FAMU-FSU College of Engineering

ExoFlex

Team 102

February 18, 2025

Introduction

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Taylor Higgins
Point of Contact & Advisor

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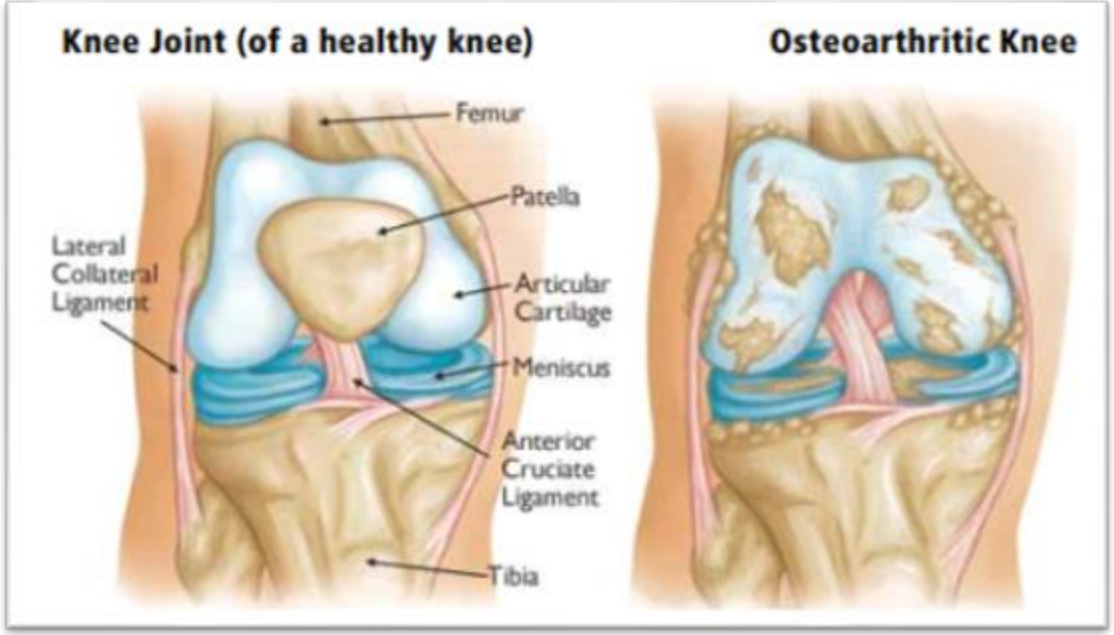
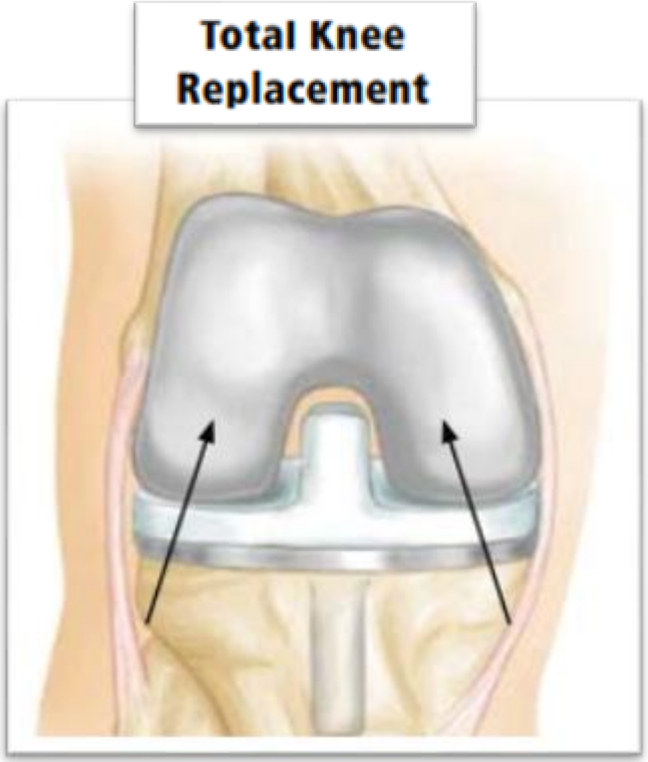
Joseph Liberato

Objective

The objective of this project is to develop a device that enhances the rehabilitation process for patients who have undergone total knee replacement (TKR) by providing mechanical resistance and electrical stimulation, intended for supervised use within established recovery protocols.

Total Knee Replacements (TKRs)





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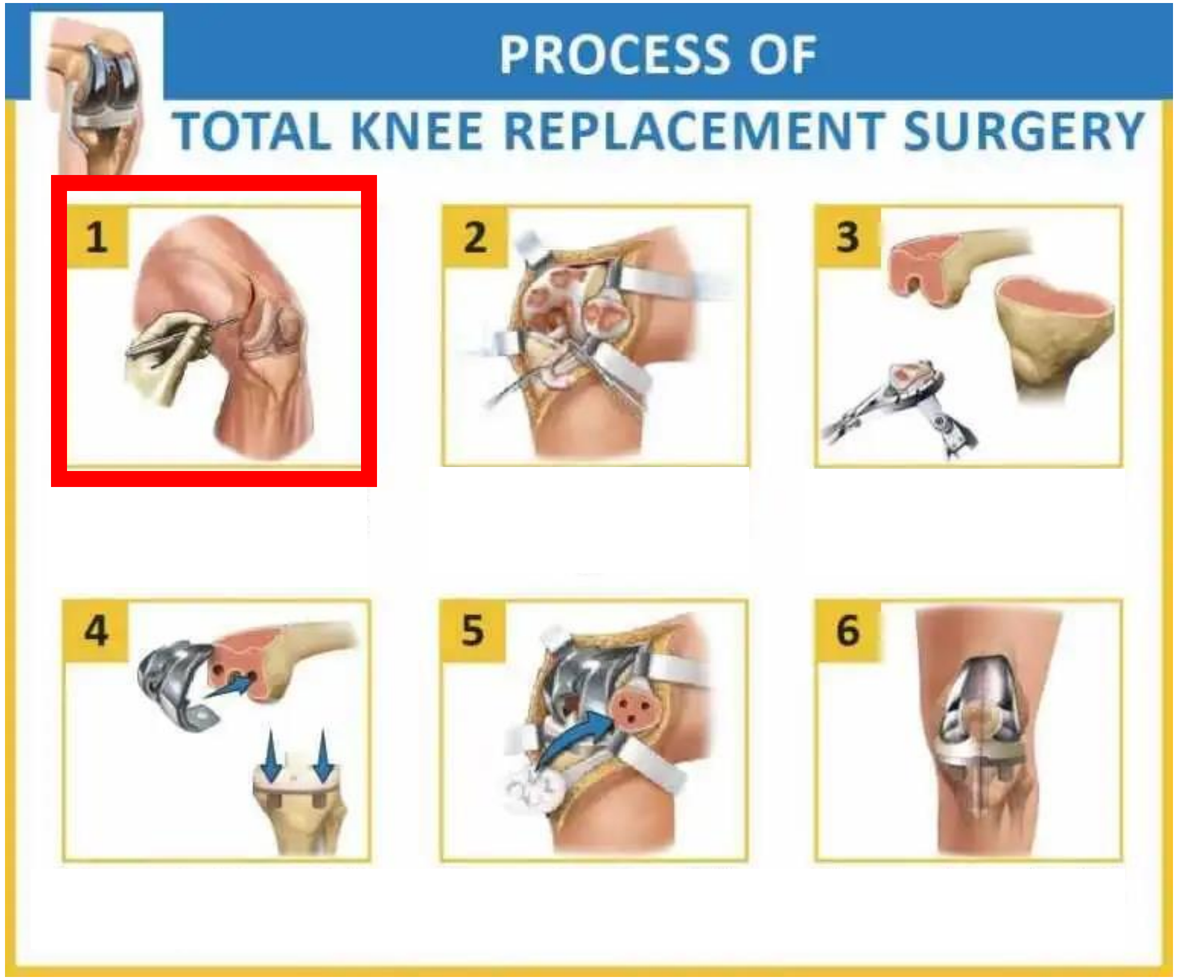
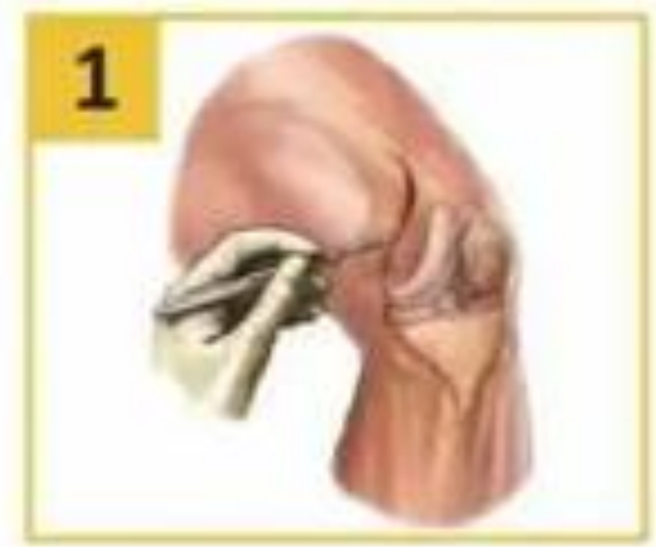
Impact of a TKR





