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# BME Knee Exoskeleton

## Team 102

October 2, 2024

# Team Introductions

Joseph Liberato
*Biomedical Engineer*

Kyle Giddes
*Mechanical Engineer*

Nikolya Cadavid
*Mechanical Engineer*

Andrew Baumert
*Biomedical Engineer*

Aaron Gonzalez
*Biomedical Engineer*

Arianna Escalona
*Biomedical Engineer*

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# Sponsors and Advisors

<u>Academic Advisor</u>
Shayne McConomy
*Professor*

<u>Academic Advisor</u>
Stephen Hugo Arce
*Professor and Sponsor*

<u>Engineering Mentor</u>
Taylor Higgins
*Point of Contact & Advisor*

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# Objective & Background

**Joseph Liberato**

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# Objective

- **Goal:** Develop a device to enhance recovery from knee surgery.
- **Target Procedures:**
  - Total Knee Replacements (TKR)
  - Anterior cruciate ligament (ACL) reconstruction
  - Medial collateral ligament (MCL) reconstruction
- **Functions:**
  - Provides immediate mechanical assistance
  - Delivers electrical stimulation (e-stim) to aid physical therapy
- **Outcome:** Accelerate patient recovery and improve rehabilitation results.



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# Project Background - Inspiration

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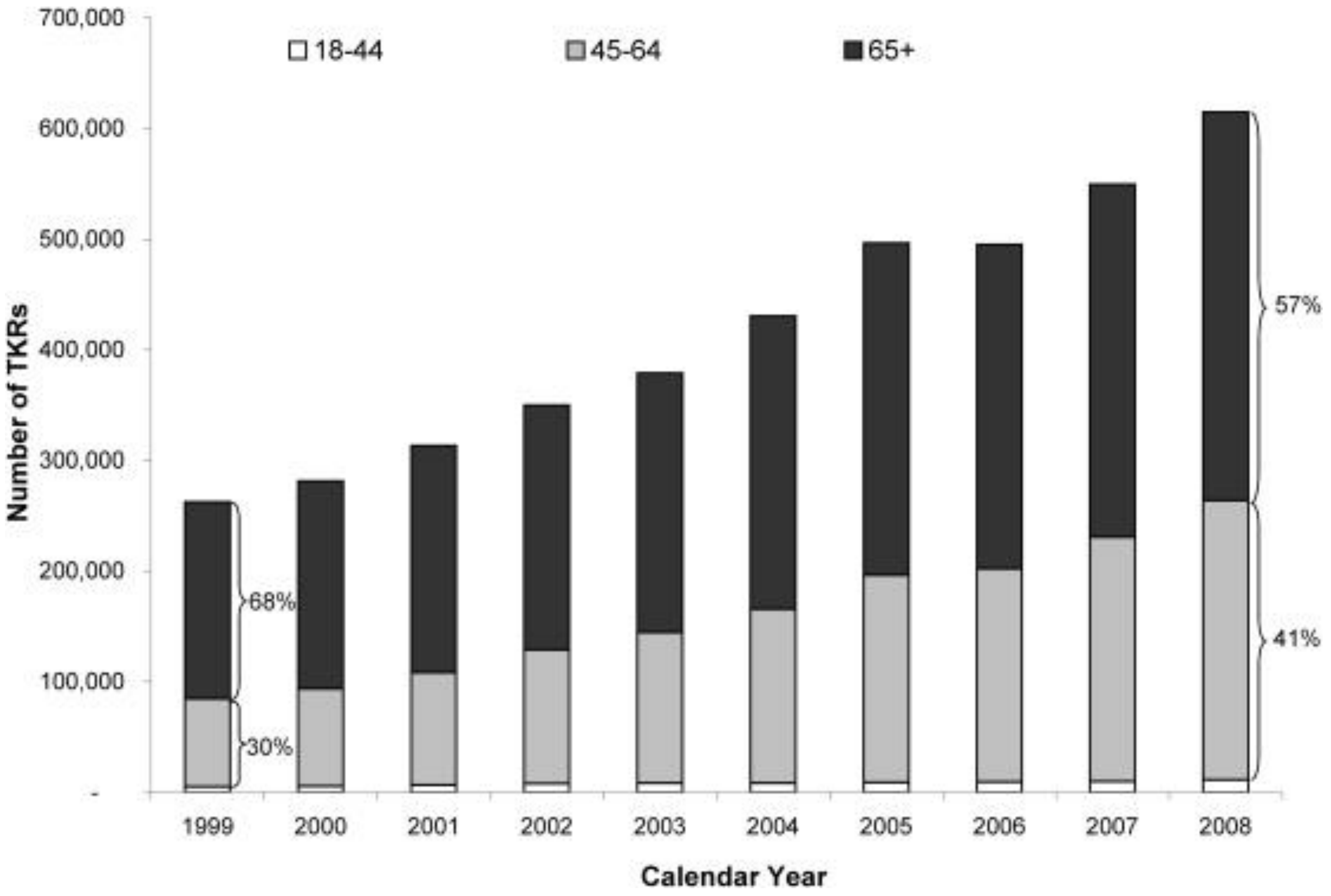
# Project Background – Clinical Background



