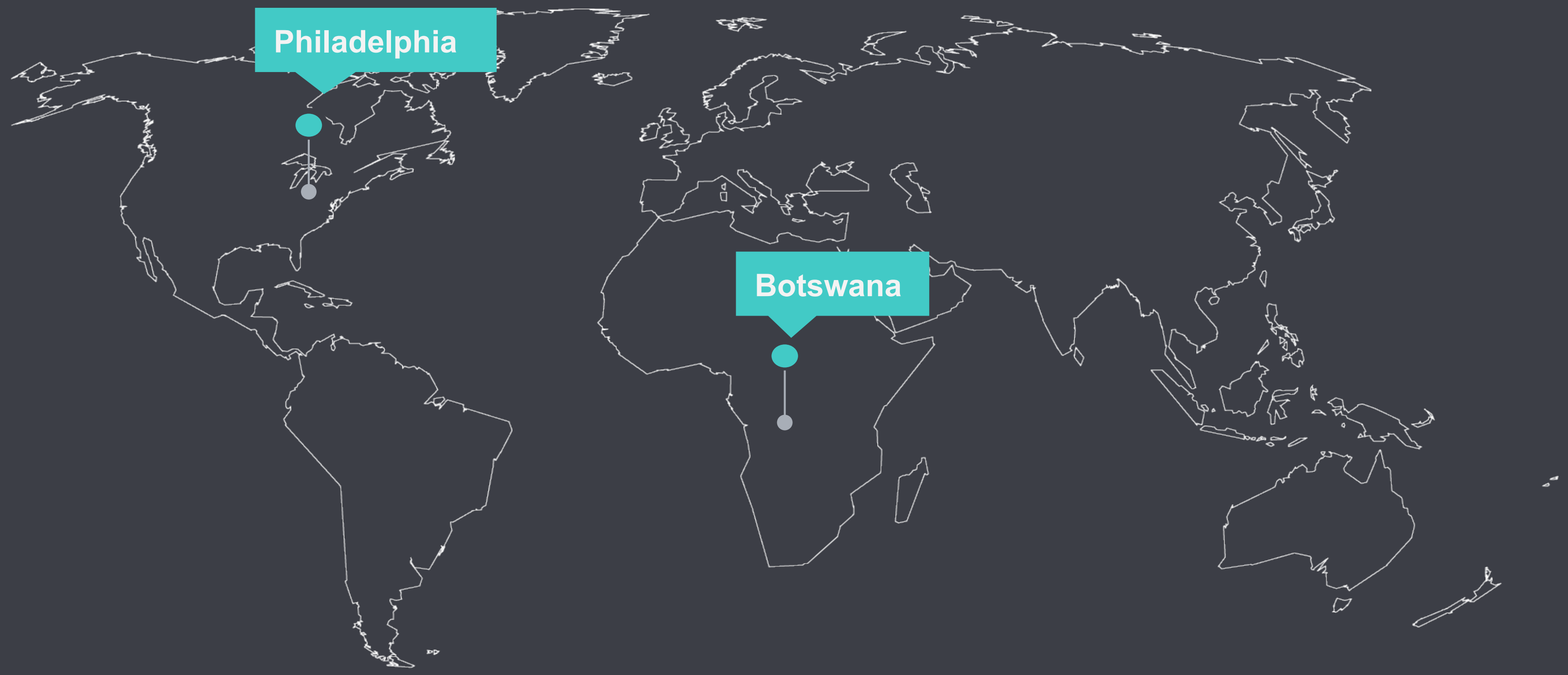
1 out of 500
live births in the United States are affected by Cerebral Palsy (CP) [1]

0
cures exist. However, frequent Physical Therapy (PT) at a young age can increase long term muscle functionality [2]

$921,000
Is the average monetary lifetime expense of living with CP [3]

[1] Stern Law Group, 2015
[2] Palisano et al., 2015
[3] CerebralPalsy.Org, 2016

Problem Statement



Device cost, energy usage, and accessibility make existing rehab devices inaccessible to people in low resource communities

Existing Solutions

Motomed Stationary Bike

[4]

$7000

Freedom Concepts Adaptive Bike

[5]

$3000

Elementary Semi-Recumbent Exercise Bike

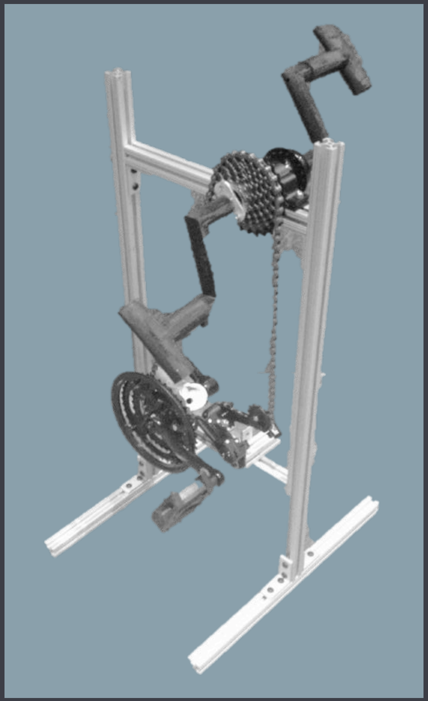
[6]