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Rehabilitation After TKR

Isometric Exercise: Terminal Knee Extensions

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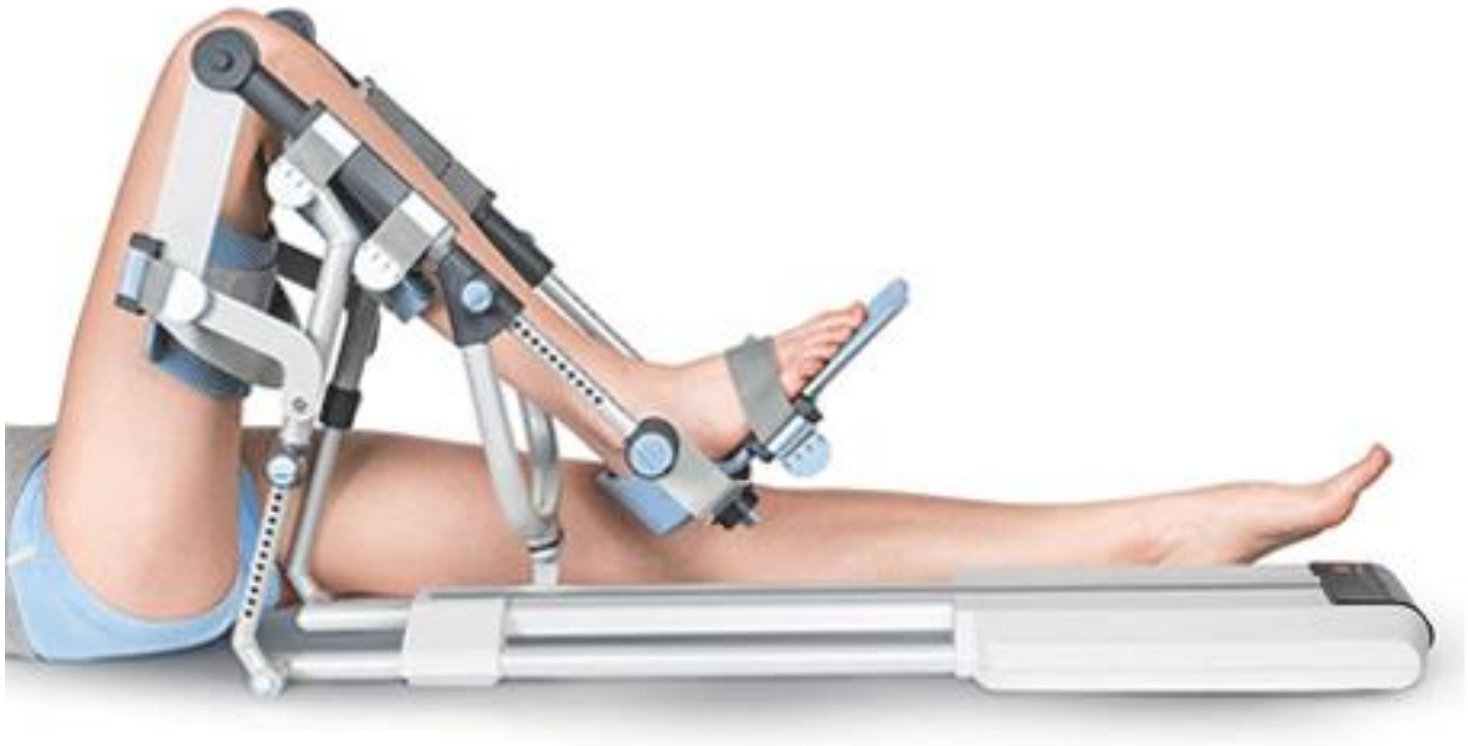
The Standard of Early Recovery