# Project Scope

**Kyle Giddes**



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# Safe, Supervised, Speedy Post-Surgery Recovery

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# Designed for (Almost) Everyone



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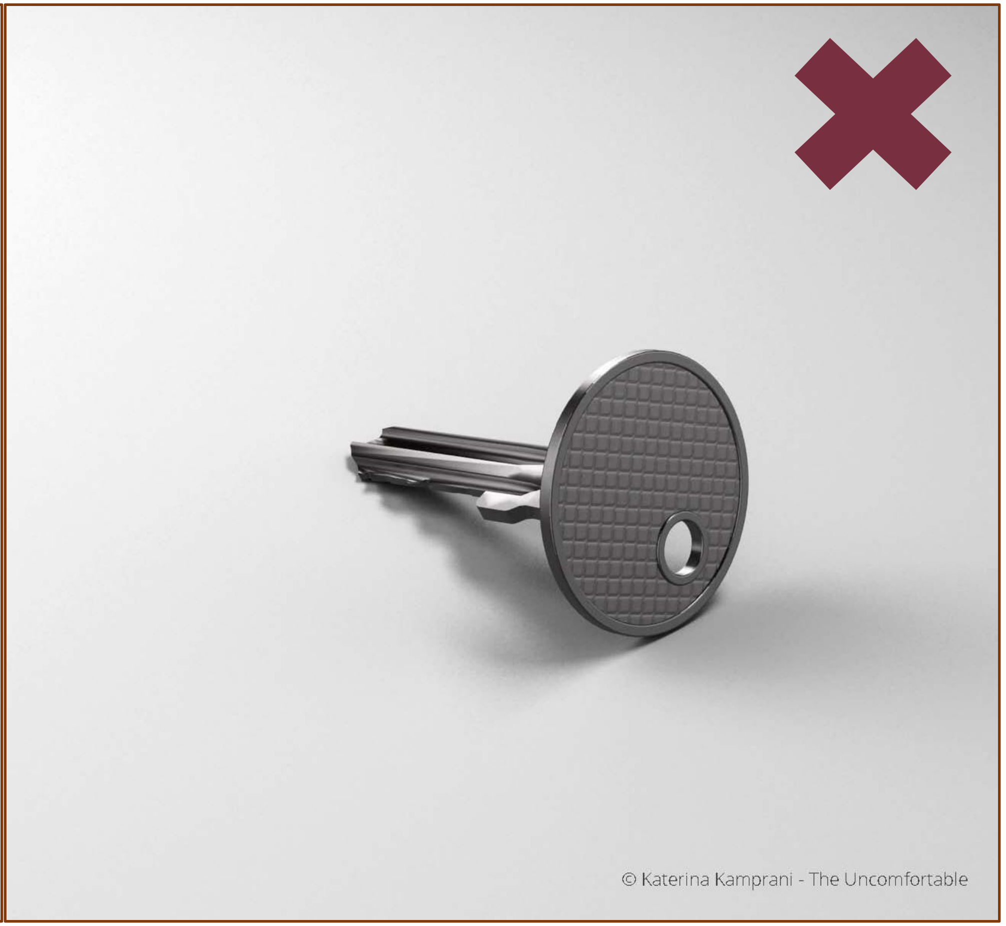
# Convenience over Novelty



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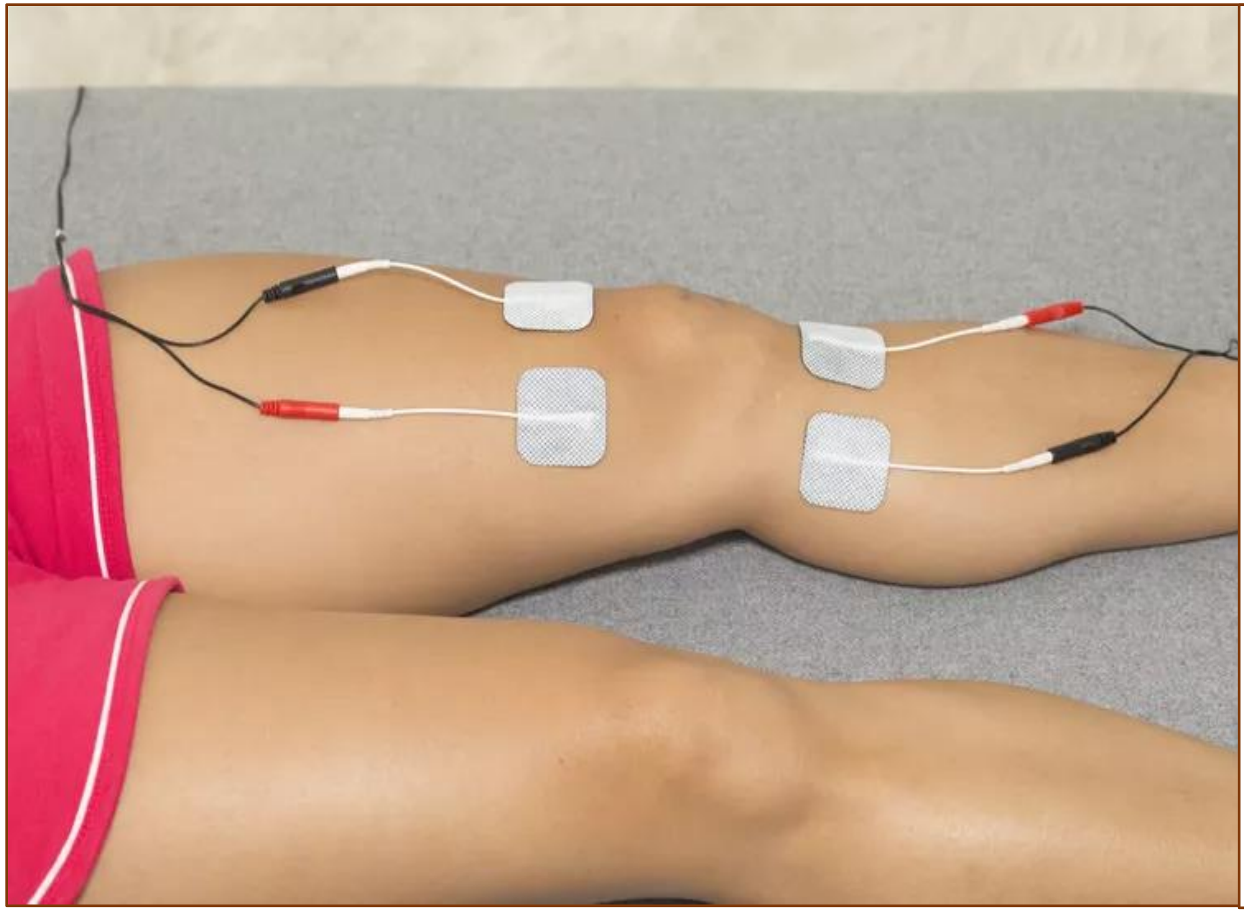
# Combining Good Ideas





