BME Design-Spring 2025 - Lucia Hockerman
Complete Notebook

PDF Version generated by

SADIE ROWE

on

Apr 30, 2025 @02:56 PM CDT

Table of Contents

Team contact Information

Lucia Hockerman - Jan 31, 2025, 9:05 PM CST

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Puccinelli	John	Advisor	john.puccinelli@wisc.edu		
Eggleston	Debbie	Client	debmegg@gmail.com		
Hockerman	Lucia	Leader	lhockerman@wisc.edu	3143036851	
Michels	Madison	Communicator	mmichels2@wisc.edu	9522589402	
Presley	Hansen	BSAC	pmhansen3@wisc.edu	2622660385	
Rowe	Sadie	BWIG	skrowe2@wisc.edu	3039038280	
Hiller	Kate	BPAG	khiller@wisc.edu	6512120320	

Project description

Madison Michels - Feb 13, 2025, 11:48 AM CST

Course Number: BME 301

Project Name: Inconspicuous Ankle Brace for Teen

Short Name: Rise and Stride

Project description/problem statement:

Ankle foot orthoses (AFOs) are designed to provide dorsiflexion support during the swing phase of walking. These devices are primarily used to treat muscular dystrophies. For this project, we are focusing on young individuals diagnosed with Facioscapulohumeral Dystrophy (FSHD), the most common type of muscular dystrophy. The team aims to design a brace for teens that assists with ankle dorsiflexion, promoting safer walking while remaining easily concealable and flexible enough to allow for functional ankle movement. The brace will be tailored specifically for the client, Maggie Eggleston. Key objectives for the device include positioning the ankle inadequate dorsiflexion, maintaining a slim, discreet design, and ensuring sufficient flexibility to minimize movement restriction

About the client:

Debbie Eggleston is a physical therapist that lives in Michigan. She has a daughter, Maggie, who suffers from FSHD. Maggie is 16 years old and currently attends high school as a sophomore. Maggie enjoys riding horses and experiences judgement for her condition, so she would like a brace that resembles an athletic brace design.

02/03: Client Meeting 1

Lucia Hockerman - Feb 03, 2025, 1:13 PM CST

Title: Client Meeting 1

Date: February 03, 2025

Content by: Lucy

Present: Kate, Maddie, Lucy, Presley

Goals: Introduce the new team to Debbie and get an update on Maggie

Plan:

1. Introduce the team (everyone goes around and introduce themselves)
2. Dive into questions

Questions:

- What are the updates with Maggie and her condition?
    - Any new priorities in functionality of the brace?
- Is she currently wearing an AFO? If so, what does she like/dislike about it?
- Any dimension preferences (ex: height of the orthotic)?

Notes:

- Maggie has a Carbon fiber AFO (complains of bulkiness) and an SMO (supramalleolar orthotic) to control medial and lateral movement. She has the option to wear just the AFO, SMO or wear both. They have helped with long hikes.
- Problems with rolling of the ankle, slipping on snow out in Michigan. She struggles to have the reaction to catch herself when falling
- Does not like how the ankle is held in one position (too rigid). *seems like ankle flexibility is still a very top requirement to create an improved device
- Posterior heel is bothering her when the AFO/SMO rubs against her skin
- Does not like how long it takes to put the orthotics on
- Certain shoes work better than others (new adidas shoes that are wider), still rubbing on the foot
- Orthotic insert can be worn with AFO but not SMO
- The current plan discussed was to send the prototype mid-semester and receive feedback from Maggie and assess with an at-home testing protocol
- Maggie is possibly going to be involved clinical trial over the summer (specifically to target a protein that is no longer needed past embryo. Attack messenger RNA)

Conclusions/action items: Continue to research and meet with Dr. P for our weekly meeting. Revise the PDS to reflect the changes in Maggie's condition and her preferences for an AFO.

01/29: Advisor Meeting 1

Lucia Hockerman - Jan 29, 2025, 1:25 PM CST

Title: Advisor Meeting 1

Date: January 29, 2025

Content by: Lucy

Present: Kate, Maddie, Lucy, Sadie, Presley

Goals: Begin our weekly meeting on Wednesday at 9am. Check in with Dr. Pucc and Lizzie on our conversation during Friday's lab.

Content:

- In lab on Friday: got everyone caught up, reached out to the client
- Talked about improvement for our original design: Maddie suggested an alternative to our rigid support as a more of plates that secure on either side of the ankle
- Our client suggested last semester to reach out to Peter Adamczyk (sounds like he is a friend of some sort)
    - He runs the UW BADGER Lab that sounds like they specialize in recovery through advanced robotic devices. It seems like his lab focuses a lot on devices effecting gait
    - Need to create a new testing plan because the software we used last semester is no longer available. Maybe his lab can help

Brief suggestions/notes from Dr. P:

- Don’t stop looking for stuff

- Send progress reports on Tuesdays

- Reach out to Dr. Adamczyn

- He expects to see improvement on prelim report/PDS

- Next meeting: go over lab archive notebook

- Blue room 1080 ECB 9 am

Conclusions/action items: Continue to research and reach out to Dr. Adamczyk

02/12: Advisor Meeting 3

Lucia Hockerman - Feb 12, 2025, 9:48 AM CST

Title: Advisor Meeting 3

Date: February 12, 2025

Content by: Lucy

Present: Kate, Maddie, Lucy, Sadie, Presley

Goals: Check in with Dr. P and Lizzie to discuss our week's progress in design brainstorming and research

Content:

- Lizzie suggested to reach out to Josh Roth for CAD models file (and Christie Willie)
- Dr. P shared a story about warning us with boa laces. One group reached out and signed an agreement to hand over the rights. Possibly look at a way to fabricate our own version of boa lace.
- Add process involved with the materials. One slide for all the materials to discuss fabrication process
- Dr. P thinks our design matrix looks good! Loves the drawings
- Can look at different vendors outside UW-madison, just need a paper trail
- On the PDS, start thinking what angles are most important to test this semester
- Meeting next week, not the week after that

Conclusions/action items: Start prototyping and begin presentation (reviewing that next week during advisor meeting)

01/31/2025 Cutting Client's Foot Cast

Kate Hiller - Feb 01, 2025, 3:34 PM CST

Title: Cutting Client's Foot Cast

Date: 01/31/2025

Content by: Kate

Present: Whole Team

Goals: To cut the patient's foot cast in half to decide how the team will create a brace around the mold of her foot

Content:

The team met on 01/31/2024 to discuss the PDS and options for the mold of the client's foot. We needed to decide if we were going to try to pour some kind of resin or molding material inside the foot cast or something else.

The team came up with the idea of scanning the foot cast into SolidWorks at MakerSpace and using the image generated to create the rigid supports of the ankle brace. In order to get the negative cross-section of the foot, we needed to cut the brace in half.

The cast was originally cut in the front in order to get the cast off of the client's foot. However, in the previous semester, the team tried to create a resin mold of her ankle and it was unsuccessful. In doing so they fused the cast back into its original shape (one-piece). Therefore, we needed to cut the cast in half to get the negative space cross-sections.

The team went to the TeamLab to cut the brace. Original considerations were to use a band saw or a hand saw to cut the brace through its sagittal plane. However, after consulting with a team member, she recommended using a dermal. Using the dermal to cut the cast was time-consuming, but was successful. We were left with two pieces of the cast ready to be scanned.

cutting the cast with a dremal, secured by a vise.

Succesful cross section cut of the cast

Conclusions/action items:

The team met to complete the PDS and cut the client's cast in preparation for creating the prototype of the brace. The team plans on using a scanner in the MakerSpace to scan the internal cross-section of the cast to create a 3D computer model of the foot to create the rigid supports of the cast. Next, the team will meet with the client to update the team on recent changes to the client and the requirements of the brace.