Continuous Passive Motion (CPM) Machine

Limits of Continuous Passive Motion Machine

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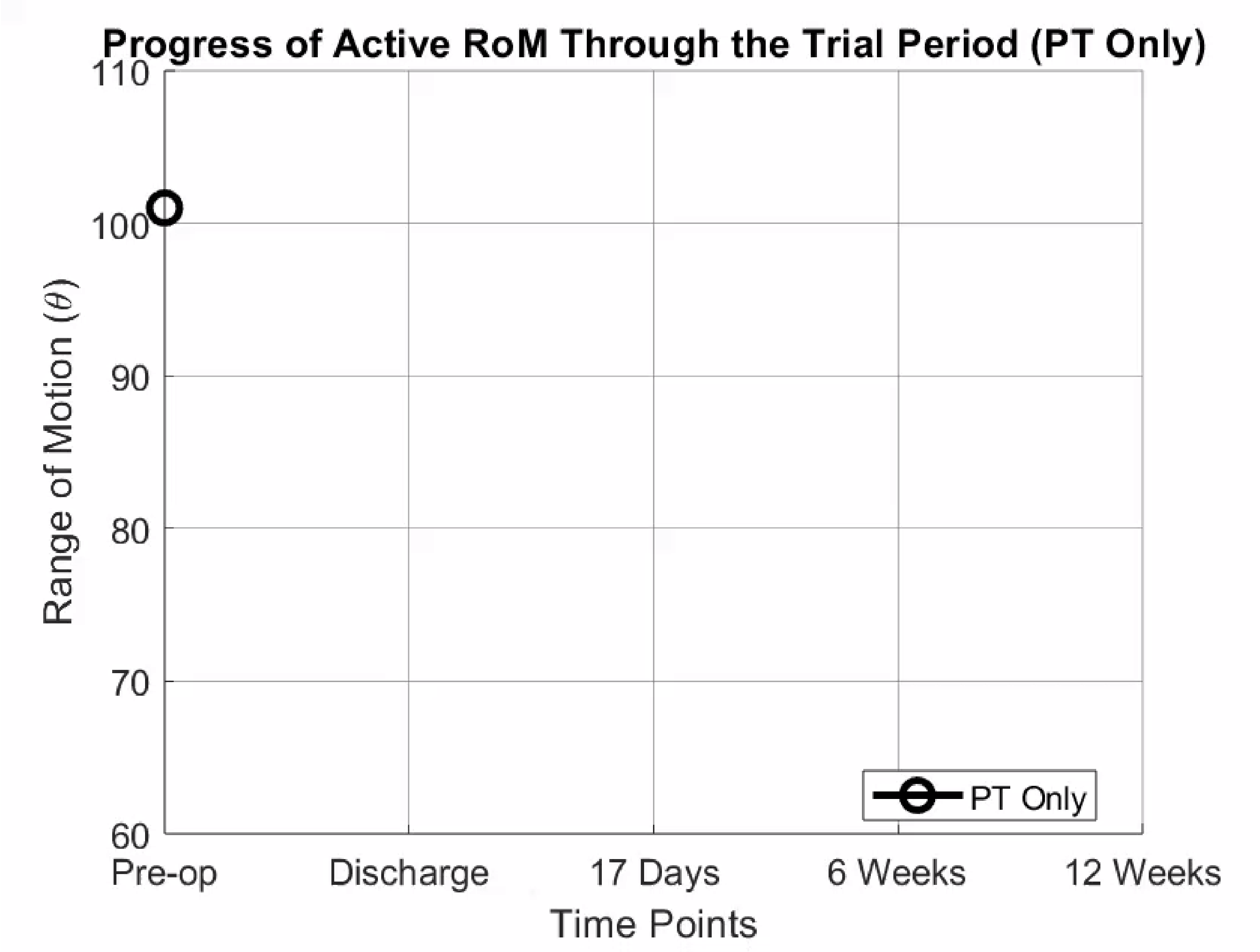

T. A. Lenssen, M. J. van Steyn, Y. H. Crijns, et al., "Effectiveness of prolonged use of continuous passive motion (CPM), as an adjunct to physiotherapy, after total knee arthroplasty," BMC Musculoskelet. Disord., vol. 9, no. 60, 2008. Available: https://doi.org/10.1186/1471-2474-9-60

Existing Devices

X10 Knee Machine

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Existing Devices

HAL Single Joint

Limited exercise modes

No e-stim

Not available in the U.S.

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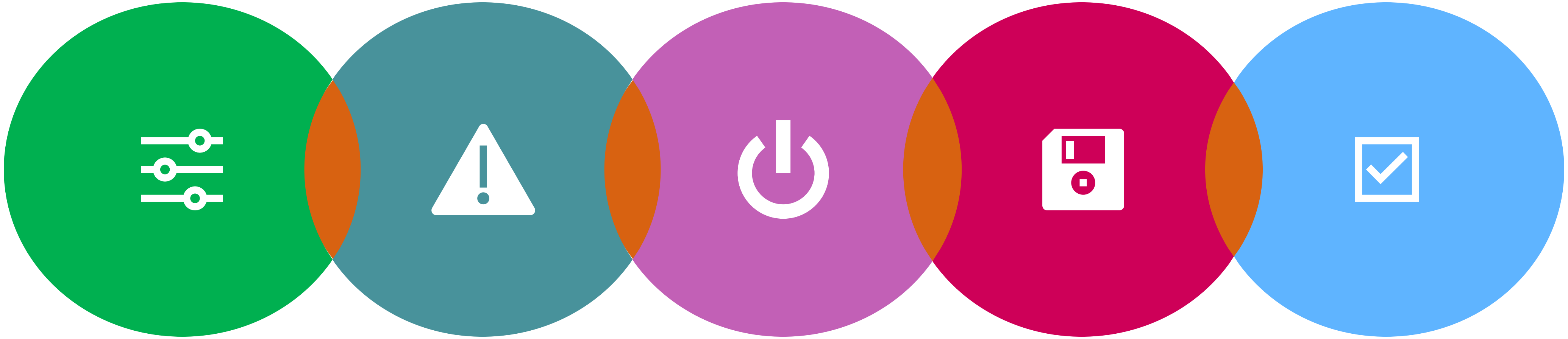
Key Goals



Adjustable Design

Safety

Electrical Stimulation

Data Aquisition

Convenience

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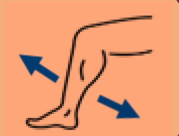
Kyle Giddes