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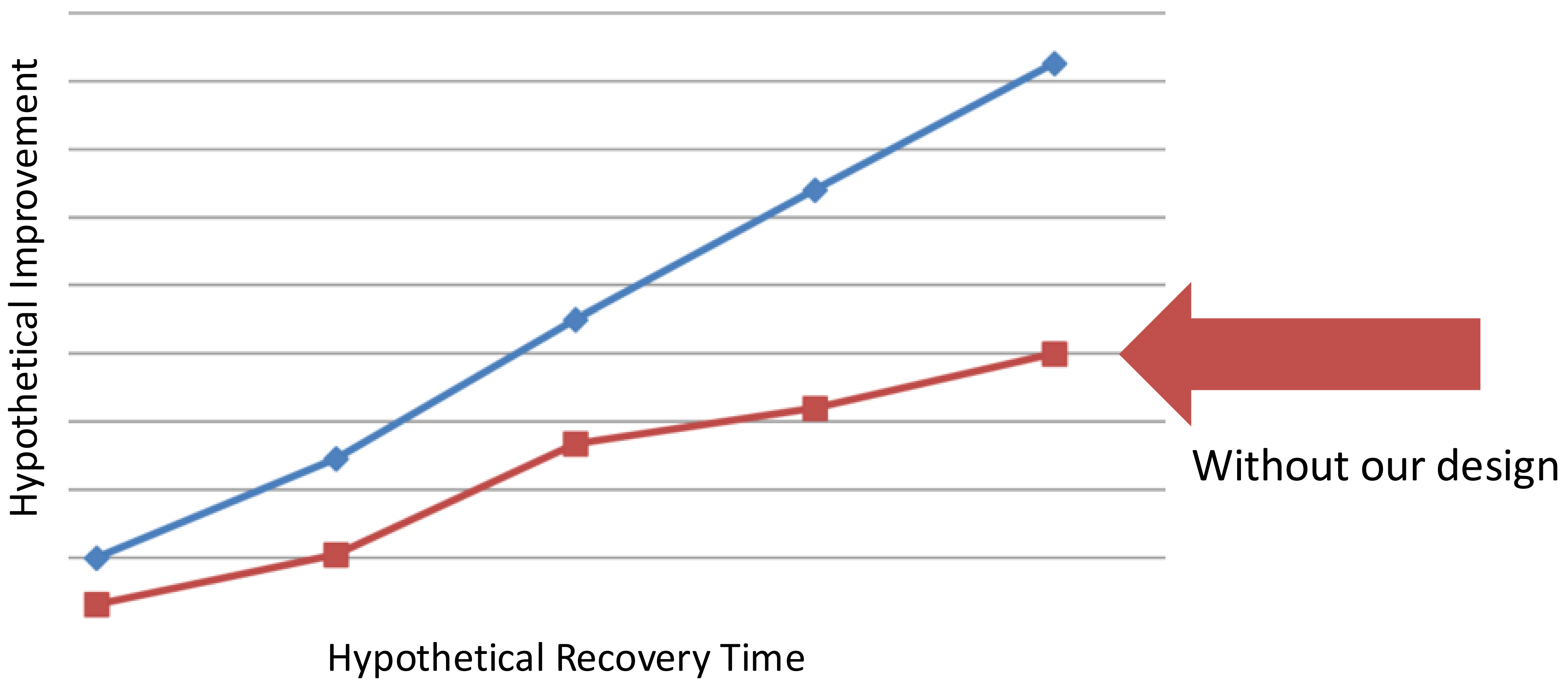