02/19/2025: Meeting with Jesse about 3D scanning

Lucia Hockerman - Feb 19, 2025, 4:13 PM CST

Title: Meeting with Jesse about 3D scanning

Date: February 19, 2025

Content by: Lucy

Present: Kate, Maddie, Presley, Sadie, Lucy, and Jesse (of course)

Goals: Explore how we can 3D print and fabricate our planned rigid design

Content:

3D scan is just a bunch of dots with no 3D dimension to create a surface --> need to thicken to create an actual brace

Three paths:

1.) 3D scan, onshape/solidworks to trim thicken/edit. Will might have problems thickening it. Could add tabs for straps. Could smooth the scan in mesh-mixer or solidworks.

2.) 3D scan, import into onshape/solidwords, create 3D mold that is close with normal techniques (loft) : recommended

3.) Measure directly

* used on shape for demonstration and recommends this platform (Free 3D for the foot model). But could also do solidworks

: make planes transverse to the surface, create a spine and loft.

Overbuilding: draw the surface bigger than wanted for trimming.

3D scanning session: 1 hour/1 hour 30 mins

Website for models: [3d.nih.gov](3d.nih.gov) (but hard time finding ankles)

Conclusions/action items:

3/18/2025 Meeting With Peter Adamczyk

Kate Hiller - Mar 18, 2025, 5:12 PM CDT

Title: Meeting with Peter Adamczyk

Date: 3/18/2025

Content by: Kate

Present: Kate, Sadie, Lucy

Goals: To get some advice about testing and recommendations for our prototype

Content:

3/18/25 Meeting with Peter Adamczyk

- Peter is family friends with client and has his own lab with OpiTrack
- He recommends the BME lab which has force plates and OpiTrack

LOOK INTO:

Neville Hogan - ankle bot studies, biomechanist

Bar under foot

Graph inversion, eversion

Ankle bot provided torque or displacement

F = kX

Normal walking, add wedge and take away wedge (wood, foam?)

- Tape the wedge to the bottom of the shoe
- Think about using elastic on the brace

POSSIBLE TESTING:

Force plates and wedges, generate differences in the ankle moment

- Maybe 5 degrees of wedge
- He builds 2 DOF ankle model that goes 10 degrees
- Shoot for 10, maybe try 5 and a 10

Give data on how the brace is beefing up strength

<u>Issues with motion tracking</u>: values will be different with a brace

Solution: Look at the **range of motion**, and not the value of an ankle for motion capture

- Can use motion capture to look at ankle angles

Look at the max and min motion of the ankle

-example: 10 to 40 degrees
- another solution: subtract the offset displacement

Another ME design team working Oxford foot model for Mayp Clinic
- Hannah Saderhome? Communicator of team
  - Studying kids with cerebral palsy, how to get the normal placement of the dots on the foot
  - Tackle the challenge for dot placement

Question: Can Maggie do testing barefoot, does she need to have shoes on?

Have Maggie sit on an exam table and move her foot
- Put a plate on the side of her leg with his transducer inside the prosthetic pylon

We want to create disturbance, generate synchrony signal to do analysis
- Put motion capture dots on the plate
- Analysis would be out of hand
- Rather do the stance phase of walking

Conclusions/action items:

Need to think about changing the rigid support design. Also think about where do you want the device to rub on the ankle and should the medial support be larger. Figure out where we would do testing.

04/01/2025: Meeting with Dr. Wille

Lucia Hockerman - Apr 02, 2025, 8:55 AM CDT

Title: In-Person Testing Discussion

Date: April 01, 2025

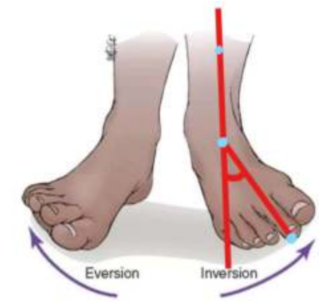
Content by: Lucy

Present: Presley, Lucy, Kate, and Maddie

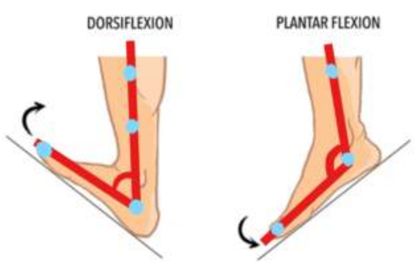
Goals: Discuss ideas and plans for testing using OpenCap and force plates

Meeting date: Tuesday, April 1 at 2:15 pm
Questions to consider:
What are the exact outcome measures you are hoping to report?

- Degrees of inversion: the angle of foot during inversion in reference to the vertical axis along lateral side



- Range of plantar and dorsiflexion motion



- Suggested by Dr. Adamczyk:
    - Using a 5-10 deg wedge, generate an ankle moment
    - Create a stiffness vs force graph?
        - It was like dorsiflexion, inversion, eversion, and plantar flexion Or just two of them and then the line represented stiffness or like “ankle support”
- Overall differences in gait with and without the brace

What are the expected changes you are hoping to see with your device?

- Decreased degrees of inversion
- Decreased force of inversion
- Greater range of dorsiflexion, minimized range of plantar flexion

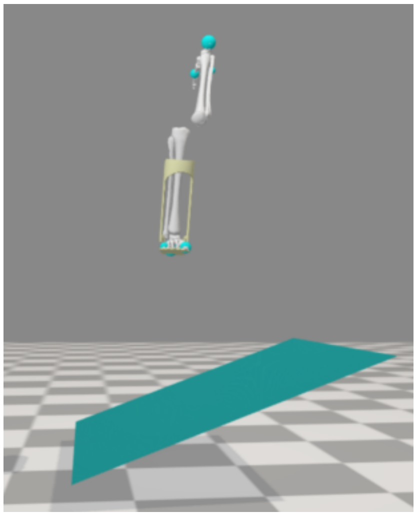
To what degree are you expecting to see a change?

- Ankle inversion of no more than 25 degrees
- Dorsiflexion movement of at least ___%?

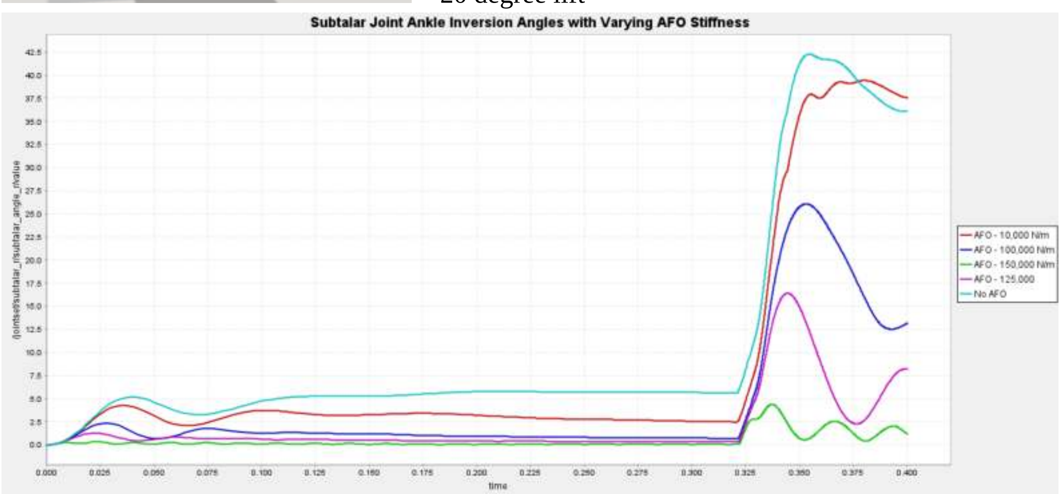
- Force of at least 266 N can be applied

Have you considered or tried using OpenCap to test your device now?

We used an ankle inversion model in OpenSim initially to test forces needed for ankle inversion with a standard AFO brace.



20 degree lift



Altered the stiffness for the AFO to determine the stiffness needed at a 20 degree slope to inhibit more than 25 degrees of ankle inversion. Our AFO should have a transverse stiffness of at least 100,000 Nm

It might also be helpful if you have an article to model some of your measurements off of and ideally an article that discusses which musculoskeletal model you want to use to measure ankle inversion.