The Targets of Mechanical Design



- Controlled, limited natural motion

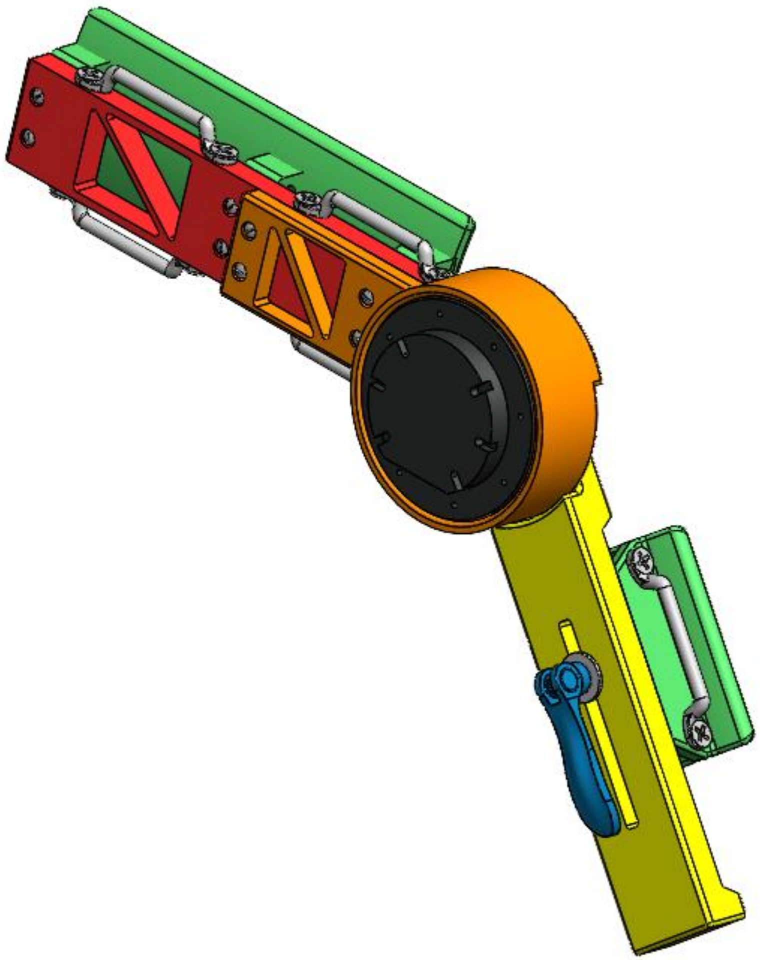
- Restrict lateral motion

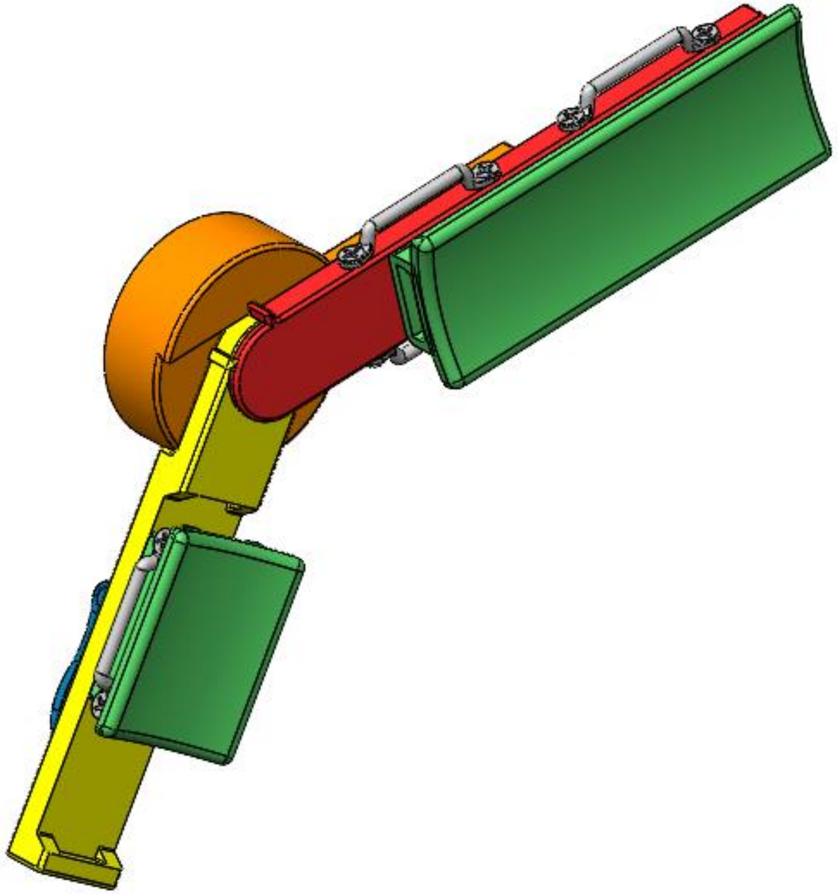
τ

- ~10 Nm of torque at the joint

Kyle Giddes

Assembled Prototype

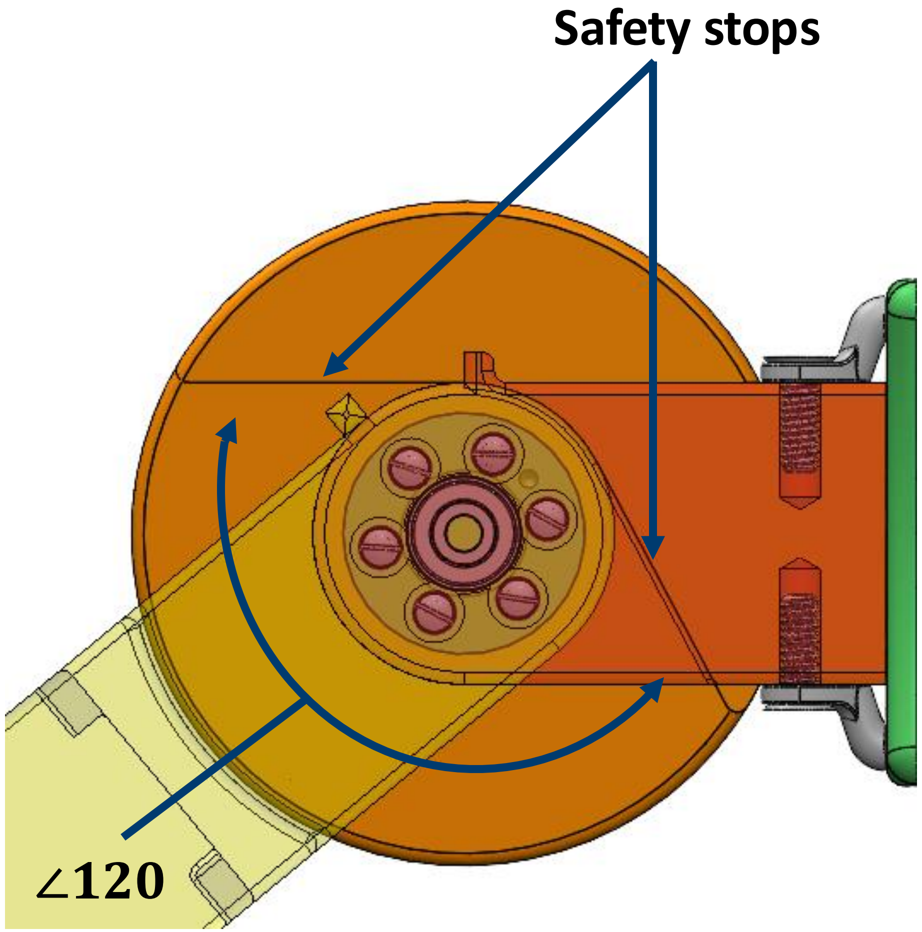




Kyle Giddes

Motion Constraints

Natural motion 0° to 120°



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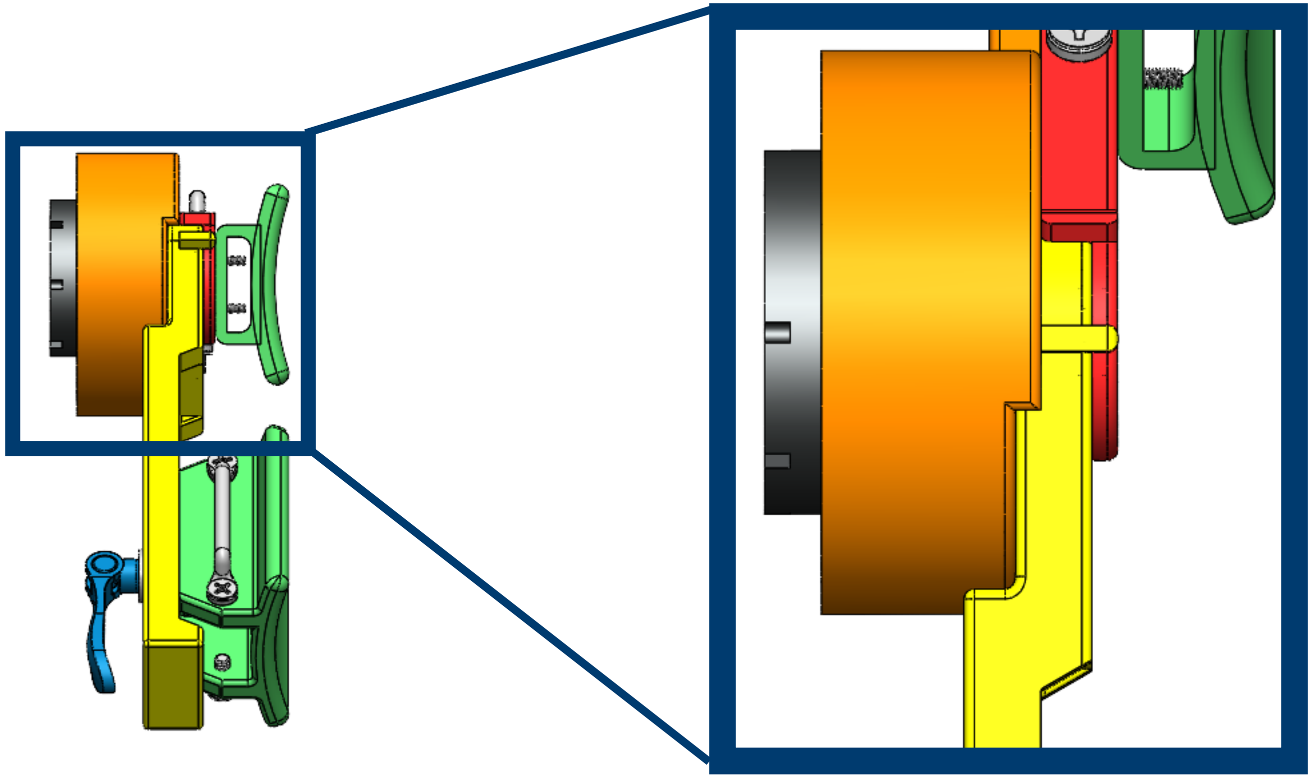
Motion Constraints