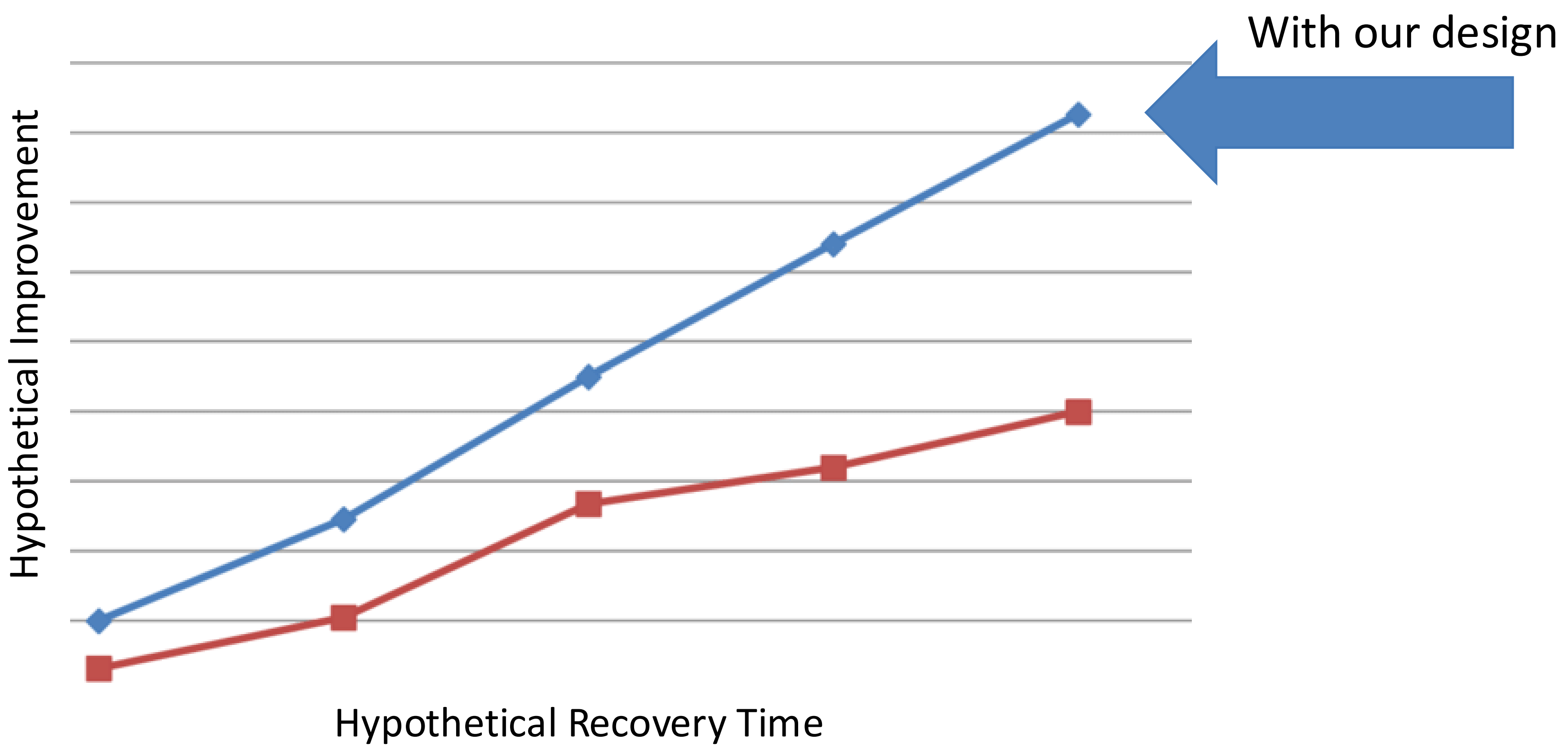
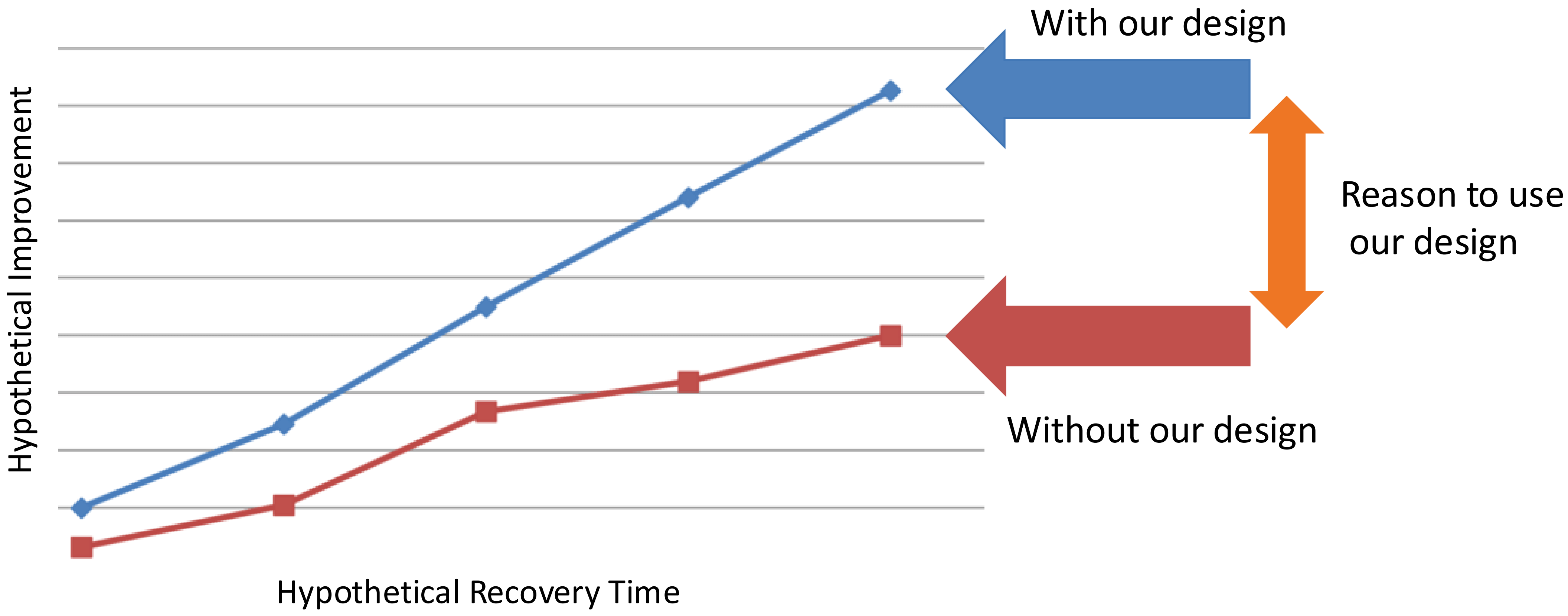
# Providing Measurable Value