Notes during meeting:

- Bring AFO/SMO
- Distance, questions during testing, repetitions, application,
- Video her taking it on and off?
- Look at mechanics “up the chain”: monitor knee and hip mechanics
- Sagittal plane data will be more telling
- Hesitations: set up time and limited inversion detection (+/- 5 deg min reading) with OptiTrack

- Consider using OpenCap: use tripods, pilot with team members and gather data from ankle, knee and hip
- Could use symmetry between legs on the force plates
- Bertek acquire??????????
    - COP
    - Balance on the force plates
- Wedge
    - COP would include wedge mass and location
    - Make sure the same across all three wedges
    - One wedge to measure COP variability while standing on the wedge
        - Quiet balance, no brace (baseline)
        - 15s eyes closed 15s eyes open, 15s with wedge – all two feet
            - Outcome: good balance = tight stabilogram
        - DO THE OTHER SIDE
        - Rotate between the brace types
- Look for improved symmetry between legs (Knee)
- Might see more knee or hip flexion (during swing phase) on impaired leg, if brace can correct it is successful
- Less force of push off during gait cycle if knee flexion compensates for ankle push off
    - Lower peak (peak 2)
    - AFO might excel in plantarflexion

Spring 2025 Expenses

Lucia Hockerman - Apr 29, 2025, 12:49 PM CDT

Spring 2025 Expense Sheet

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total		Total Budget Spent	Link
Category 1 - Rigid Support												
CF-PLA	Carbon Fiber PLA 3D Print	Shen Printer		MakerSpace		2/28/2025	1	$0.86	$0.86			
CF-PLA	Carbon Fiber PLA 3D Print	Shen Printer		MakerSpace		3/5/2025	1	$2.42	$2.42			
CF-PLA	Carbon Fiber PLA 3D Print	Shen Printer		MakerSpace		3/14/2025	1	$3.66	$3.66			
CF-PLA (red)	Carbon Fiber PLA 3D Print	Shen Printer		MakerSpace		4/4/2025	1	$3.92	$3.92			
CF-PLA	Carbon Fiber PLA 3D Print	Shen Printer		MakerSpace		4/4/2025	1	$1.54	$1.54			
Category 2 - Straps and Padding												
Carpet Tape		Capitol	305-150D	Menards	2051560	4/2/2025	1	$7.36	$7.36		$7.36	link
Mesh Padding	3D Air Sponge Mesh Fabric	Tong Gu		Amazon		3/7/2025	1	$16.99	$16.99		$16.99	link

Download

BME_301__Spring_2025_Expense_Sheet.pdf (105 kB)

02/13/2025 - Design Matrix

Madison Michels - Feb 13, 2025, 11:52 AM CST

Title: Design Matrix

Date: 02/13/2025

Content by: Entire Group

Present: Entire Group

Goals:

The goal of our design matrix is to outline our design concepts and material considerations for our project. We evaluated criteria to determine the best design and material to construct the rigid support aspect of our AFO brace.

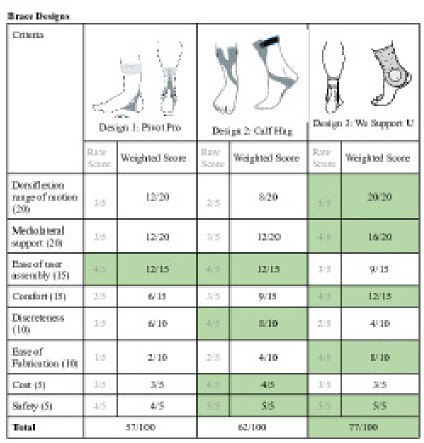
Content:

All content is included in the design matrix attached below.

Conclusions/action items:

In conclusion, we have chosen to move forward with fabricating the "We Support U" brace using carbon fiber reinforced PLA and potentially coating it with fiberglass tape.

Madison Michels - Feb 13, 2025, 11:51 AM CST



Brace Designs

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	

Download

Rise_and_Stride_Design_Matrix.pdf (1.7 MB)

2/11: Ankle Joints

Lucia Hockerman - Feb 11, 2025, 11:59 PM CST

Title: Ankle Structure and Function

Date: February 11, 2025

Content by: Lucy

Goals: The group was discussing the dorsiflexion/inversion aspect of our project. I wanted to explore more on specific joint types that allow this movement.

Content:

Joints of interest: TC joint, ST joint, MT joint (TN and CC)

Talocrural (TC) joint (ankle joint): formed between the talus, tibia, and fibula. **Synovial hinge joint** that allows for **dorsiflexion and plantarflexion**. The walls of the socket consist of the lateral and medial malleoli (sides of the fibula and tibia respectively). Roof of the socket is formed by the inferior surface of the tibia.

Bind the lateral and malleoli together: various ligaments the the interosseus membrane

Talus: articulates with the tibia and fibula, has a head, neck and body. **When the foot is dorsiflexed it is more stable because the talus is wedged between the malleoli.**

Collateral ligaments: line either side of the joint (medial (deltoid) ligaments and lateral ligaments)

Main muscles:

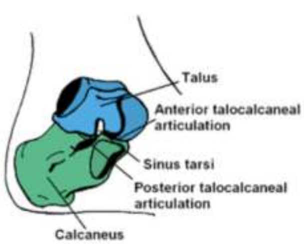
- Gastrocnemius and soleus: primary muscles involved in plantarflexion

- Tibialis anterior muscle: primary muscle that facilitates dorsiflexion

- Peroneus longus and peroneus brevis: found in the lateral part of the leg, function to facilitate eversion

Subtalar (ST) joint: also known as the talocalcaneal joint and formed between the talus and calcaneus.

- Allows for inversion and eversion of ankle and hindfoot



Midtarsal (MT) joint: also known as transverse tarsal joint or Chopart's joint. Consists of two joints: Talonavicular (TN) joint and Calcaneocuboid (CC) joint

- Allows for inversion and eversion

Kinematics:

Talocrural joint (ankle joint):

- During dorsiflexion: the joint axis runs from lateral, posterior, plantar --> medial, anterior, dorsal

- During plantarflexion: the joint axis runs lateral, posterior, dorsal --> medial, anterior, plantar

Dorsiflexion: Plantarflexion:


Subtalar joint: planar dominance in the transverse and frontal planes (i.e. most movement occurs in rotation and side-to-side directions)

MT joint locking: during heel strike, the foot needs to be flexible in order to adjust to the surface and the MT join unlocks to provide this flexibility. During propulsion, the MT join locks to propel to weight of the foot forward.

Conclusions/action items: Discuss with team how this information can help with a new rigid design

2/17: Ankle mediolateral force

Lucia Hockerman - Feb 17, 2025, 4:32 PM CST

Title: Ground Reaction Force: Biomechanics

Date: February 17, 2025

Content by: Lucy

Goals: From a reliable source, research the mediolateral forces during the gait cycle to determine a minimum strength requirement from our rigid support.

Content:

Ground reaction force: force that acts on the body as a result of resting or hitting the ground. Made up of three forces acting in three directions at the centre of pressure (vertical, anterior-posterior and mediolateral)

The mediolateral force component:

- At heel strike a lateral thrust occurs during loading.

- After initial force (heel strike), forces push in a medial direction as the body moves over the stance limb

- The most variable ground reaction force and is greatly affected by footwear and orthotics

- Normal maximum medial force is between **0.05 and 0.1 times the person's body weight.**

Citation: “Ground Reaction Force - an overview | ScienceDirect Topics.” Accessed: Feb. 17, 2025. [Online]. Available: https://www.sciencedirect.com/topics/immunology-and-microbiology/ground-reaction-force

Conclusions/action items: Based on this article and the assumption that a 16 year old female girl weighs around 120 lb, the minimum flexural strength of the rigid support should be 6-12 lb (26.6 N - 53.4 N). This is well below the flexural strength of all suggested materials. Need to update the PDS and preliminary presentation with this information.