Lateral motion from 0 ± 2° will be restricted



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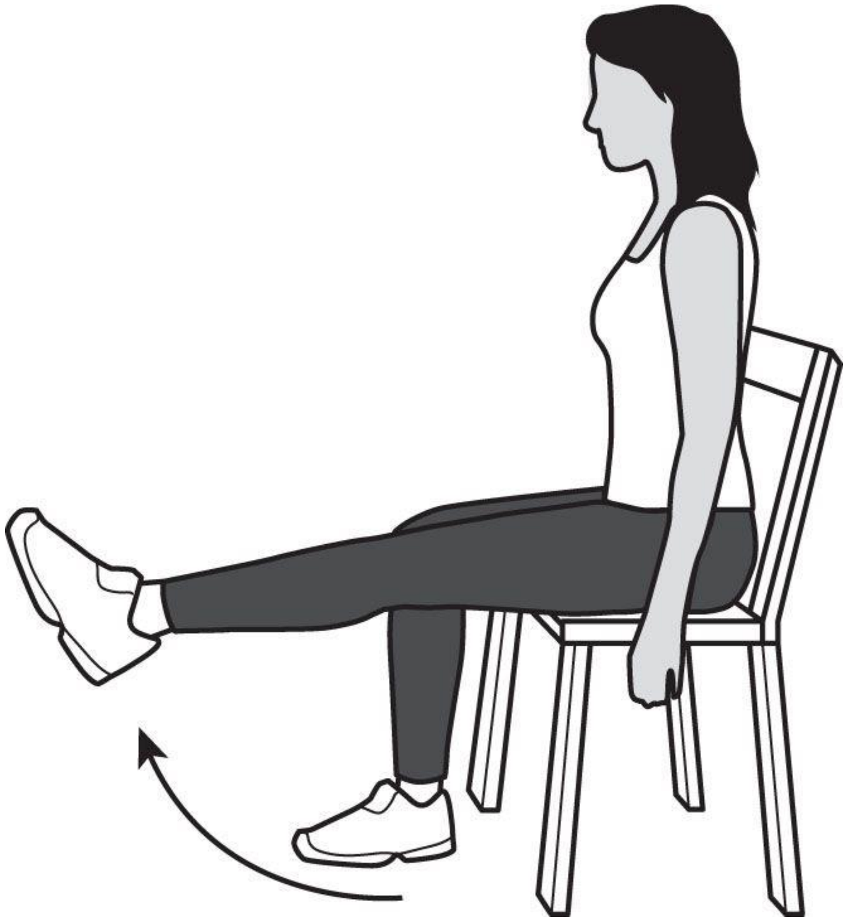
Primary Exercise

- Leg extension exercise strengthens the patellar tendon and quadricep muscle

- Force needed: Adjusted relative to the patient's body weight and phase of recovery, but 10 lbf is a "good start point"

  -Dr. Emily Eastburg, FSU PT



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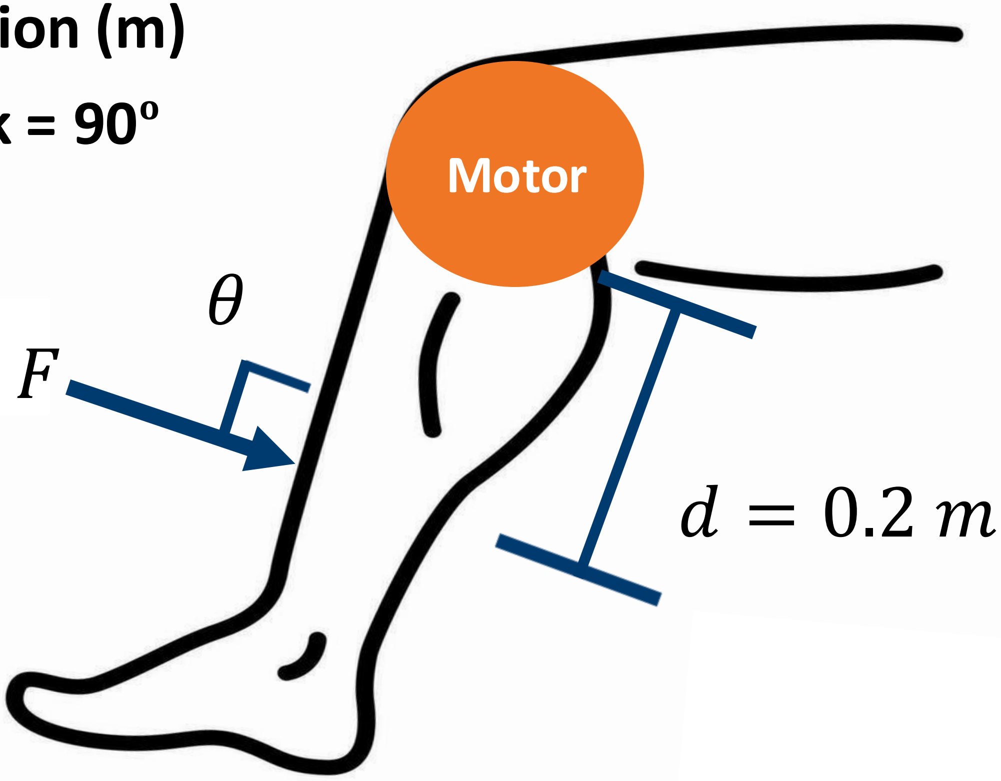
Torque Equation

