# Inconspicuous Ankle Foot Orthosis (AFO) for Teen

*Team Rise and Stride*

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# Overview

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# Background

**Facioscapulohumeral muscular dystrophy (FSHD):**

A rare neuromuscular condition stemming from a genetic mutation that causes progressive muscle weakness [1]

**Client background:** Debbie Eggleston, physical therapist and activist

**Patient:** High school student with FSHD

**Global Impact:** Three to five people out of every 100,000 have FSHD [1]

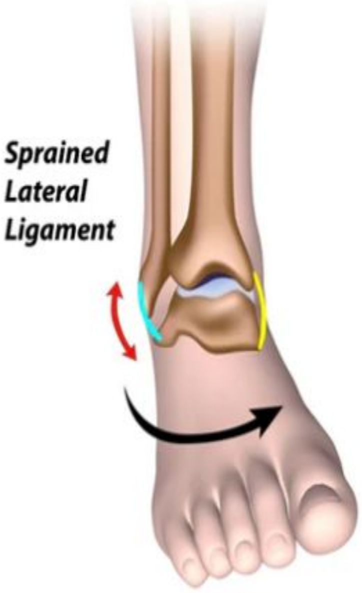



**Figure 1:** Ankle Inversion Diagram [2]

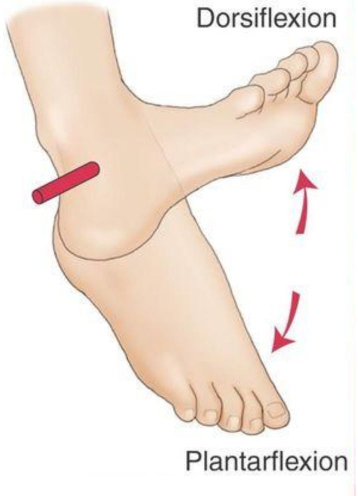



**Figure 2:** Ankle Dorsiflexion Diagram [3]

# Problem Statement

**Project Description:** This project aims to raise awareness for FSHD and explore the benefits of discrete Ankle Foot Orthoses (AFOs) for individuals with this progressive muscle weakness. The team aims to design a comfortable, flexible, and discrete brace tailored for a young individual diagnosed with FSHD to facilitate natural gait.

# Previous Work

- Compression sock with gel pads
- Foot brace with CF-PLA piece
- Adjustable bungee cord system
- Gait Analysis
    - Pros: comfortable, no negative impact on gait, and aids dorsiflexion
    - Cons: not easily removable and rigid support

**Figure 3:** Final Design on Mold of Patient

**Figure 4:** Final Design on Team Member’s Foot for Testing

# Competing Designs

**Figure 5:** Supra Malleolar Orthosis (SMO) [4]

**Figure 6:** Jointed AFO [5]

**Figure 7:** Passive Dynamic-AFO [6]

**Figure 8:** Variable Stiffness Orthosis [7]

# Product Design Specifications

- Patient-specific dimensions and comfort needs
- Mimic normal gait and allow more than 30° of motion from neutral ankle position [8]
- Support dorsiflexion, provide resistance 5-10 Nm per 10° of plantarflexion [8]
- Prevent inversion angles greater than 25° [9]
- Rigid support resists torsional forces ±30 Nm and withstand 266 N of force [10]
- Discrete design for day-to-day use, including horseback riding

