INCONSPICUOUS ANKLE FOOT ORTHOSIS (AFO) DEVICE FOR TEEN

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BME 301, Spring 2025

UW BME Design

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Problem Statement

- Ankle foot orthoses (AFOs) provide dorsiflexion and mediolateral support
- AFOs are often bulky and limit natural ankle mobility
- Develop a lightweight, discreet AFO that balances support, comfort, and flexibility for a teenager with Facioscapulohumeral Muscular Dystrophy (FSHD)
- Last semester bungee cord compression design to aid in dorsiflexion

Figure 1: Dorsiflexion Diagram [1].

Figure 2: Ankle Inversion Diagram [2].

Condition & Impact

Client: Debbie Eggleston, a physical therapist and activist for FSHD
Patient: A high school student with FSHD

FSHD:
- Genetic disorder causing progressive muscle weakness [3]
- Limited clinical research involving children

Global Impact: 3 to 5 people out of every 100,000 have FSHD [3]

Figure 3: Supra Malleolar Orthosis [7].

Existing AFOs:
- **Supra Malleolar Orthosis (SMO)** [4]:
  - Thin and flexible thermoplastic
  - Support just above ankle bones
  - Comfortable in shoes
- **Jointed AFO** [5]:
  - Full ankle range of motion
  - Bulky design
- **Passive-Dynamic AFO** [6]:
  - Flexible, energy-absorbing design
  - Does not prevent ankle inversion

Figure 4: Jointed AFO [8].

Figure 5: Passive-Dynamic AFO [9].

Design Specifications

- Prevent ankle inversion angles greater than 25° [10]
- Rigid support that withstands 260 N of force [11]
- Have a slim, lightweight, discreet, and flexible design
- Stay within a budget of $100
- Meet patient-specific dimensions and comfort needs

References

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Final Design

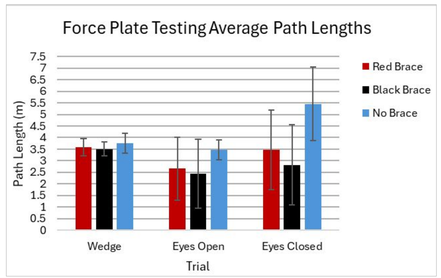
Figure 6: Inversion Support with Dimensions.

Fabrication Process:
- Creality RaptorX 3D scanning
- Using OnShape, created CAD model from mesh file
- 3D printed with carbon fiber reinforced PLA
- Sewed on velcro straps and attached mesh foam using a liquid adherent
- Two sizing options for comfort and support testing

Figure 7: Creality RaptorX 3D scanning.

Design Features:
- Two rigid supports designed to avoid pressure points
- Double layered mesh foam
- Top and bottom adjustable straps
- Fully assembled design includes inversion support, compression sleeve, and bungee cord mechanism

Force Plate Testing and Results



Figures 8: Path Length Bar Chart and Standard Deviation Table.

Figure 9: Force Plate Wedge Trial.

Methods:
- Wedge (17°), eyes closed, eyes open trials
- Stability improvement via center of pressure

Results:
- No statistically significant difference in path length

MTS Testing and Results

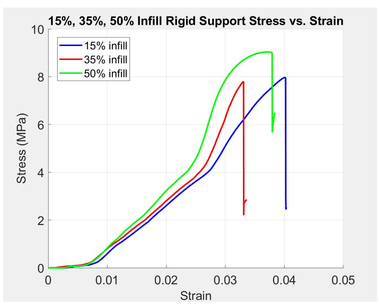


Figure 10: Stress vs. Strain Curve.

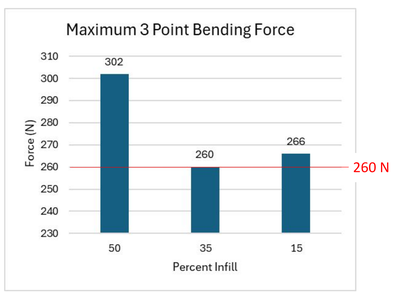


Figure 11: Maximum Force Bar Plot.

Client Testing and Results

Patient Comfortability Testing:
- Comfort rated on a scale 1 to 10
- Reported pain anterior to medial malleolus

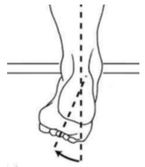


Figure 12: Subtalar Ankle Inversion Angle [1].

Figure 13: Patient Pain Map [2].

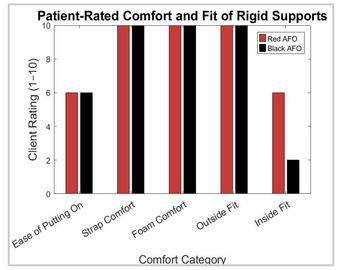


Figure 14: Client Comfortability Rankings.

Markerless Motion Capture Testing: used OpenCap to evaluate ankle inversion

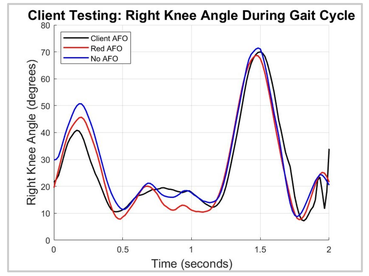


Figure 15: Knee Angle Comparison between Client's AFO, No AFO, and Red AFO.

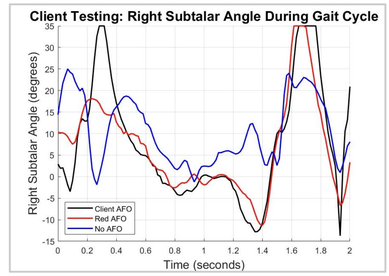


Figure 16: Right Subtalar Angle Comparison between Client's AFO, No AFO, and Red AFO.

Discussion

- **Rigid Support:**
  - Rigid support material selection was limited to accessible 3D printable materials
  - Mechanically effective but future iterations should utilize stronger material
- **Testing Limitations:**
  - Tests performed on healthy subjects due to client unavailability
  - Psychological bias in force plate testing
  - Measured position discrepancies in markerless OpenCap from brace thickness
  - Create a MTS testing fixture
- **Comfort:**
  - Foam padding and straps provided good comfort
  - Ergonomic refinement to minimize localized discomfort

Figure 17: Assembled Ankle Brace Prototype.

Future Work

- Integrate the rigid support and bungee compression sleeve
- Explore using a lace-up bungee mechanism for dorsiflexion support
- 3D scan client's foot to refine rigid support design and improve anatomical fit
- Improve rigid support by exploring stronger materials to enhance brace mechanics
- Use a non-optical motion capture inertial measurement unit (IMU) system on a treadmill
- Client force plate testing

Acknowledgements

- Dr. Puccinelli
- Lizzie Maly
- Matthew Mabee
- Jesse Darley
- Dr. Peter Adamczyk
- Dr. Christa Wille