- F = Force applied (N)
- d = distance from the axis of rotation (m)
- θ = angle of force applied to shank = 90º
- τ = torque of the motor (Nm)

$$\tau = F \cdot d \cdot \sin(\theta) \approx 10\ Nm$$

$$F = \frac{\tau}{d} = 50\ N \ \approx \mathbf{11.2}\ \boldsymbol{lbf}$$



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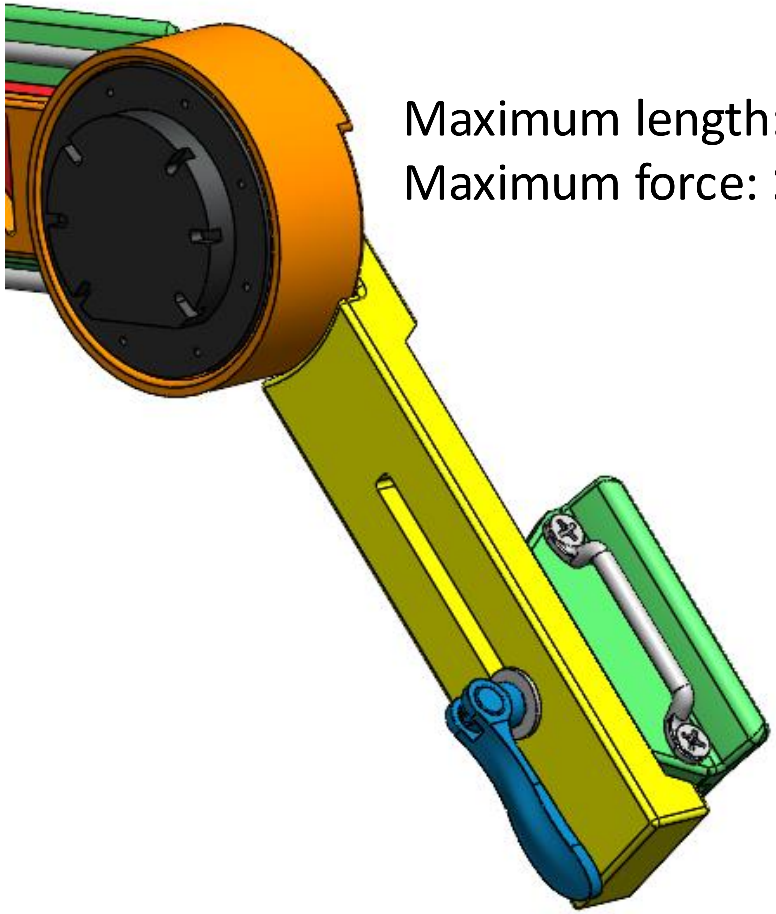
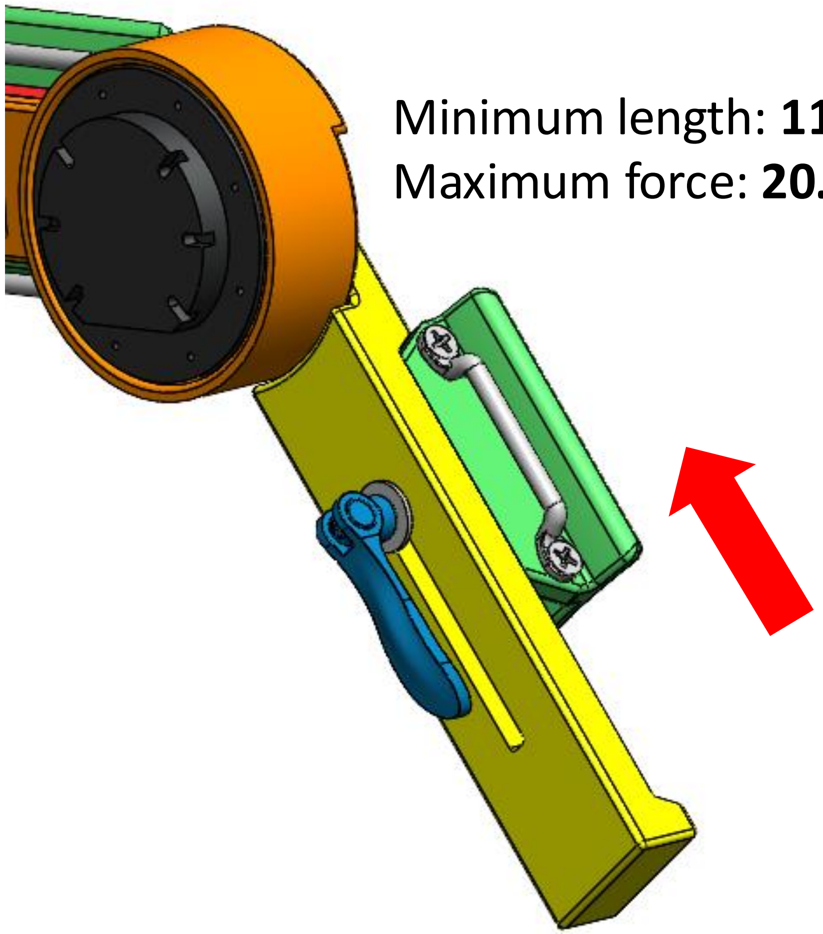
Adjustable Shank



Maximum length: **20 cm**
Maximum force: **11.2 lbf**



Minimum length: **11 cm**
Maximum force: **20.2 lbf**

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Motor Specifications

- Active actuator system
- Integrated encoder
- Versatile usage
  - Isometric: Tension w/o lengthening
  - Eccentric: Lengthening of muscle
  - Concentric: Shortening of muscle
- Rated torque: 10 Nm
- Stall torque: 25 Nm
- Operating voltage: 48V

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Material Selection

- 3D print using Nylon 12
- Nontoxic and Biocompatible
- Formlabs Fuse 1+ printer at Innovation Hub
- Batting material/leather for human contact

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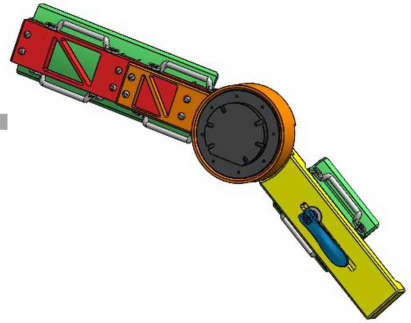
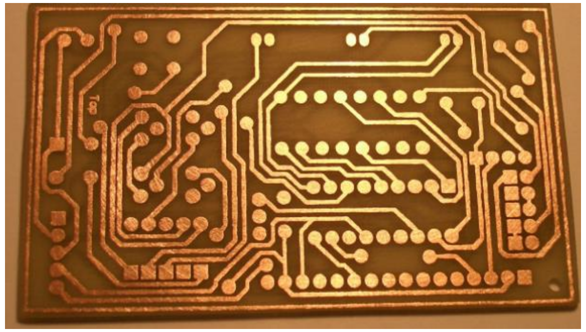
Kyle Giddes

Next Steps for Mechanical Design

Motor Control

Design the motor control system for leg movement and exercise.





Integrate E-Stim

Add physical connections of e-stim components to the device.