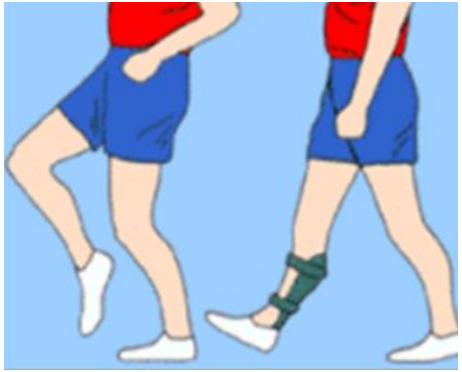


**Figure 9:** Foot Drop With Negative Pitch Angle [11]

**Figure 10:** Ankle Inversion vs. No Inversion [12]

# Rigid Support Designs

## Pivot Pro

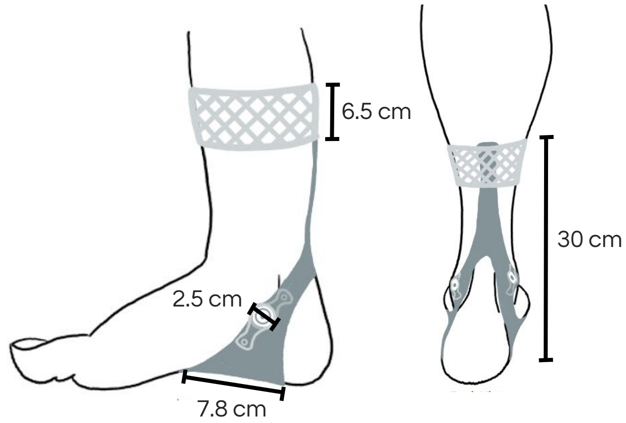



**Figure 11:** Pivot Pro Design Medial and Posterior Views

## Calf Hugger

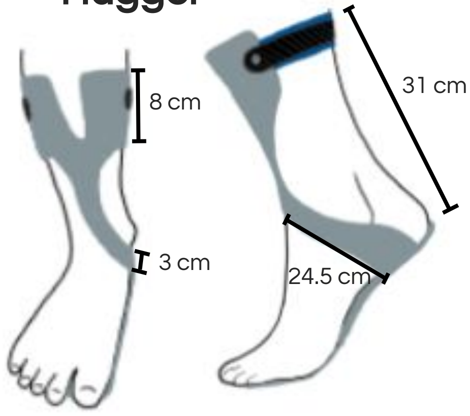



**Figure 12:** Calf Hugger Front and Lateral Views

## We Support U

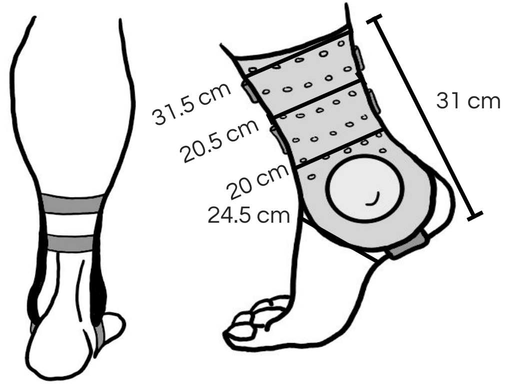



**Figure 13:** We Support U Medial and Posterior Views

# Rigid Support Matrix

| Criteria |  Design 1: Pivot Pro | |  Design 2: Calf Hug | |  Design 3: We Support U | |
|---|---|---|---|---|---|---|
| | Raw Score | Weighted Score | Raw Score | Weighted Score | Raw Score | Weighted Score |
| Dorsiflexion range of motion (20) | 3/5 | 12/20 | 2/5 | 8/20 | 5/5 | 20/20 |
| Mediolateral support (20) | 3/5 | 12/20 | 3/5 | 12/20 | 4/5 | 16/20 |
| Ease of user assembly (15) | 4/5 | 12/15 | 4/5 | 12/15 | 3/5 | 9/15 |
| Comfort (15) | 2/5 | 6/15 | 3/5 | 9/15 | 4/5 | 12/15 |
| Discreteness (10) | 3/5 | 6/10 | 4/5 | 8/10 | 2/5 | 4/10 |
| Ease of Fabrication (10) | 1/5 | 2/10 | 2/5 | 4/10 | 4/5 | 8/10 |
| Cost (5) | 3/5 | 3/5 | 4/5 | 4/5 | 3/5 | 3/5 |
| Safety (5) | 4/5 | 4/5 | 5/5 | 5/5 | 5/5 | 5/5 |
| **Total** | 57/100 | | 62/100 | | 77/100 | |

**Table 1:** Rigid Support Design Matrix

# Material Considerations

### Carbon Fiber Reinforced PLA composite (CF-PLA)

**Figure 14:** CF-PLA material [13]

- Used in current design
- 3D printed, compatible with 3D scanning
- 470 MPa flexural strength [14]

### Fiberglass Plaster

**Figure 15:** CFN Medical Fiberglass Casting Tape [15]

- Multiple color options, easily accessible
- Simple water activation application process [16]
- 50 MPa flexural strength when wrapped at least twice [17]

### Thermoplastics

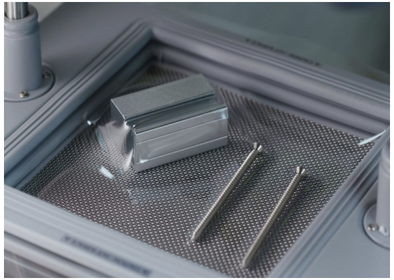


**Figure 16:** Thermoplastic sheet vacuum-formed onto objects [18]

- Most common method for AFO fabrication [19]
- Heated thermoplastic sheets vacuum-formed onto mold [20]
- Flexural strength [21]:
  - Polypropylene (PP): 10-20 MPa
  - Polyethylene (HDPE): 10-50 MPa