$2000

Our Solution

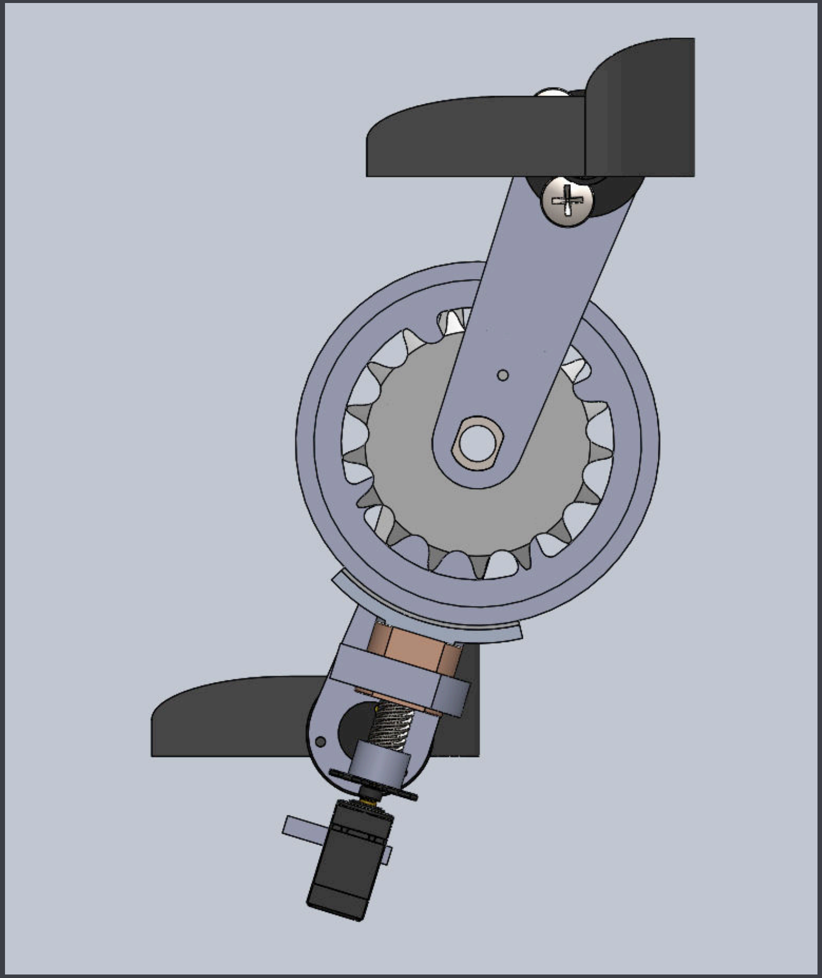
$500-1000

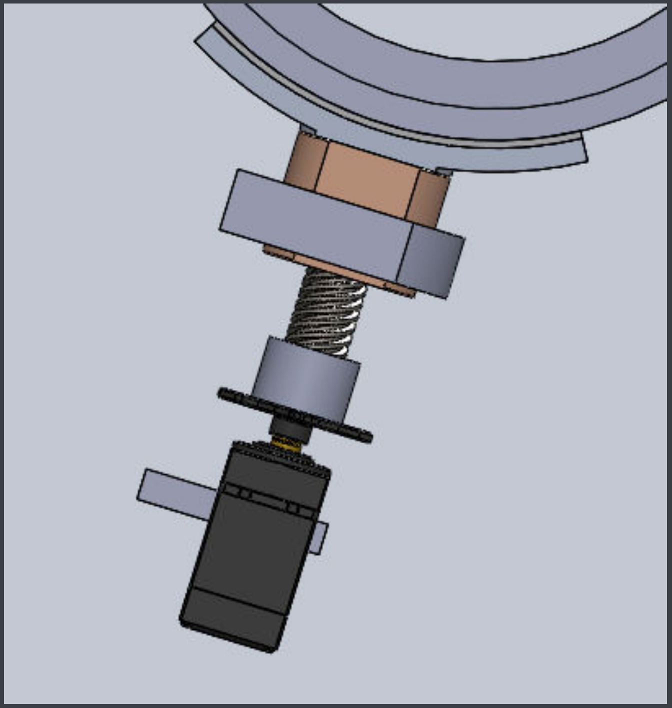
Project Progress: Design Iterations



Project Progress: Updated Design

Project Progress: Braking Design





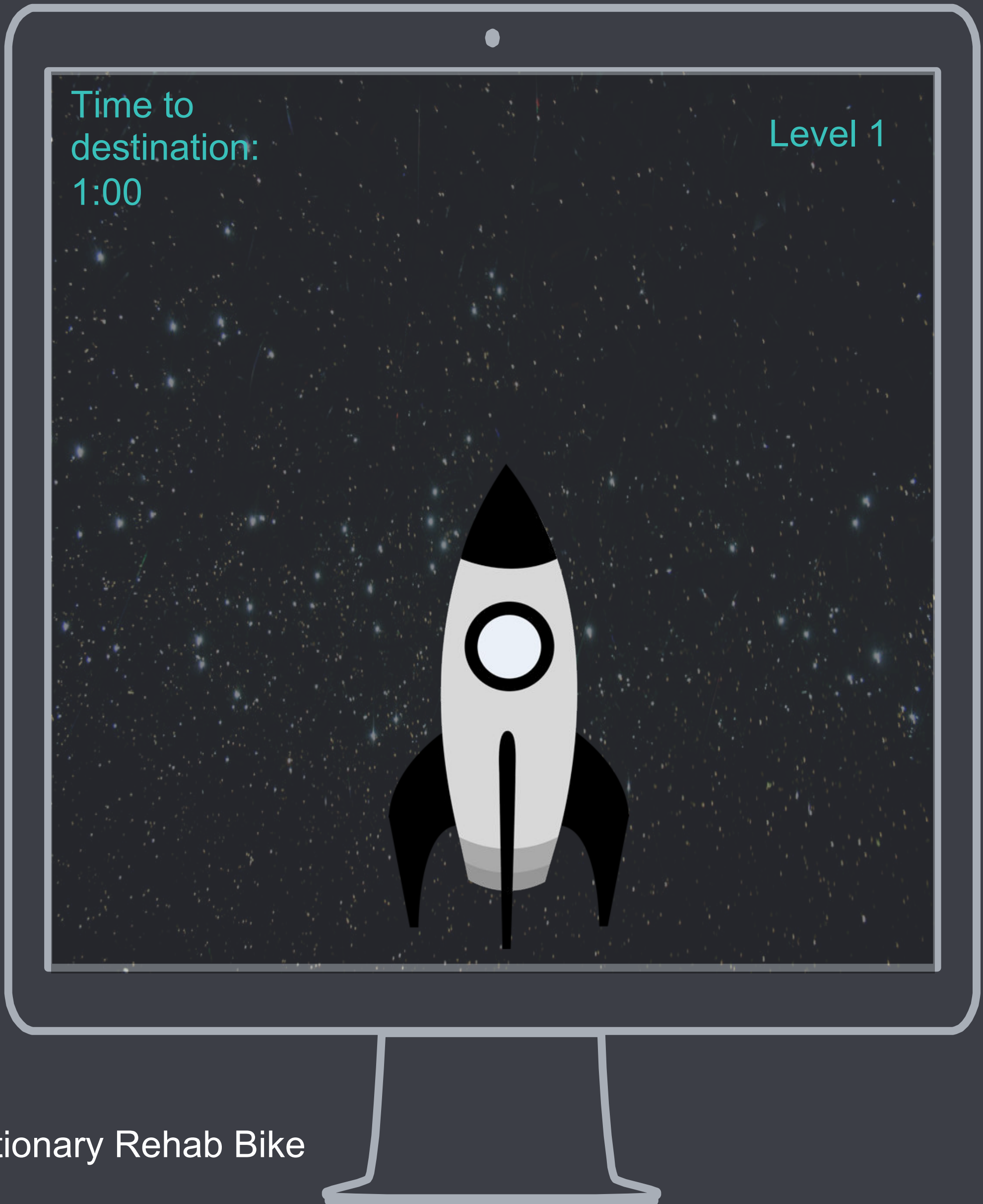
Project Progress: Relevant Calculations

- Chain Tension
  - Allowable torque of chain needed to resist torque from child's spasm without breaking
- Tipping
  - Static equilibrium (by balanced moments) to ensure support for off-center weight of chil
- Sizing
  - Overall dimensions set for an average 9yr old. Safe/comfortable joint angles
- Braking
  - Servo and lead screw optimized to allow for 0-6lbs resistance force.