2/11: SMO and its function

Lucia Hockerman - Feb 11, 2025, 3:55 PM CST

Title: What is an SMO and its function?

Date: February 11, 2025

Content by: Lucy

Goals: Learn the basics about a SMO to update as a competing design on the PDS

Content:

SMO (Supra-Malleolar Orthosis): foot support device that stabilizes the foot just above the anklebones, primarily controlling the subtalar joint alignment.

Subtalar joint: located between the talus and calcaneus (heel hone), essential for side-to-side foot movement.

The SMO prescription basis: typically for individuals with flexible flat feet, excessive pronation, toe walking, or low muscle tone. SMOs help correct issues by maintaining a neutral heel position, improving balance, and reducing muscle fatigue.

Pediatric SMOs: think, flexible thermoplastic (allows for natural muscle development while providing stability), fits comfortably in shoes

Link: https://www.infinitetech.org/what-is-an-smo-and-its-function (in zotero)

Conclusions/action items: Continue research on updated competing designs

2/11: Variable stiffness orthosis (VSO)

Lucia Hockerman - Feb 11, 2025, 4:13 PM CST

Title: What is an SMO and its function?

Date: February 11, 2025

Content by: Lucy

Goals: Learn the basics about a VSO

2

Content:

Variable Stiffness Orthosis (VSO) was developed to address the rigidity of current orthoses and the difficultly to make devices commercially available due to challenges like reliability, weight and cost.

The device:

- VSO features a customizable cam-based transmission to allow for users to swap out components for personalizes torque-angle functions (customizable gear system)

- Real-time stiffness adjustments by modifying support conditions on a leaf spring

Research findings: For a participant with sciatic nerve injury, the VSO reduced foot drop, increased walking speed, improved ankle moments, and minimized abnormal gait patterns compared to traditional AFOs

Link: https://neurobionics.robotics.umich.edu/research/wearable-robotics/variable-stiffness-orthosis/ (in zotero)

Conclusions/action items: Finish the design matrix, keeping these new competing designs in mind

01/31: Bullying, Physical Disability and the Pediatric Patient

Lucia Hockerman - Feb 05, 2025, 7:46 AM CST

Title: Bullying, Physical Disability and the Pediatric Patient

Date: January 31, 2025

Content by: Lucy

Goals: To gain a better impact on the potential societal impact of our research and brace, the goal is to learn more about the affects physical disabilities can have during interactions with peers.

Content:

Introduction:

The study compares rates of bullying in two groups of children attending hospital clinics through a **matched-design study:**

1.) attends childhood development centre (CDC) with conditions affecting their appearance and/or gait (visible abnormality)

2.) Attends the general pediatric clinic with conditions not associated with visible abnormalities (outpatient control)

Aim: to compare the rates of bullying and determine how a visible disabilities effects the differences observed by the two groups.

Methods:

- Identify the first 50 children aged 8-11 years and the first 50 aged **13-16 years** (only ended up with 31) who attended CDC from patient index cards: children were diagnosed with cerebral palsy, **muscular dystrophy**, marked co-ordination disorders, poliomyelitis, spina bifida or Erb's palsy

- Outpatient control: 50 children in each age group who had been referred to the pediatric outpatient department (OPD) selected from the computer index

- Intro and permission letter was given to the parents

- Asked to fill out the (anonymous) Olweus bullying questionnaire (26 questions about experiences in school)

- Their definition of bullying "We say a child is being bullied when another pupil or group of pupils say nasty and unpleasant things to him or her. It is also bullying when a pupil is hit, kicked, threatened, locked inside a room and things like that. These things may take place frequently and it is difficult for the pupil being bullied to defend himself or herself. It is also bullying when a pupil is teased repeatedly in a negative way. But it is not bullying when two pupils of about the same strength quarrel or fight."

Total of 103 questionnaires were analyzed:

- 57 control: 34 boys and 23 girls

- 46 CDC: 30 boys, 16 girls

- Similar ethnic backgrounds and religion to reflect the "local population."

Results:

- 50% CDC compared to 21% of control have been bullied at least once

- 30% CDC compared to 14% of control are bullied "regularly"

Conclusion: children with cerebral palsy and similar conditions affecting their appearance, gait and mobility should also be seen as a vulnerable group. **Based on this study, those with visible disabilities are around x2 as likely to get bullied in school settings.**

Conclusions/action items: This study was conducted in 1996 and seems to be outdated. Additionally, the sample size was small and not reflective of the general population. More research on a more recent and larger study is needed.

01/31: Enhancing Economic and Environmental Sustainability - AFO case study

Lucia Hockerman - Feb 05, 2025, 7:58 AM CST

Title: Enhancing economic and environmental sustainability benefits across the design and manufacturing of medical devices: a case study of ankle foot orthosis

Date: January 31, 2025

Content by: Lucy

Goals: Dive into the economic and environmental affect of manufacturing AFOs in hopes to create design with minimal impact on the environment and improve economic sustainability.

Content:

Introduction: there is a major increase in additive manufacturing (AM), which allows for increase availability for tailored devices to address individual needs. 3D-printing reduces the mass and energy consumption that contribute to greenhouse gases and global warming. Advancements make it possible to use a **laser scanner** to generate CAD models of patient's foot dimensions.

Current customized AFO process: plaster of paris mold made from a patient's leg, which is wrapped by a heated, softened polypropylene. Fiberglass bandage is wrapped around the foot, ankle and calf and after curing, cut away from the patient and plaster is poured into the fiberglass shell mold.

Objective/Aim: address the existing challenges in the design and manufacturing of O&P devices (which include inefficient processes, mass and energy consumption reduction). The objective is to develop a multi-criteria decision-making framework to integrate sustainable ideology in the AFO fabrication processes.

Methodology: explore a system where users can upload their foot measurements, which is converted into the 3D CAD model.

Case study: A CAD model of an AFO is designed using the combination of parametric design and NURBS technique. The goal is to enhance sustainability benefits (minimize energy consumption, and total cost) by altering different shape complexities, layer thickness, materials, and 3D printer machines.

Shape complexity (SC) definition, overall SC is the sum of these three aspects:

1.) Aspect ration (height and cross-sectional sizes)

2.) Feature scale (triangle number and volume)

3.) Internal feature (channels and holes)

Two AFO fabricated using **AM Fused Deposition Modeling (FDM)** process. Part 1 = child-size AFO, Part 2 = adult-sized AFO

Assumptions: rated power of FDM machine is 23 kW, price of electricity is $0.2/kWh

Results:

Case Scenario	Part 1	Part 2
Material	ABS	ASA
Machine	uPrint SE Plus	Fortus 450mc
Material Volume (mm^3)	74,725	237,235
Support Volume (mm^3)	14,912	48,260
Build Time (hr)	7.3	24.2

Figure 1: Differences between Part 1 and Part 2

Ele = environmental impacts of electricity used

Elm = environmental impacts of material used

Elt = environmental impacts of transportation

Table 4. Cradle-to-gate GWP over 100-year time horizon for the AFO fabrication

Substance	Emission Factor	Part 1 (kg CO_2 eq.)	Part 2 (kg CO_2 eq.)
EI_e	7.40E-01	1.33E+02	4.16E+02
EI_m	3.77E+00	3.01E-01	9.57E-01
EI_t	2.50E-04	4.00E-03	1.27E-02
Total	-	1.34E+02	4.17E+02

Figure 2: Overall emission estimate of each part

* Cradle-to-gate GWP: partial assessment of a product's environmental impact from raw material extraction to the entrance in factory --> source: https://www.arbor.eco/blog/what-is-cradle-to-gate-in-carbon-calculations-carbon-101#:~:text=related%20environmental%20footprint.-,What%20is%20the%20meaning%20of%20cradle%2Dto%2Dgate?,material%20choices%20and%20production%20methods.