# Materials Design Matrix

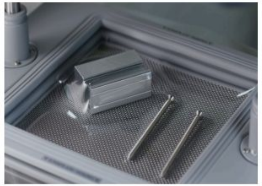
| Criteria |  Carbon Fiber reinforced PLA composite (CF-PLA) | |  Fiberglass Plaster | |  Thermoplastics | |
|---|---|---|---|---|---|---|
| | Raw Score | Weighted Score | Raw Score | Weighted Score | Raw Score | Weighted Score |
| Strength/rigidity (30) | 5/5 | 30/30 | 4/5 | 24/30 | 4/5 | 24/30 |
| Ease of Fabrication (20) | 4/5 | 16/20 | 5/5 | 20/20 | 1/5 | 4/20 |
| Cost (20) | 5/5 | 20/20 | 3/5 | 12/20 | 4/5 | 16/20 |
| Safety (20) | 5/5 | 20/20 | 3/5 | 12/20 | 5/5 | 20/20 |
| Environmental Impacts (10) | 5/5 | 10/10 | 4/5 | 8/10 | 2/5 | 4/10 |
| **Total** | 96/100 | | 76/100 | | 68/100 | |

**Table 2:** Materials Design Matrix

# Final Design

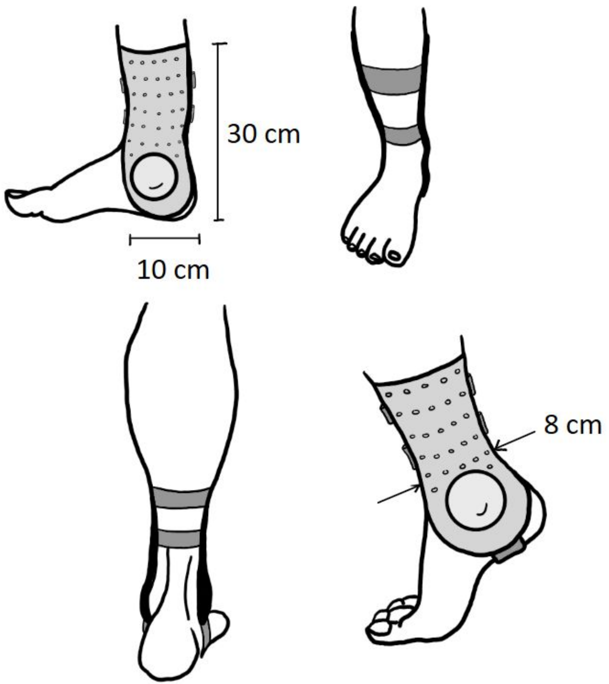



**Figure 17:** Rigid Support Final Design (We Support U)

## Rigid Support

- Free range of dorsiflexion
- Supportive
- Simple assembly

## Material

- High strength
- Inexpensive & Accessible
- Environmentally conscious

**Figure 18:** Carbon Fiber Reinforced PLA Composite (CF-PLA) [13]

# Future Work

## Prototyping

- Model client's foot
  - 3D scanning cast
  - Silicone molding
- Post processing for 3D printing
  - Alternative: fiberglass plaster

**Figure 19:** Provided cast of client's foot

## Testing & Compatibility

- Team & Client evaluation
  - Comfort
- IMU and MoCap Testing via OptiTrack
  - Quantify angle inversion
    - Inversion < 25°
  - Track Dorsiflexion
    - ROM ＞30° from resting
- Finite Element Analysis (FEA)
  - Force: 266 N
  - Torsion: ±30 Nm

# Acknowledgements

**Advisor**

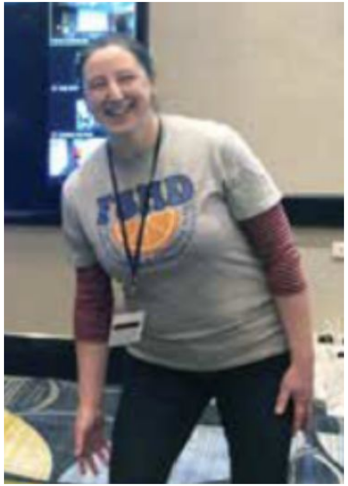
Dr. John Puccinelli

**TA**

Lizzie Maly

**Client**

Debbie Eggleston



**Design Engineer**

Jesse Darley

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# Questions?