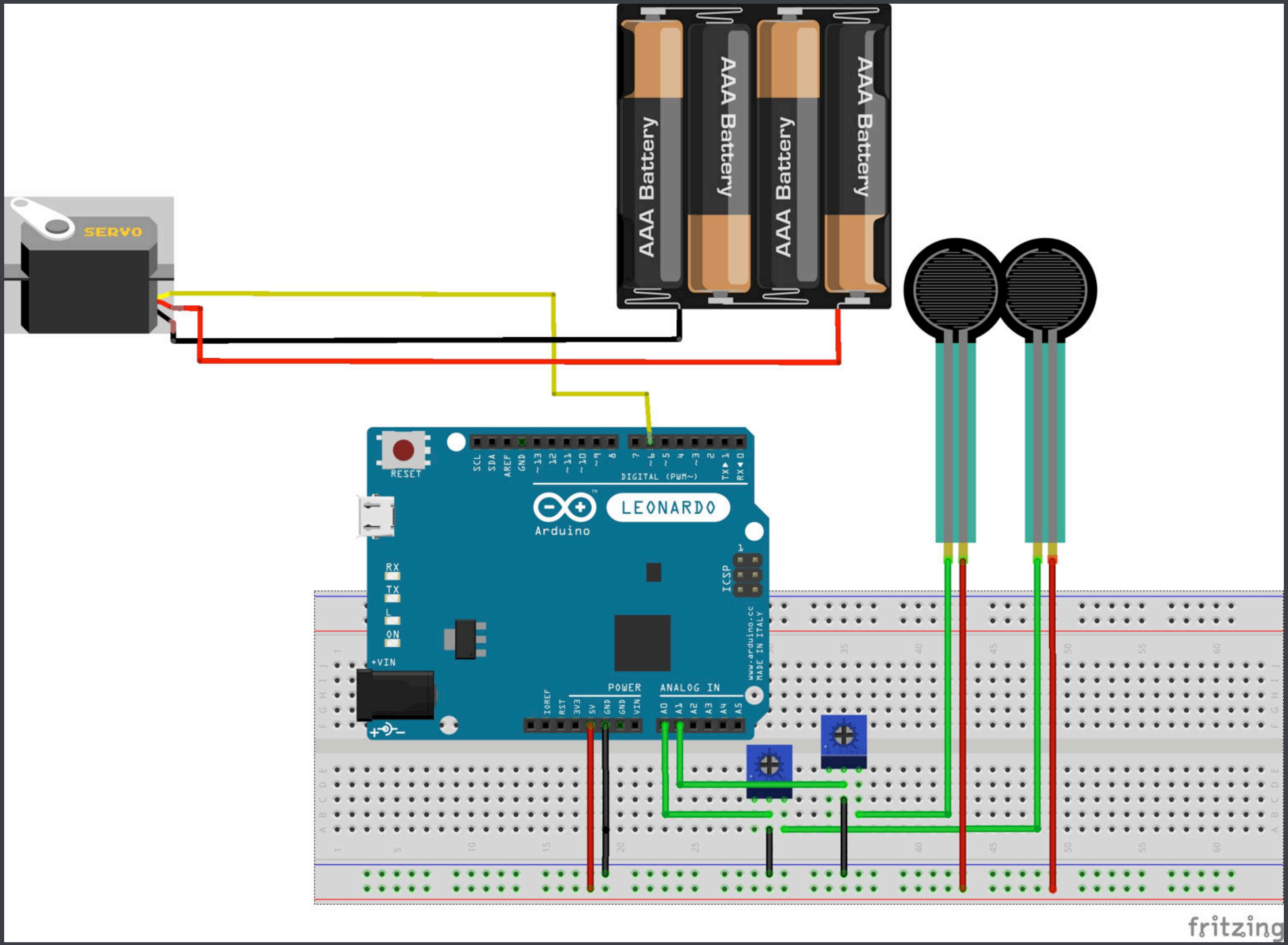
Project Progress: Manufacturing

Frame	Machined and Assembled
Power Transmission	Machined and Assembled
Hand Pedals	Options 3D Printed-awaiting testing
Foot Pedals	Revising Design
Braking	Ready to Machine
Power Generation	Mostly donated, but interface needed
Cover	Ready to Machine/Thermoform

Project Progress: Arduino Coding

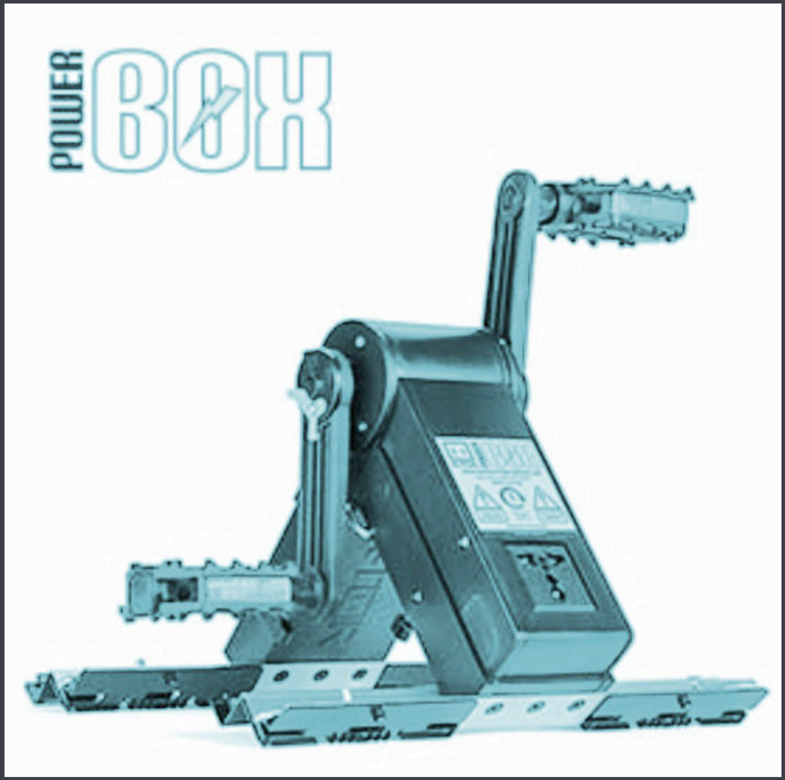


Project Progress: Arduino Coding



Project Progress: Energy Generation

- Gained a new sponsor, K-TOR Human Energy
- Donated pedal-powered generators allow us to revise our previous energy-consumption limits



[7]

Validation: Goals and Objectives

- Due to both time and HIPAA*-related constraints, we will not be able to quantitatively assess whether our project is “useful”

- Utilizing resources within CHOP and Penn Engineering, we will be able to both quantitatively and qualitatively be able to determine whether our device is “useable”