# Providing Measurable Value



# Providing Measurable Value

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# Instilling Confidence

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# Key Goals

- Modular Design
- Convenience
- Integrated Electrical Stimulation
- Data Aquisition
- Safety

# Customers

**Primary Market:**

**Physical Therapy Clinics**

**Secondary Market:**

**Post-Surgery Patients**

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# Customer Needs

**Nikolya Cadavid**



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# Customer Concerns




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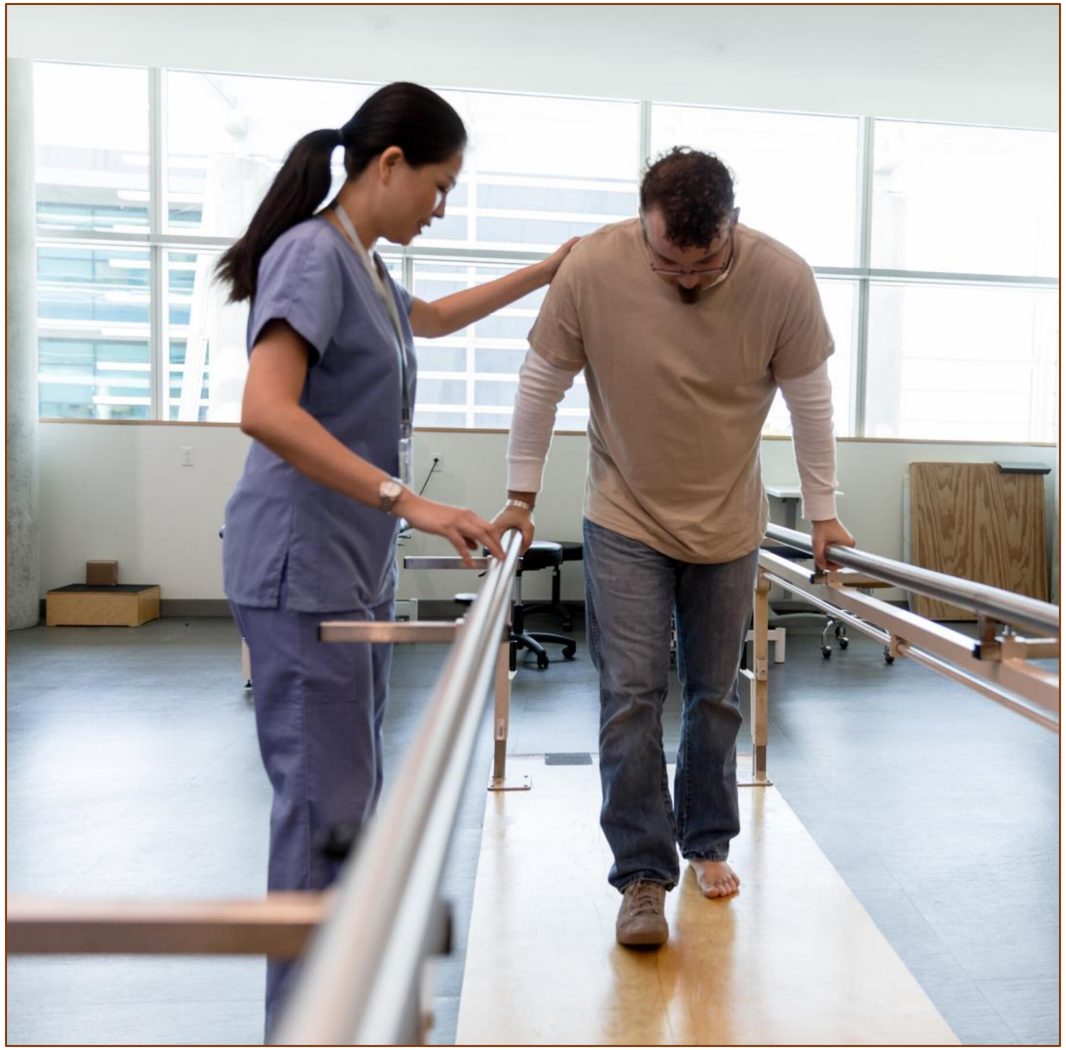
# What is most important?