Physical Construction

Final 3d print and sew padding

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Key Goals

Adjustable Design

Safety

Electrical Stimulation

Data Aquisition

Convenience

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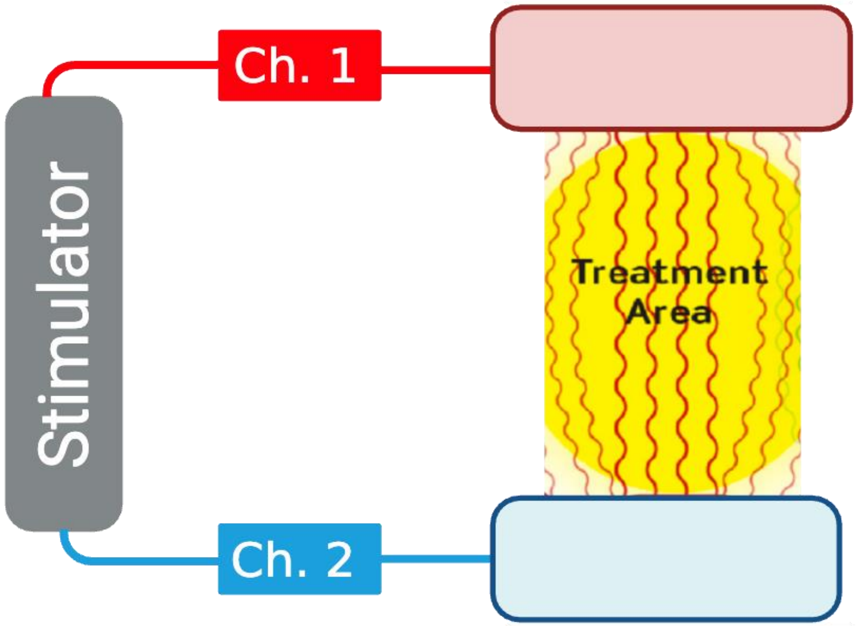
The Targets of E-Stim

- Restore quad activation
- Promote early muscle contraction
- Reduce swelling and discomfort

Aaron Gonzalez

Neuromuscular Electrical Stimulation (NMES)



- Moderate to High Amplitude
- Pulse Frequency: 30 – 80 Hz
- Pulse Duration: 2ms – 4ms

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Key Goals

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The Targets of Data Acquisition

- Facilitates progress tracking
- Visualize feedback for PT
- Provide metrics to improve patient motivation

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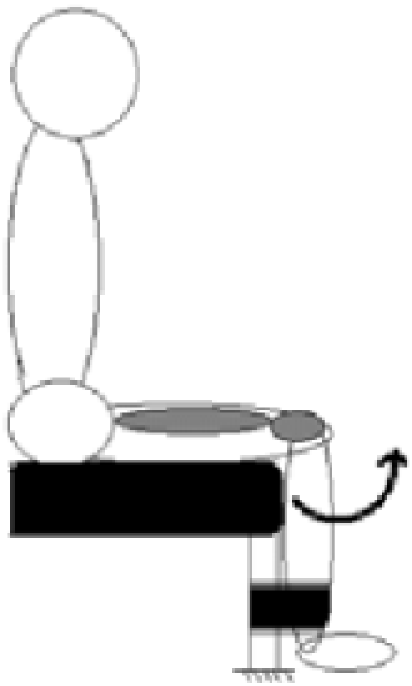
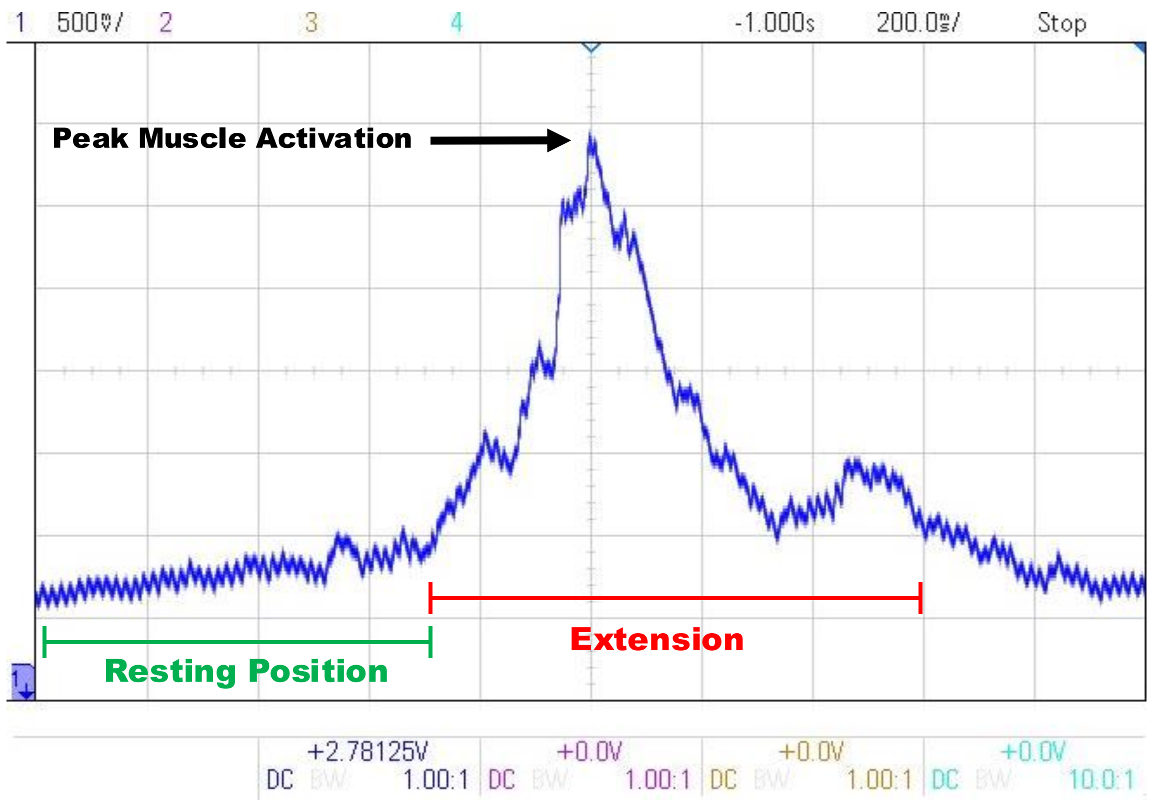
Measuring Muscle Recovery



Set up for Maximum Voluntary Contraction



EMG Signal from Circuit Output

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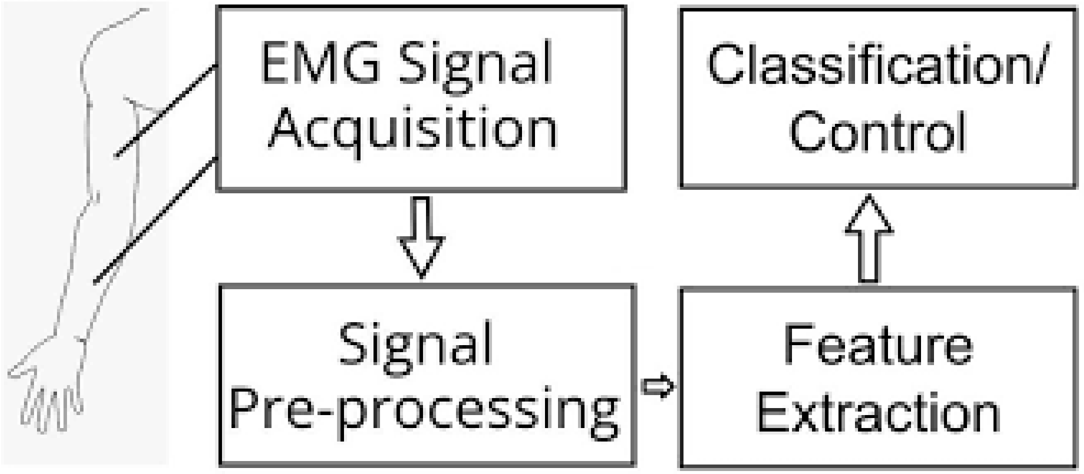
Capturing and Processing the Signal