Physical therapy for cerebral palsy patients improves flexibility, strength, mobility and function

*HIPAA = Health Insurance Portability and Accountability Act

Testing Plan: CHOP

- Met with Rehab specialists at CHOP
- In the process of getting “Observer” Credentials
    - Determine if CP children can power electronics
        - Calculate power consumption of system
        - Measure average cadence of CP children, plot cadance vs. power output
        - Success = children can meet threshold
    - Quantify comfort of handles, seat in survey
    - Measure the forces CP children can exert on the hand pedals
        - Success = all values lie in a determinable, codeable range

Testing Plan: Meeting with Experts

- Our clearance will allow us to visit CHOP on “CP Clinic” days and interact with PT experts and families of children with CP

With this their help, we can have expert feedback on the device’s:

- Game premise and interface
- Design/concept
- “Buying Potential”

Testing Plan: Penn Engineering

- Some of our group members and existing members of the Penn community lie within the 95th percentile height/weight range of our potential users

- We can have these able bodied users test our fully-assembled system
  - Proof of Concept
  - Durability
  - Paid/volunteer testing

Project Timeline

Weeks 25-27

- Run tests at CHOP
- Complete coding
- Integrate all subsystems
- Thermoform case

Weeks 27-29

- Redesign based on conclusions from testing
- Visit CHOP and reiterate again if possible