| Customer Requirements | IWF: |
|---|---|
| 1. Biomechanically Acc. | 10 |
| 2. Mechanical Rehab | 9 |
| 3. Adjustability (Fitting) | 7 |
| 4. Electrical Rehab | 7 |
| 5. Data Acquisition | 6 |
| 6. Ease of Use | 5 |
| 7. Comfort/Pain reduction | 4 |
| 8. Cost | 3 |
| 9. Modularity (Component) | 2 |
| 10. Durability | 2 |
| 11. Bulkiness/Aesthetic | 0 |



# Establishing Design Inputs

**Andrew Baumert**

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Checkpoint 2

# Existing Solutions

The X10 Knee Recovery System™


Bioness L300 Go®


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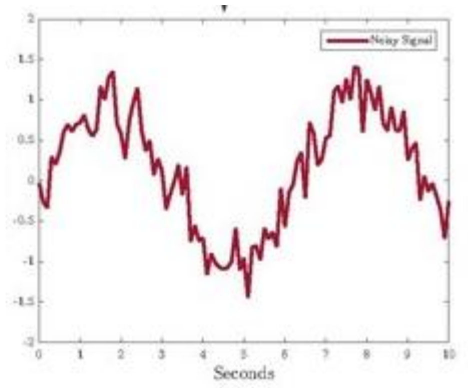
Checkpoint 2

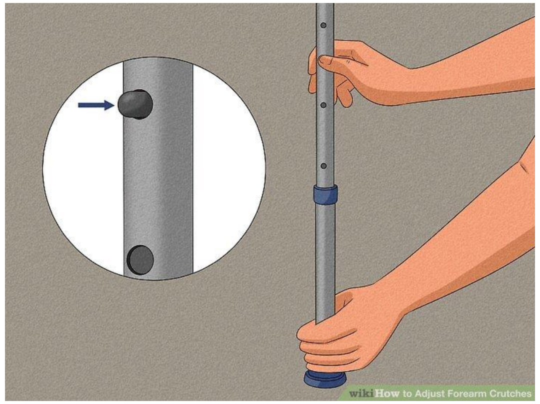
# Design Inputs and Function Bases

- Data Acquisition




- Mechanical Assistance/Resistance

- Modularity



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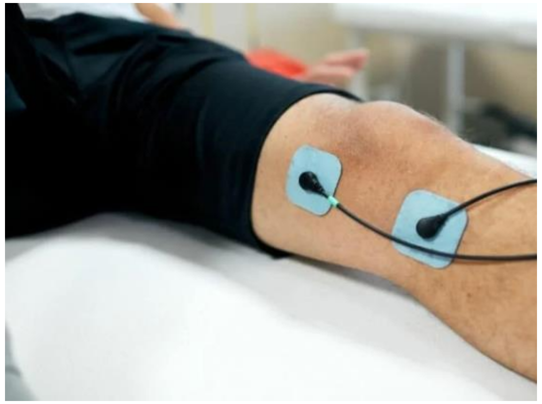
Checkpoint 2

# Design Inputs and Function Bases

- Safety
- Electrical Stimulation
- Comfortability





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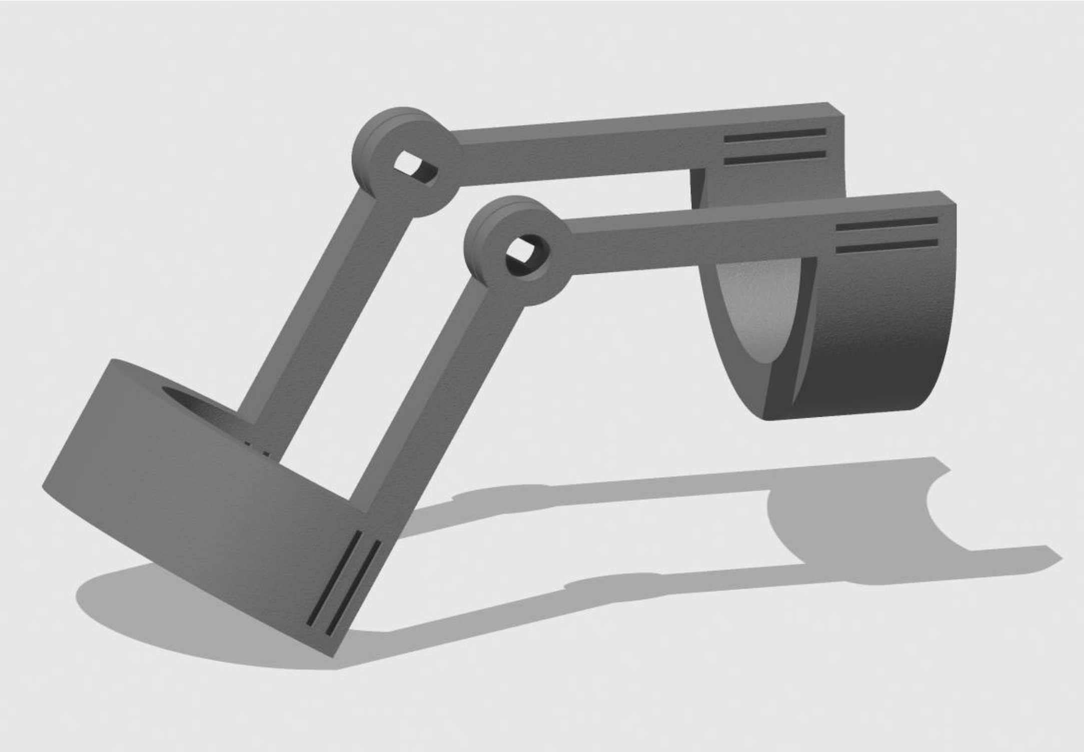
Checkpoint 2