* Emission factor : coefficient that measures how much a pollutant is released into the atmosphere from a specific activity --> source: https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification#:~:text=An%20emissions%20factor%20is%20a,the%20release%20of%20that%20pollutant.

Conclusions: The use of NURBS and parametric design has significant potential to contribute towards the growing needs of the users while remaining sustainable.

02/01: Recycling and Remanufacturing of Carbon Fiber Reinforced PLA Composites

Lucia Hockerman - Feb 01, 2025, 5:55 PM CST

Lucia Hockerman - Feb 05, 2025, 8:06 AM CST

Title: Recycling and remanufacturing of 3D printed continuous carbon fiber reinforced PLA composites

Date: February 01, 2025

Content by: Lucy

Goals: Understand the recycling process of carbon fiber reinforced PLA as this was the material we used for our ridged support for last semester's final design and a material we are considering for the new support.

Content:

Introduction:

- Carbon fiber reinforced PLA is high in strength, is low weight, and durable, but due to their heterogeneous nature, the composites are difficult to recycle (especially thermoset-based ones)

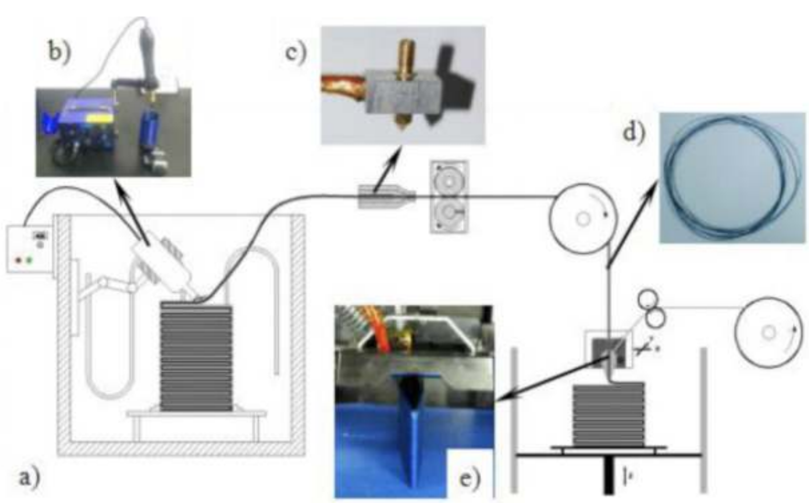
- Thermoplastic-based fiber composites are easier to recycle (PLA reinforced with carbon fiber)

Aim: develop a cleaner production pattern and recycling system for carbon fiber reinforced PLA.

Methods:

- 3D printing methods: feeding thermoplastic filaments into a printer head, to melt and mix with continuous carbon fibers (creating a composite). The orderly fiber distribution enables effective recycling

- Recycling/remanufacturing methods: reverse the 3D printing process. Use hot air gun to melt the composite to recovered carbon fiber (coated with thermoplastic) is smoothed used a remolding nozzle and used in the next printing process. New method that conserves the length of the fibers to preserve material strength. To preserve the PLA, pure PLA is added during remanufacturing.



Results: analyzing the properties of the remanufactured continuous fiber-reinforced thermoplastic composites (CFRTPCs)

Tensile strength: Significant increase in strength with continuous fiber reinforcement even after remanufacturing process (CF/PLA = 256 MPa and pure PLA = 62 MPa)

Flexural Strength:

- Remanufactured composites showed a 25% improvement in flexural strength (263 MPa) than originally printed composites

- Flexural modulus slightly decreased from 14.5 GPa to 13.3 GPa likely due to PLA matrix degradation

Charpy Impact Strength: Originally printed CF/PLA composites had an impact strength of 34.5 kJ/m^2 compared to 20.0 kJ/m^2 for pure CF

Overall: the remanufactured CF/PLA is stronger compared to pure PLA and originally printed CF/PLA (improves the matrix-fiber bonding)

Energy consumption: recycling/remanufacturing process consumes 67.7 MJ/kg, which is higher than conventional recycling methods but lower than additional CF/PLA production. Downsides are slow processing speeds and open-environment heating.

Conclusions: Recycling process successfully recovers 100% of carbon fiber and 73% of the PLA matrix. The remanufactured composite preserves or even improved the mechanical properties of CF/PLA.

02/01: Exploring the rational for prescribing ankle-foot orthoses and supramalleolar orthoses

Lucia Hockerman - Feb 03, 2025, 9:55 PM CST

Title: Exploring the rationale for prescribing ankle-foot orthoses and supramalleolar orthoses (SMO) in children with cerebral palsy: A narrative synthesis of rationale statements

Date: February 03, 2025

Content by: Lucy

Goals: During our client meeting, Debbie mentioned Maggie now wears variations between her AFO, SMO or both. This is a new development, so the goal is to understand more about a SMO and the rationale for its prescription.

Content:

Additional background information: SMO are commonly worn by children and they are shorter and less bulky (photo and information from: https://www.thefeetpeople.com.au/services/custom-ankle-foot-orthotics/surestep-smo/#:~:text=and%20reduced%20discomfort.-,What%20is%20an%20SMO%3F,typically%20covers%20the%20foot%20arch.)

Background: study explores rationale for prescribing AFOs and SMOs for children with cerebral palsy (CP), a neurological condition that affects movement and gait. AFOs are pretty well researched, but SMOs have limited evidence on their effects.

Methods: conducted a database search across multiple databases. Studies were included if they:

- Were experimental or observational studies

- Involved participants under 18 years old with CP

- Included AFO or SMO prescription

- Were published in English within the last 10 years

Results: analyzed 47 studies on AFOs and SMOs specifically for children with CP, all 47 studies included an AFO and 5 also include SMOs.

Types of AFOs: solid (43%), non articulated (14%), or articulated (36%)

Rationale for orthotic use: 5 major themes for prescribing AFOs and SMOs

1.) Improve gate outcomes

2.) Reduce energy expenditure to improve walking efficiency

3.) Protect and correct musculoskeletal alignment to prevent deformities

4.) Improve balance and coordination

5.) General prescription rationale

About SMOs:

- No studies examined SMOs as a standalone intervention

- Inconsistent reported details about SMO properties so they were hard to compare across studies

- The primary rational for prescribing SMOs was a foot and ankle alignment correction rather than more generic gait modifications. Specifically, they are used **to stabilize excessive pronation or supination** when children with CP have mild to moderate foot deformities

- SMO "is prescribed primary to control hindfoot and midfoot varus/valgus"

- Some studies suggest SMOs can improve join kinematics and postural responses by providing proprioceptive sensory input during gait

- SMOs are linked to improved energy use, stability, and prevention of joint contractures

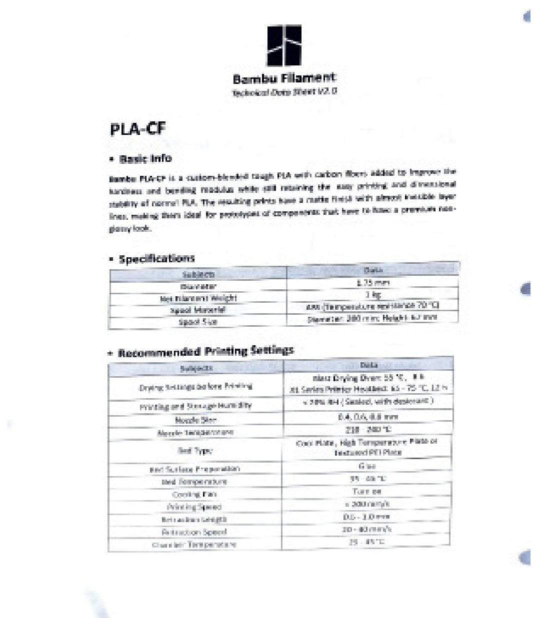
- Studies did not specify whether the SMOs were custom-made or prefabricated

Conclusions: there is strong evidence supporting AFOs for gait improvement, but SMOs lack a well defined rationale.