Weeks 29-31

- Assemble final findings into paper
- Prepare for final presentation

Week 31

- Hand over to Dr. Johnson and her lab

Advisors

Dr. Michelle Johnson
Assistant Professor, HUP Physical Medicine & Rehabilitation

Dr. Phillip Bryant
CHOP Chief of Physical Medicine & Rehabilitation

Dr. Laura Prosser
research Scientist, CHOP Physical Medicine & Rehabilitation

Sponsors

K-TOR
Human Energy

Orbex Group
Revolution In Motion

The Rehabilitation Robotics Lab at Penn

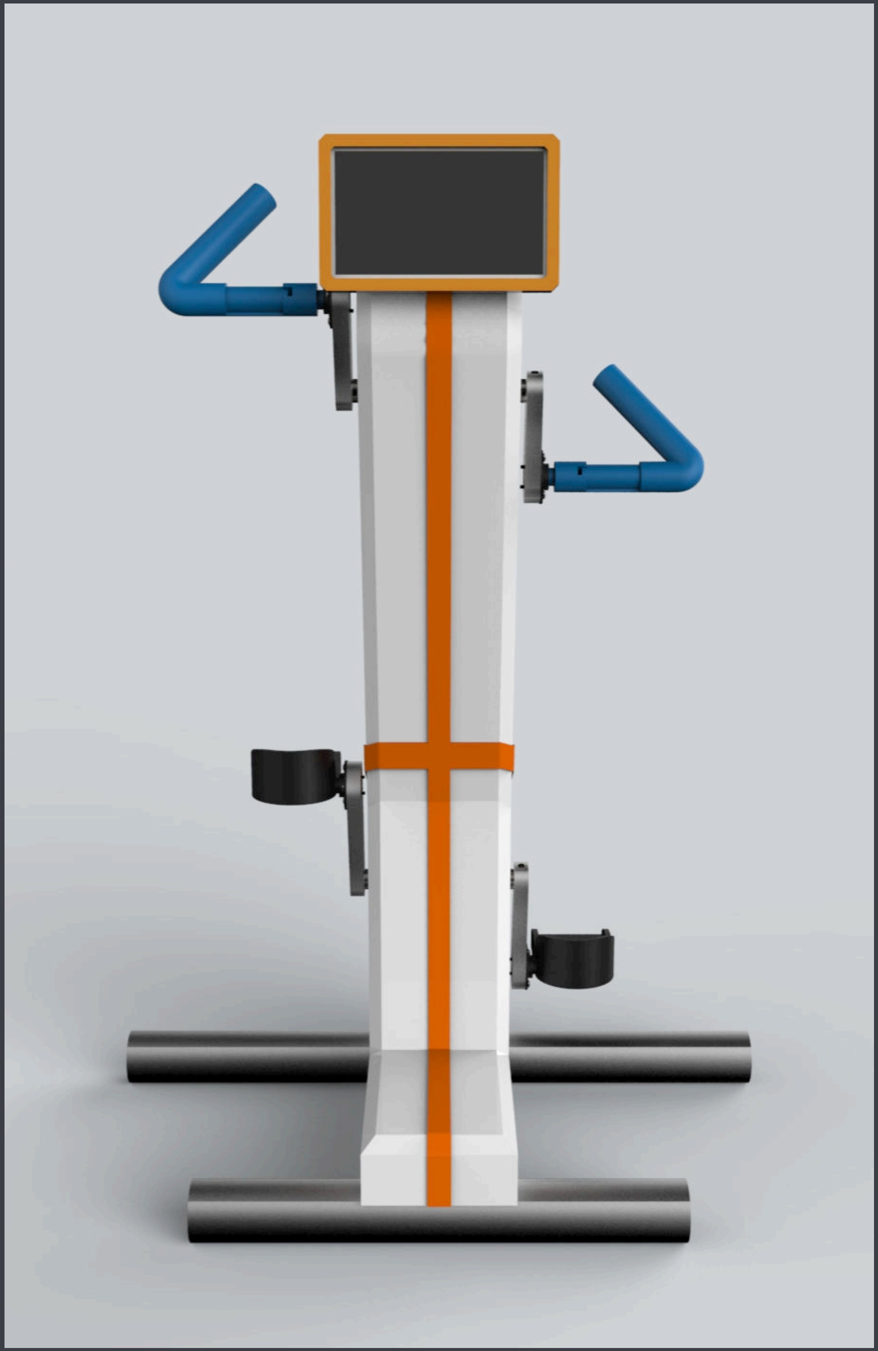
Penn Medicine

GoodShepherd
Penn Partners

GRASP
Laboratory





Reference List

[1] Stern Law Group, PLLC. "The Ultimate Resource for Everything Cerebral Palsy." [Online]. Available: http://cerebralpalsy.org/about-mychild/

[2] Palisano, Robert, Peter Rosenbaum, Stephen Walter, Dianne Russell, Ellen Wood, and Barbara Galuppi. (1997). "Gross Motor Function Classification System for Cerebral Palsy." [Online]. Available: http://wiredspace.wits.ac.za/bitstream/handle/10539/6922/Appendix%20IV.pdf?sequence=5