# Additional Objectives

- Meet with Class TA for a Progress Check
- CAD Simple Prototype



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# Mechanical Progress

**Aaron Gonzalez**

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# Mechanical Progress

- **Assistive / Resistive features**
  - Adjustable Assistance
  - Personalized Resistance Levels

- **Passive and Active Components**

# Mechanical Progress

- Frame Design
  - Lightweight Material
  - Adjustable Fit
- Control System for Mechanical Components
  - Motor Control
- Modularity and Attachments
  - Customizable Components

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# Next Steps for Mechanical Development

- Refining CAD Model
- Improving Adjustability
- Integrate Motors and Springs
- Consider Safety Improvements



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# E-Stim Progress

**Arianna Escalona**

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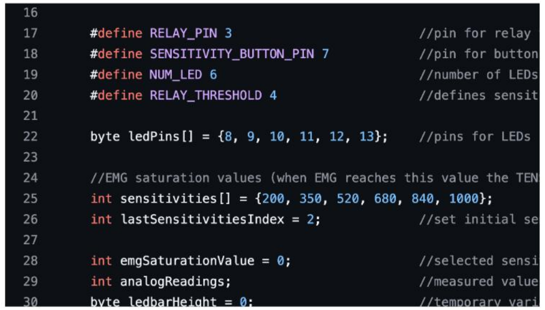
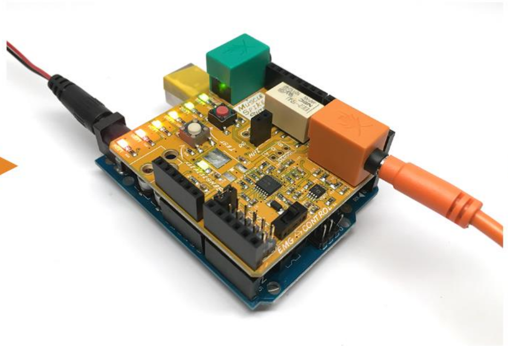
# E-stim Progress

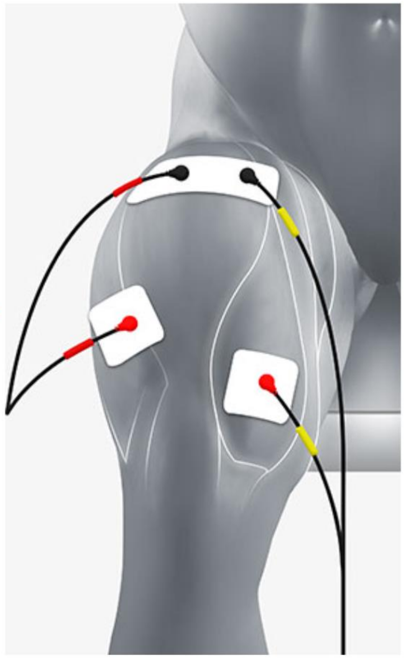

```
#define RELAY_PIN 3                          //pin for relay
#define SENSITIVITY_BUTTON_PIN 7             //pin for button
#define NUM_LED 6                            //number of LEDs
#define RELAY_THRESHOLD 4                    //defines sensit

byte ledPins[] = {8, 9, 10, 11, 12, 13};     //pins for LEDs

//EMG saturation values (when EMG reaches this value the TEN
int sensitivities[] = {200, 350, 520, 680, 840, 1000};
int lastSensitivitiesIndex = 2;              //set initial se

int emgSaturationValue = 0;                  //selected sensi
int analogReadings;                          //measured value
byte ledbarHeight = 0;                       //temporary vari
```