Conclusions/action items: Ask Debbie additional questions about her doctor's rationale for prescribing a SMO other than it's less obvious and bulky design.

CF-PLA: Makerspace reference sheet

Lucia Hockerman - Feb 17, 2025, 4:10 PM CST



Bambu Filament
Technical Data Sheet V2.0

PLA-CF

- Basic Info

Bambu PLA-CF is a custom-blended tough PLA with carbon fibers added to improve the hardness and bending modulus while still retaining the easy printing and dimensional stability of normal PLA. The resulting prints have a matte finish with almost invisible layer lines, making them ideal for prototypes of components that have to have a premium non-glossy look.

- Specifications

Subjects	Data
Diameter	1.75 mm
Net Filament Weight	1 kg
Spool Material	ABS (Temperature resistance 70 °C)
Spool Size	Diameter: 200 mm; Height: 67 mm

- Recommended Printing Settings

Subjects	Data
Drying Settings before Printing	Blast Drying Oven: 55 °C, 8 h X1 Series Printer Heatbed: 65 - 75 °C, 12 h
Printing and Storage Humidity	< 20% RH (Sealed, with desiccant)
Nozzle Size	0.4, 0.6, 0.8 mm
Nozzle Temperature	210 - 240 °C
Bed Type	Cool Plate, High Temperature Plate or Textured PEI Plate
Bed Surface Preparation	Glue
Bed Temperature	35 - 45 °C
Cooling Fan	Turn on
Printing Speed	< 200 mm/s
Retraction Length	0.5 - 1.0 mm
Retraction Speed	20 - 40 mm/s
Chamber Temperature	25 - 45 °C

Download

CF-PLA.pdf (4.74 MB)

Lucia Hockerman - Feb 23, 2025, 7:17 PM CST

Based on the Design Innovation Lab 3D printer cost calculator, CF-PLA is $0.05 per gram of material.

Citation:

"3D Printer Cost Calculator," Design Innovation Lab. Accessed: Feb. 23, 2025. [Online]. Available: https://making.engr.wisc.edu/3dprint-cost/

2/17: Fiberglass plaster using water-based gel technique

Lucia Hockerman - Feb 17, 2025, 3:31 PM CST

Title: Fiberglass cast application

Date: February 17, 2025

Content by: Lucy

Goals: In preparation for preliminary presentations, I am diving into more research about our three selected material's application process. The goal of this article is to learn more about fiberglass plaster application.

Content:

Introduction: Typically, fiberglass plaster is applied with water activation but this process is messy and less accurate in positioning limbs. This article explores using a water-based gel for a cleaner and precise application process.

Technique:

- Stockingnette sleeve and additional gel padding is used as a base material to lessen the itching and increase comfort.

- Physician must wear glove for this process because many synthetic casting materials can create an exfoliative dermatitis when exposed to bare skin.

- Dry fiberglass plaster is applied to the desired limb. It is stretched and allowed to relax to adjust on the limb. The whole roll is used in this process

- A water-based gel (such as KY Jelly) is applied evenly to the outside of the plaster

- Material will begin to harden and bubble. A further roll may be applied and the process is repeated

- Excess gel can be wiped off after the cast has set

Figure 1: Application of gel onto dry cast

Citation: G. D. Smith, R. G. Hart, and T.-M. Tsai, "Fiberglass cast application," *The American Journal of Emergency Medicine*, vol. 23, no. 3, pp. 347–350, May 2005, doi: 10.1016/j.ajem.2005.02.031.

Conclusions/action items: Overall, the gel-based application process is a technique that could be used for our project that would give us the flexibility and accuracy to create the rigid supports for our design.

2/17: Thermoplastics - PP vs PE

Lucia Hockerman - Feb 17, 2025, 5:24 PM CST

Lucia Hockerman - Feb 17, 2025, 5:41 PM CST

Title: Polyethylene vs polypropylene: When to Choose What?

Date: February 17, 2025

Content by: Lucy

Goals: In preparation for preliminary presentations, I want to learn more about the most commonly used thermoplastics used for AFO manufacturing, specifically the flexural strength of each of the materials.

Content:

* Note that all specific properties will vary depending on manufacturing techniques and grades from different suppliers.

<u>Polyethylene (PE)</u>: more widely produced and available. Generally more expensive that PP (HDPE: $0.5-$1.5 per lb). Resistant to moister and chemicals, easy to recycle.

Available as:

- Low-density polyethylene (LDPE): flexible and transparent

- High-density polyethylene (HDPE): rigid polymer with higher density (likely selected if used in our project)

- Linear low-density polyethylene (LLDPE): flexible and tough form that combines the properties of LDPE and HDPE

<u>Polypropylene (PP):</u> known for its high strength and stiffness. Homopolymer PP is priced around $0.30-$0.70 per lb. Has a high temperature resistance, possible to recycle but more complicated process

Physical properties material comparison:

Property Name	Polyethylene	Polypropylene
Density	0.91-0.94 g/cm³	0.90 to 0.91 g/cm³
Melting point	115-135°C	130-171°C (266-340°F)
Transparency	Transparent or translucent	Mostly translucent
Flexibility	Partially flexible	Mostly rigid & stiff
Chemical resistance	Resistant to acids, alkalis, and solvents	Resistant to acids, alkalis, and solvents including strong bases & organic solvents
Dielectric constant	2.25 to 2.35	1.78 to 2.20
Electrical resistivity	10^{16} to 10^{18} ohm-cm	10^{14} to 10^{16} ohm-cm
Water absorption rate	0.01% to 0.5%	0.01% to 0.8%
Temperature resistance	115°C	170°C

Mechanical properties material comparison:

Property Name	Polyethylene	Polypropylene
Tensile strength	▪ LDPE: 1050 to 2100 psi ▪ HDPE: 4550 to 6100 psi	4000 to 5800 psi
Impact resistance	Better impact resistance absorbs impacts and deforms without breaking	Slightly less than PE
Flexural strength	▪ LDPE: 6 to 26 MPa ▪ HDPE: 10 to 50 MPa	10 to 20 MPa
Clarity retention	Less than PP	Better than PE, less prone to yellowing or discoloration when exposed to UV radiation or prolonged use
Creep resistance	Higher than PP because of fewer branches and linear structure	Less than PE due to branching which reduces its packing density
Flash point	▪ LDPE: 343°C ▪ HDPE: 388°C Higher flammability than PP	260°C
Barrier properties	Against moisture, water vapor, oxygen, and carbon dioxide	More against grease, oil, and chemicals than PE
Moisture vapor transmission rate	0.5 to 5 g/m^2/day	1 to 10 g/m^2/day, Higher tendency to absorb moisture than PE

Citation: “Polyethylene vs Polypropylene (PE vs PP): A Comprehensive Comparison Guide.” Accessed: Feb. 17, 2025. [Online]. Available: https://omnexus.specialchem.com/tech-library/article/polyethylene-versus-polypropylene

Conclusions/action items: Edit preliminary presentation with new data

Lucia Hockerman - Feb 17, 2025, 5:25 PM CST

3/11: Gait Analysis Using Wearable Sensors

Lucia Hockerman - Mar 11, 2025, 1:12 PM CDT

Lucia Hockerman - Mar 11, 2025, 1:57 PM CDT

Title: Gait Analysis Using Wearable Sensors

Date: March 11, 2025

Content by: Lucy

Goals: Understand the pros and cons of different types of various sensors used for gait analysis

Content:

Gait Analysis with Wearable Sensors: Motion sensors attached to body parts (e.g., foot, waist) collect movement data.

- Cost-effective, convenient, and efficient for health-related applications.
- Used in clinical rehabilitation, medical diagnosis, and sports science.
- Types of sensors: accelerometers, gyroscopes, force sensors, strain gauges, inclinometers, goniometers, and electromyography (EMG).

Accelerometer:

- Measures acceleration typically of the feet or legs.
- Common types: piezoelectric, piezoresistive, and capacitive.
- Used for motion status and foot/leg acceleration detection.