[3] "Costs of Cerebral Palsy." CerebralPalsy.Org. [Online]. Available: http://www.cerebralpalsy.org/about-cerebral-palsy/costs

[4] "MOTOMed." Walk on Wheels. [Online]. Available: http://www.walkonwheels.net.au/motomed_cat_7.php

[5] "Freedom Concepts Discovery Series." RehabMart.com. [Online]. Available: http://www.rehabmart.com/product/freedom-concepts-discovery-dcp-12-pediatric-trike-28481.html?gclid=Cj0KEQiAu9q2BRDq3MDbvOL1yaYBEiQAD6qoBoGanpRJ0JbGjj0puBGMFtbFAFwCmbO5QY5T_I014t4aAvmr8P8HAQ

[6] "Elementary Semi-Recumbent Exercise Bike." RehabMart.com. [Online]. Available: http://www.rehabmart.com/product/elementary-semirecumbent-exercise-bike-35361.html?gclid=Cj0KEQiAu9q2BRDq3MDbvOL1yaYBEiQAD6qoBn8XOEvTACzgXEfvfwvQ4Htvj7TXRUzarbthri5AsWEaAqdr8P8HAQ

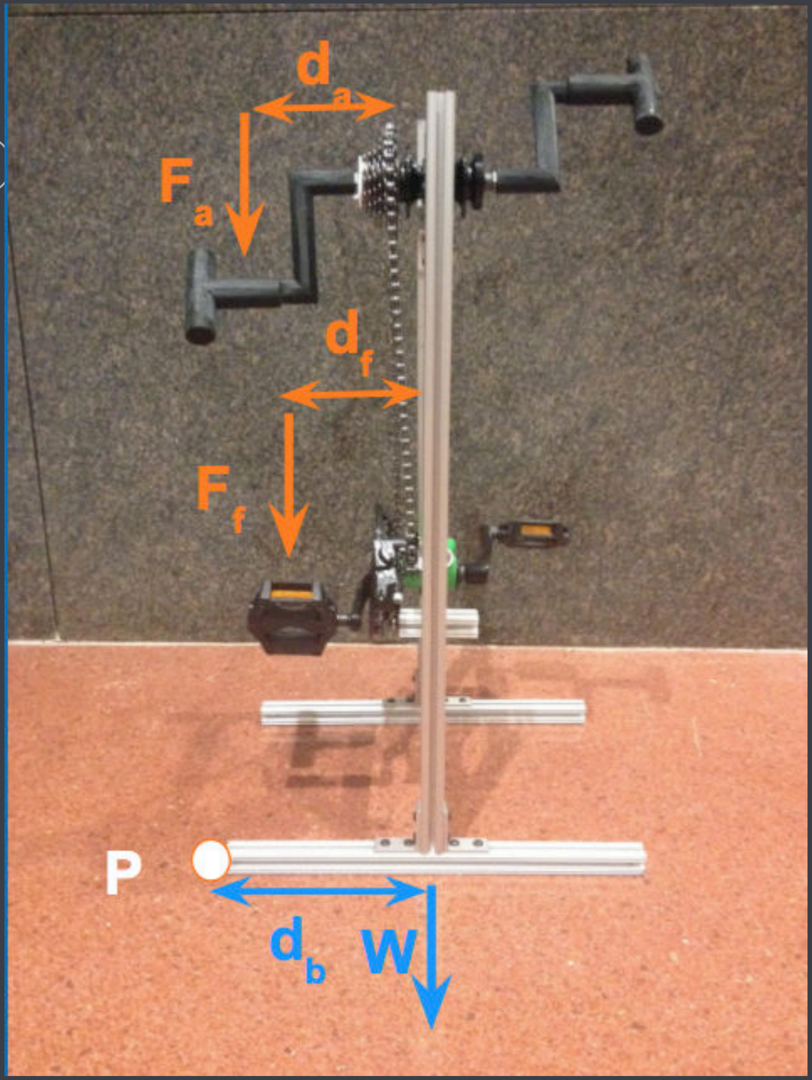
[7] "Power Box." K-TOR Human Energy. [Online]. Available: https://www.k-tor.com/power_box.php

[8] A. R. Tilley, *The measure of man and woman: human factors in design*. New York: Wiley, 2002.