- **Human-Human Interface Kit**



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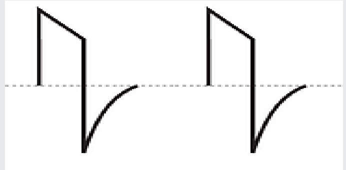
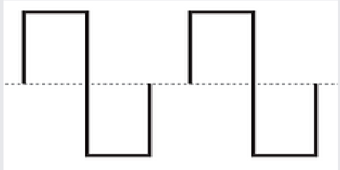
| Parameter | TENS (for pain relief) | NMES (for Quadriceps Activation) |
|---|---|---|
| Pulse Frequency (Hz) | Typically **50-150 Hz** | Typically **30-80 Hz** |
| Intensity (Amplitude) | **Low to moderate** | **High** |
| Pulse Duration (µs) | **50-100 µs** | **200-400 µs** |
| Waveform |  |  |
| Target Nerves | **Sensory nerves** | **Motor nerves** |
| Duration of Use | **Longer sessions** (30-60 minutes per session) | **Shorter sessions** (10-30 minutes per session) |

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# Next Steps for E-Stim Development

- Testing TENS Unit
- Understand Circuit Design
- Meet with Expert
- Review FDA Guidelines
- Consider Power Options

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# Thank you!

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# References


- Brett Sears, P. (2023, February 16). *6 types of electrical stimulation used in PT*. Verywell Health. https://www.verywellhealth.com/estim-use-in-physical-therapy-2696490
- *Exoskeleton and exosuits in the workplace: Amtrust Financial*. AmtrustFinancial. (n.d.). https://amtrustfinancial.com/blog/loss-control/exoskeleton-and-exosuits-in-the-workplace
- Gb-Bossm. (2022, May 4). *Why do I get "stimulated" during physical therapy?* Boston Sports Medicine. https://www.bostonsportsmed.com/2015/09/electric-stimulation-physical-therapy/
- *GUIDE: Physical therapy guide to knee pain*. Choose PT. (2020, September 22). https://www.choosept.com/guide/physical-therapy-guide-knee-pain
- Knee extension. (n.d.). https://www.axelgaard.com/App/Anatomy/Knee
- Ko, D. (2017, October 17). *Katerina Kamprani designs sublimely dysfunctional everyday objects*. Intro to Cinema 4D for Designers. https://www.3dfordesigners.com/blog/katerina-kamprani-the-uncomfortable
- Ladenburg, T. (2023, July 17). *Biodex isokinetics - orthorehab physical therapy*. OrthoRehab Physical Therapy - Physical Therapy in Northwestern Montana. https://orthorehab.com/services/biodex-isokinetics/
- *Neo 550 Brushless Motor*. REV Robotics. (n.d.-a). https://www.revrobotics.com/rev-21-1651/
- *Neo Vortex Brushless Motor*. REV Robotics. (n.d.-b). https://www.revrobotics.com/rev-21-1652/


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# References Continued


- *Passive exoskeleton*. Exoskeleton Report. (n.d.). https://exoskeletonreport.com/type-of-exoskeleton/passive/
- Peter. (n.d.). *Freedom key assists : Pack of 3 : Arthritis key turner AIDS*. The Wright Stuff, Inc. | ArthritisSupplies.com. https://www.arthritissupplies.com/dynatomy-key-assists-pack-of-3.html
- Pfeffer, S. E. (2023, May 12). *Al Roker shares video of him moving around the hospital 1 day after knee replacement surgery: "up and walking."* People.com. https://people.com/health/al-roker-walks-1-day-after-knee-surgery-in-video/
- A sample graph to illustrate topic detection technique. the graph is... | download scientific diagram. (n.d.). https://www.researchgate.net/figure/A-sample-graph-to-illustrate-topic-detection-technique-The-graph-is-formed-in-the_fig1_309775588
- Smith, D. G. (2021, July 6). *What to look for in a physical therapist*. The New York Times. https://www.nytimes.com/article/physical-therapist-search.html
- "GUIDE: Physical Therapy Guide to Knee Pain." *Choose PT*, APTA, 22 Sept. 2020
- Amazon.com: Elbow Brace Compression Sleeve for Men & Women (1 pair), arm support sleeves forearm pain relief pads braces for tendonitis, Tennis & Golfers Elbow Treatment, arthritis, workout, Weight Lifting : Health & Household. (n.d.-b). https://www.amazon.com/Compression-Support-Tendonitis-Treatment-Arthritis/dp/B09C4L23QS


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# Binary Pairwise Comparison

| Binary Pairwise Comparison | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Customer Requirements | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | IWF: |
| 1. Biomechanically Acc. | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 |
| 2. Adjustability (Fitting) | 0 | - | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| 3. Modularity (Component) | 0 | 0 | - | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| 4. Durability | 0 | 0 | 1 | - | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 5. Bulkiness/Aesthetic | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6. Mechanical Rehab | 0 | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | 9 |
| 7. Electrical Rehab | 0 | 1 | 0 | 1 | 1 | 0 | - | 1 | 1 | 1 | 1 | 7 |
| 8. Cost | 0 | 0 | 1 | 1 | 1 | 0 | 0 | - | 0 | 0 | 0 | 3 |
| 9. Comfort/Pain reduction | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | - | 0 | 0 | 4 |
| 10. Data Acquisition | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | - | 1 | 6 |
| 11. Ease of Use | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | - | 5 |
| Total: | 0 | 3 | 8 | 8 | 10 | 1 | 3 | 7 | 6 | 4 | 5 | |

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