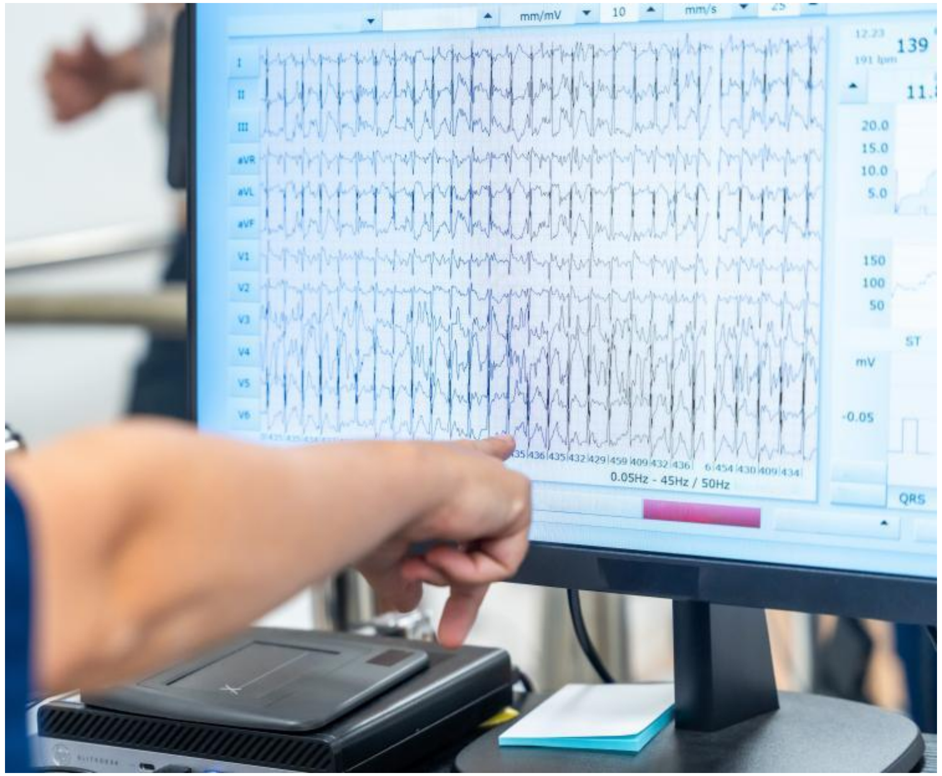
- Device Detects EMG Signal
- Stored and Processed
- Pattern Identification related to Fatigue and Strength



Example Data Acquisition Protocol

Better Rehab Outcomes

- Faster Recovery Time
- Personalized Rehab Plans Based on Data
- Increased Patient Engagement



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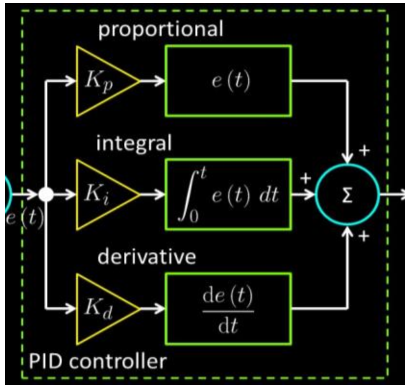
Next Steps for ExoFlex

Systems Integration

Plan for integration of mechanical, electrical, and data acquisition aspects.



Control System

Simulate the system and test control strategies.

Testing

Undergo safety and performance testing.

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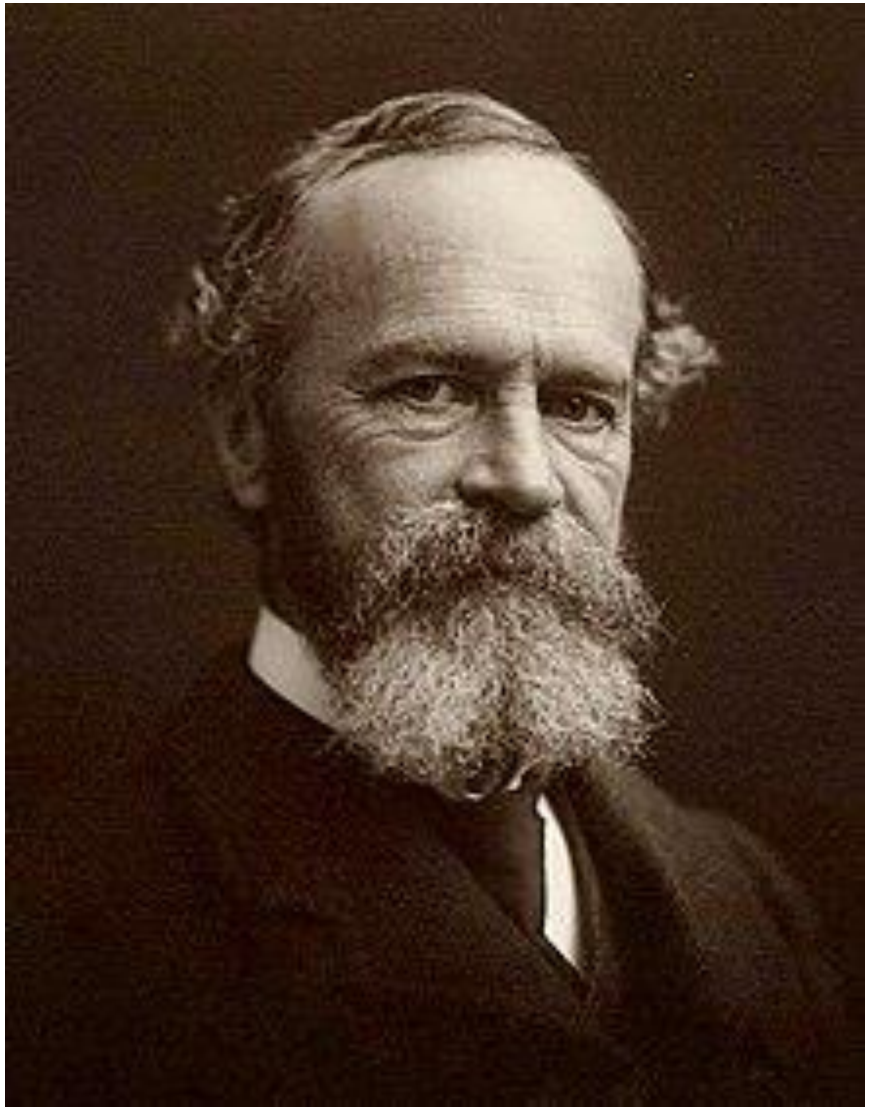
"Act as if what you do makes a difference. It does."

- William James



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