[9] Willemse, L., Brehm, M. A., Scholtes, V. A., Jansen, L., Woudenberg-Vos, H., &Dallmeijer, A. A. (2013). Reliability of Isometric Lower-Extremity Muscle Strength Measurements in Children With Cerebral Palsy: Implications for Measurement Design. *Physical Therapy*, 93(7), 935-941. Accessed March 01, 2016. http://ptjournal.apta.org/content/93/7/935.full.pdf+html.

Appendix Slides

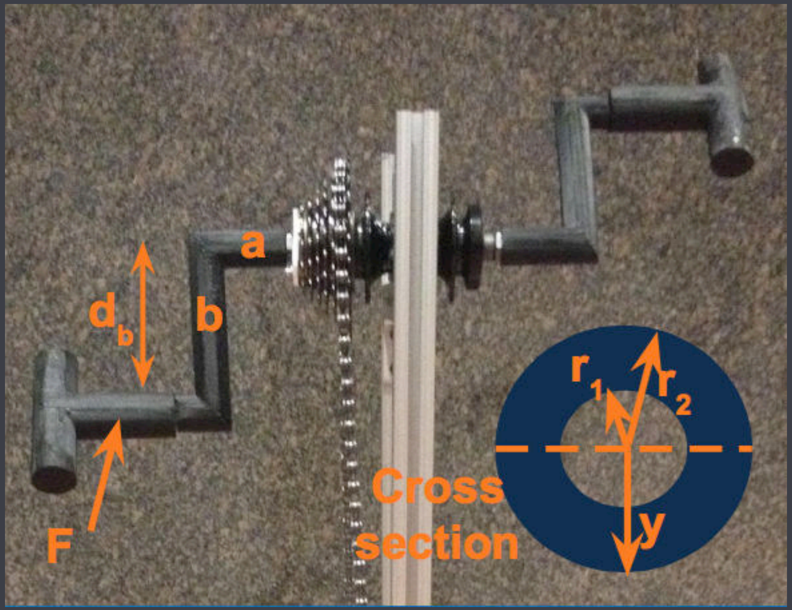
Tipping Calculations



$\Sigma M_p = -F_a(d_b - d_a) - F_f\,(d_b - d_f) - Wd_b$

So as d_b and W increase, less likely to tip

Pedal Stress Calculations

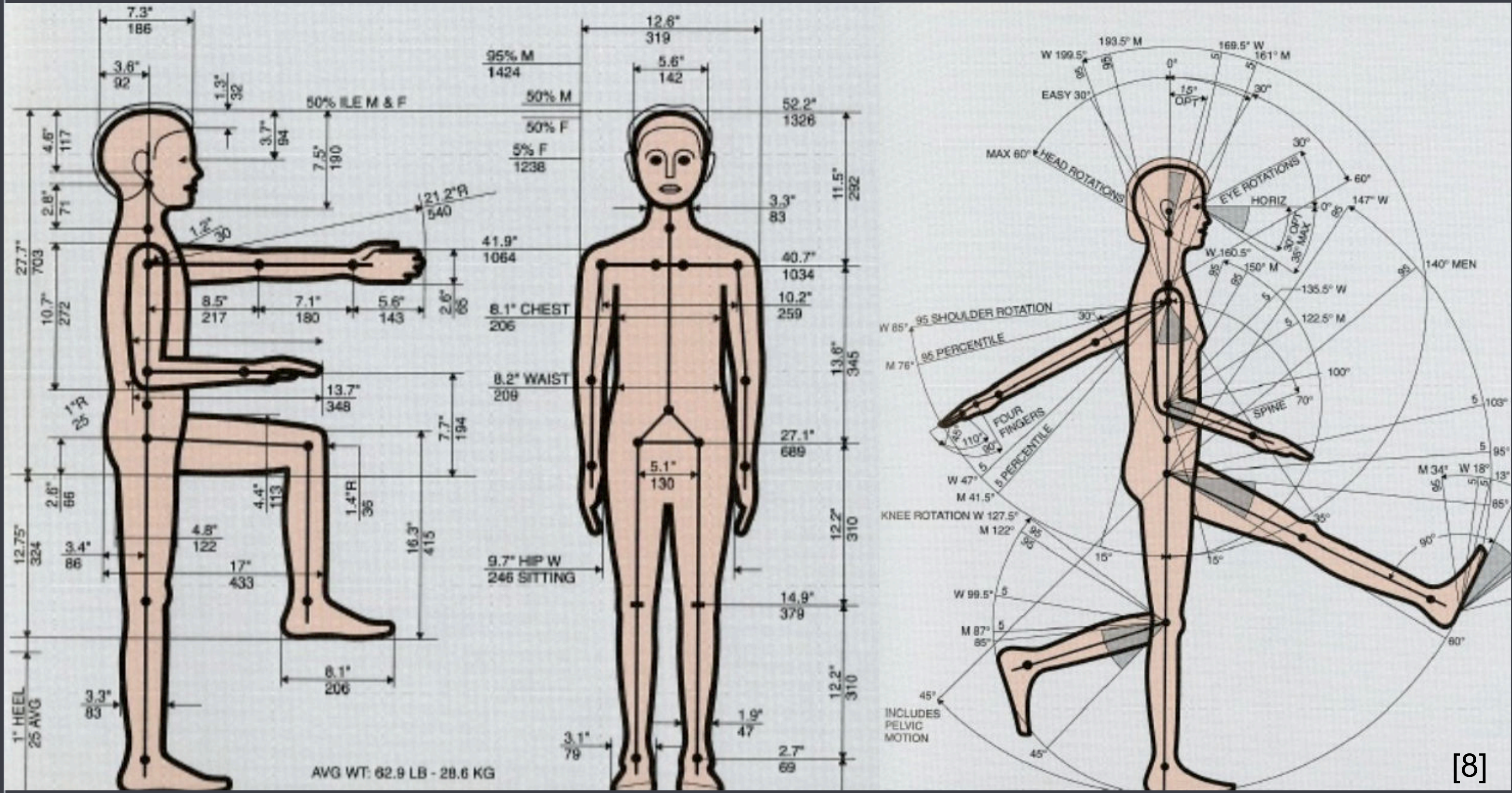


Worse case scenario:
F = weight of child (W), and
angular acceleration is zero

$$\sigma = \frac{My}{I} = \frac{W d_b y}{\frac{\pi}{4}({r_2}^4 - {r_1}^4)}$$

In this prototype's case,
PLA has a maximum
compressive stress of 2600psi

Sizing Calculations



[8] Tilley, 2002

Braking Calculations

Lead Screw Torque
Torque (Nm) = Force (N) x Lead/(2 x pi x .6)

Target: 0- 6lb braking force at foot pedal (½ the resistance range of adult exercise bikes)

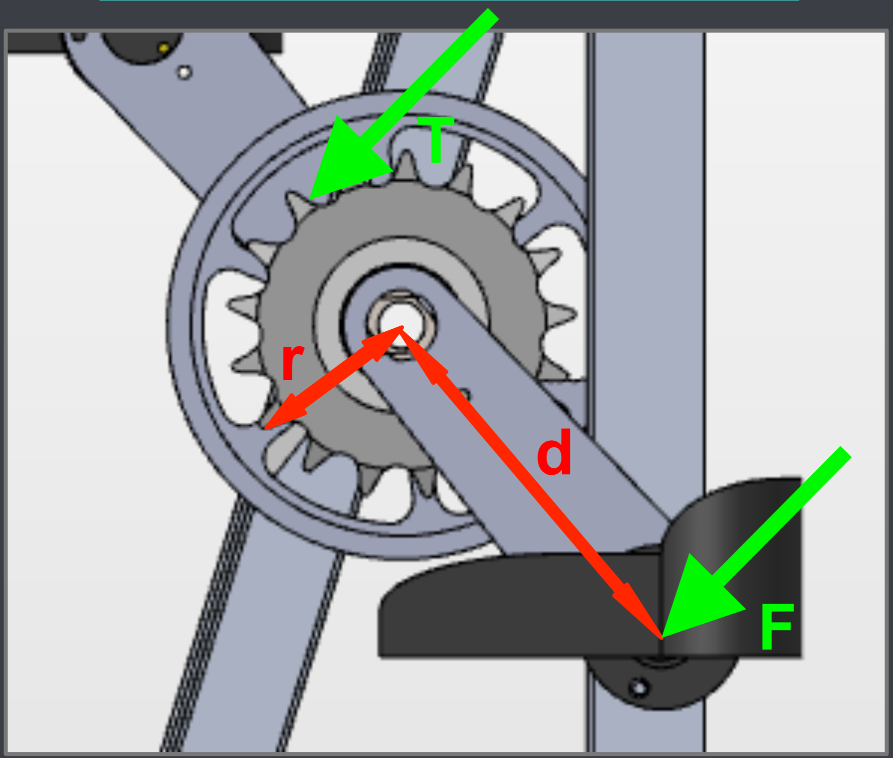
Limitations: Maximum reasonable Flywheel radius ~3”
Pedal Arm 4.25”

Force needed on flywheel = 8.5lb (39N) | Average Felt-Metal Friction Coefficient = .2 | Force exerted by lead screw = 42.6lb (193N) | Max Servo Torque =240 oz-in (1.69 Nm)

Chain Tension Calculation

Torque Balance

$rT > dF_{max}$



d = 4.25” based on average child size/ comfortable movement

F_{max}= 86lb based on strongest user (95% CP 12-yr-old’s force)*

‘rT’ chosen to be greater than dF_{max} with 2x tolerance

$rT > 2dF_{max}$ = 731lb*in

‘T’ chosen to optimize strength and cost → T = 561lb

‘r’ chosen small as possible to still make equation true → r = 1.86”

rT = 1043lb*in > 731lb*in