Gyroscope:

- Measures angular velocity.
- Helps determine foot/leg angular motion in gait analysis.
- Usually combined with gyroscope

Magnetoresistive Sensors:

- Measures changes in resistance due to magnetic fields.
- Estimates body segment orientation relative to magnetic north.
- Complements accelerometers and gyroscopes.

IMUs: combine accelerometers and gyroscopes (sometimes magnetometers)

Flexible Goniometer:

- Measures joint angles between body segments.
- Includes strain gauge, mechanical, inductive, and optical fiber types.
- Used for knee and joint movement analysis.

Electromagnetic Tracking System (ETS):

- Uses controlled magnetic fields to track 3D position and orientation.
- Requires a transmitter and sensors placed on the body.
- Used in kinematic studies and gait analysis.

Sensing Fabric:

- Flexible textile sensors embedded with piezoresistive, piezoelectric, or piezocapacitive materials.
- Comfortable for wearable applications.
- Can measure human posture and movement.

Force Sensors:

- Measures ground reaction forces (GRF) during walking.
- Instrumented treadmill
- Common types: piezoelectric, strain gauge, capacitive, and optical fiber-based.

Electromyography (EMG) Sensors:

- Measures muscle activity via surface or wire electrodes.
- Provides data on muscle contraction timing and intensity.
- Can be wireless for easier use in motion studies.

Gait Kinematics: measures movement patterns

- Gait kinematics involves measuring and analyzing human movement to recognize gait phases
- Two primary measurement techniques:
    - Camera-based systems – Traditionally used in specialized labs.
    - Wearable sensors – A more recent and flexible method using accelerometers, gyroscopes, and magnetoresistive sensors to track body segment movements.
- Wearable sensors enable ambulatory gait analysis:
    - Accelerometers – Track movement and classify activities.
    - Gyroscopes – Measure joint angles.
    - Other technologies: flexible goniometers, electromagnetic tracking systems (ETS), and smart sensing fabrics.
- Advanced data analysis techniques:
    - Machine learning, filtering methods (e.g., Kalman filter) to refine movement assessment.

Gait Kinetics: Analyzes forces involved in movement

- Gait kinetics studies the forces and moments driving movement, with a focus on ground reaction force (GRF).
- Traditional measurement methods:
    - Stationary force plates – Limited to single strides.
    - Instrumented treadmills – Overcome some limitations, but still restrict movement (e.g., no turning).
- Wearable sensors provide mobile solutions for GRF and center of pressure (CoP) measurement:
    - Pressure sensors – Measure GRF during walking.
    - Instrumented shoes – Track GRF and CoP in ambulatory settings.
- Inverse dynamics calculates joint moments and powers for clinical evaluations of movement disorders.

EMG and Muscle Force: evaluates muscle activity

- Electromyography (EMG) detects electrical activity in muscles during walking.
- Wearable EMG sensors provide insights into:
    - Muscle activation patterns.
    - Muscle fatigue and neuromuscular health.
- Muscle force estimation:
    - EMG can estimate muscle force but may not be directly proportional to muscle tension.
    - Optimization methods and musculoskeletal modeling (e.g., OpenSim, Anybody) improve accuracy in muscle force prediction and movement visualization

Citation: W. Tao, T. Liu, R. Zheng, and H. Feng, “Gait Analysis Using Wearable Sensors,” *Sensors (Basel)*, vol. 12, no. 2, pp. 2255–2283, Feb. 2012, doi: 10.3390/s120202255.

Conclusions/action items: IMUs still remain the most practical solution. Still need to decide on the best system to use on campus. Testing further down the line could include EMG to give more insight into muscle activation.

3/11: Accuracy measurement comparison of Optotrak Certus and OptiTrack

Lucia Hockerman - Mar 11, 2025, 3:57 PM CDT

Title: Accuracy Measurement of different marker based motion analysis systems for biomechanical application: a round robin study

Date: March 11, 2025

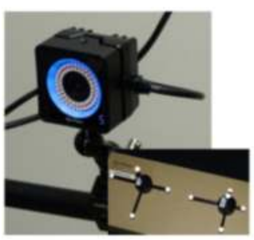
Content by: Lucy

Goals: Compare the accuracy of the two motion capture systems in the Mechanical Engineering building

Content:

This study assess 7 different measurement system. For the purpose of this research, I am only focusing on the two motion capture systems available on campus: Optotrak Certus and OptiTrack

Optotrak



OptiTrack

Specifications:

Measurement System	Markers	Measurement Accuracy/Resolution (Manufacturer)	Used Frequency/Max. Frequency	Max. analyzable volume	Calibration	Camera
Optotrak	Active markers, Orthopaedic Research Pins (20mm)	0.1 mm/ 0.01 mm	410/2000 Hz	4.2x3.0x5.5 m	Calibration was carried out by the manufacturer	Three camera sensors

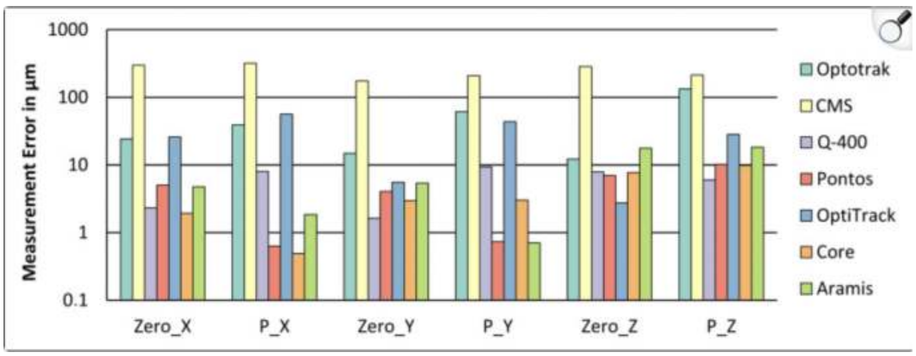
OptiTrack	Passive Markers; two rigid bodies KS1 = 5 markers & KS2 = 4 markers	+- 0.2 mm 1.3 MP	240/240 Hz	5x5x3 m	Using a calibration stick with passive markers on it before measurement	Seven cameras (Prime 13)

* OptiTrack at UW-Madison uses a 12 camera system (not 7 cameras)

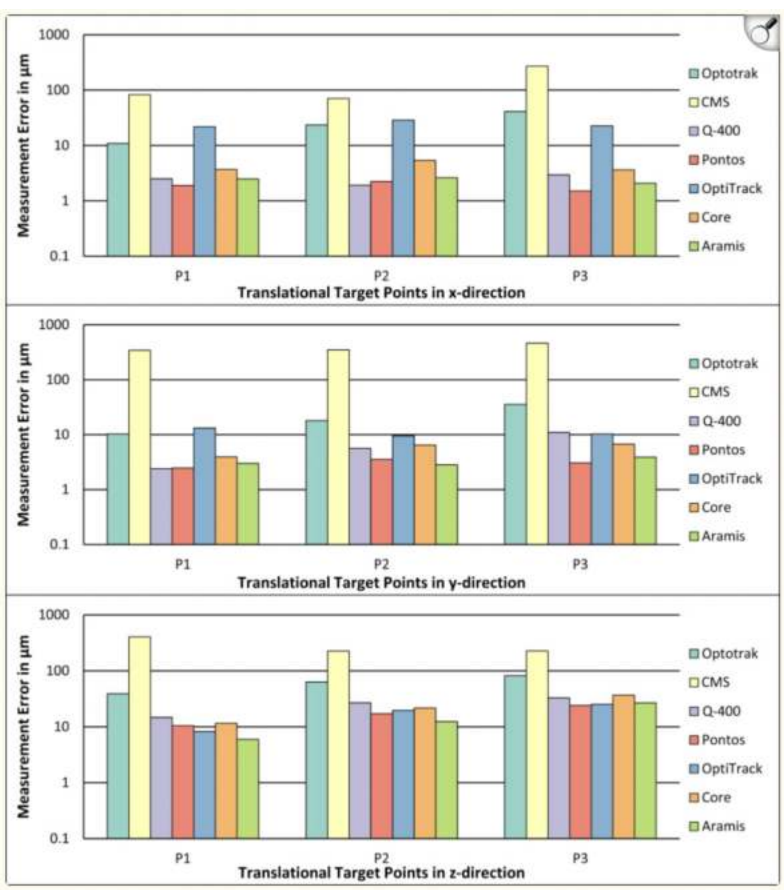
Compared the systems output coordinate values to two reference coordinate methods:

1.) Coordinate measurement machine: sensor positioned in the corner of the room with an accuracy of 2.0 micrometers

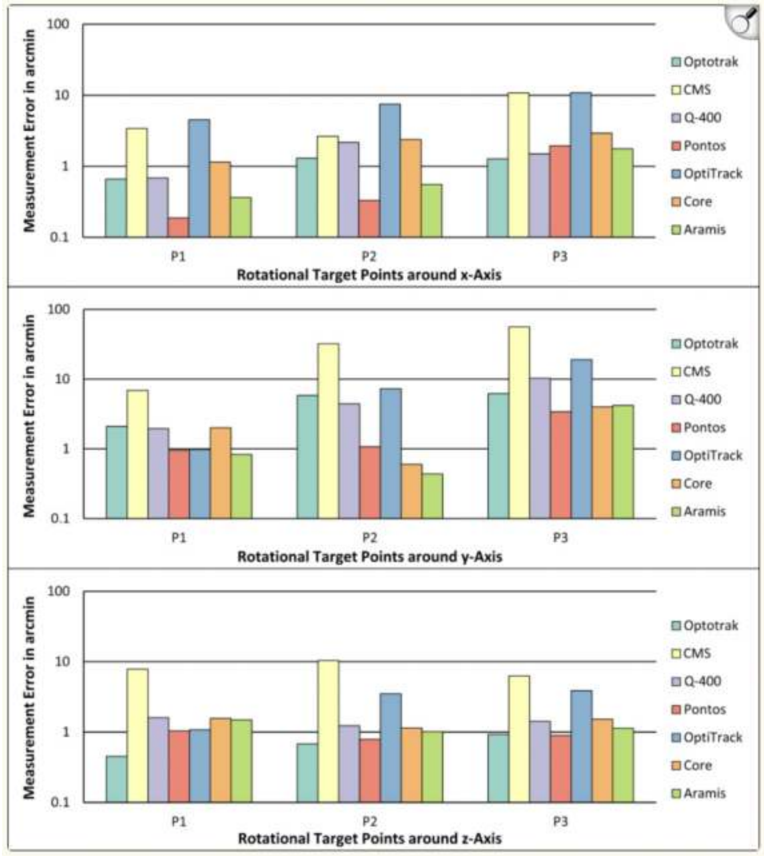
Measured and compared: position and zero offset in the x, y, and z directions by moving 10 mm in those directions. Calculated the measurement error:



Measured and compared: measured 9 different positions in the x,y, and z directions and calculated the measurement error



Rotational findings: measured the error for rotational measurement around the x, y, and z



<u>Overall: Manual reference device revealed similar trends in translational positions, but showed Optotrak had a lower measurement in error for rotation</u>

Citation: S. Schroeder *et al.*, “Accuracy measurement of different marker based motion analysis systems for biomechanical applications: A round robin study,” *PLoS One*, vol. 17, no. 7, p. e0271349, Jul. 2022, doi: 10.1371/journal.pone.0271349.

Conclusions/action items: Based on the study's results, Optotrak system was less accurate for translational position but more accurate for rotational position movements as compared to OptiTrack.

3/5: UW-Madison 3D motion capture options

Lucia Hockerman - Mar 11, 2025, 2:32 PM CDT

Lucia Hockerman - Mar 11, 2025, 2:52 PM CDT

Title: Testing equipment on campus

Date: March 05, 2025

Content by: Lucy

Goals: Learn about the different motion capture systems available on campus (outside of ECB)

Content:

UW BADGER LAB and UW Neuromuscular Biomechanics Lab (Dr. Adamczyk): located in mechanical engineering building

Motion analysis lab: 12-camera, **240 Hz OptiTrack passive-marker motion capture system,** two Bertec force plates mounted in a 20 meter walkway, and analog data acquisition system. Also, has a variety of wearable inertial sensors.

Source: https://uwbadgerlab.engr.wisc.edu/facilities/

Also in mechanical engineering:

- **Active Motion Capture System (Optotrak Certus)**
- Embedded 6D Bertec Forceplate
- Back Projected Virtual Reality System
- Research Grade Ultrasound (Ultrasonix SonixTouch)
- MRI compatible musculoskeletal loading devices
- MTS Criterion 43, 10 kN Capacity (MTS Systems Corp.)
- 2D and 3D Load Cells, Digital Goniometers
- **Differential Electrodes for Wired and Wireless EMG analysis**

In badger athletic performance lab:

- Bilateral Jump Forceplates
- Lunar iDXA Scanner
- Star Excursion Balance Test Platform and Forceplate
- System 4 Dynamometer

Source: https://uwnmbl.engr.wisc.edu/facilities.php

Conclusions/action items: Research specifically the accuracy and reliability of the OptiTrack passive-marker motion capture system and Active Motion Capture System (Optotrak Certus)

2/11: Rough sketch of initial design idea

Lucia Hockerman - Feb 17, 2025, 4:41 PM CST

Title: Initial design idea

Date: February 11, 2025

Content by: Lucy

Goals: Start brainstorming mediolateral supports with the team and create rough sketches to narrow down which designs to be used for the design matrix

Content:

I drew this during our team brainstorming meeting. Ultimately not chosen, so further dimensions and details were not added. The design features two rigid side supports (medial and lateral), straps to secure in place, and a hinge joint to allow for one-dimensional flexibility.

Conclusions/action items: Finish design matrix criteria with chosen designs.

03/03/2025: Initial Prototype Fabrication

Lucia Hockerman - Mar 11, 2025, 4:08 PM CDT

Title: Initial Prototype Fabrication

Date: March 03, 2025

Content by: Lucy

Present: Maddie and Lucy

Goals: Learn how to sew and fabricate the initial prototype.

Content:

The supports were 3D printed with CF-PLA at the Markerspace. They were replicates of the inside 3D scan of the cast. To complete the fabrication, we added foam to the inside of both supports and sewed on velcro to scrap material that was inserted through the slots of the design.

Fully fabricated piece:

Maddie Sewing!

Conclusions/action items: Based on our evaluation of the prototype, next steps include creating longer supports (using inside and outside foot dimensions) and replacing foam with an improved cushion.

04/17/2025: Final Prototype Fabrication

Lucia Hockerman - Apr 30, 2025, 12:49 PM CDT

Title: Final Prototype Fabrication

Date: April 7, 2025

Content by: Lucy

Present: Myself, Maddie, Kate, Sadie

Goals: Finish the final prototype so the team can send to the client for at-home testing.

Content:

Fabrication involved:

1.) Removing supports from the freshly printed inversion supports

2.) Outlining the mesh foam to the specific shape of the supports with a bright fabric marker

3.) Cutting out two pieces (of same shape) for each support

4.) Sew the two pieces of mesh foam together

5.) Use Weld-on 4 to attach the foam to the insides of the supports and cut slits in the foam for the straps.

6.) Cut scrap fabric into 1 in wide strips

7.) Attach velcro to fabric straps with the velcro adhesive and sewing

8.) Thread the straps through the slits of the support.

9.) Send to client!

Final prototype:

Scrap fabric used for straps:

Conclusions/action items: Prepare at-home testing protocol

04/14/2025: Analyzing Healthy Subject OpenCap Data

Title: Analyzing Healthy Subject OpenCap Data

Date: April 14, 2025

Content by: Lucy

Present: Sadie, Kate, myself

Goals: Discuss how to organize OpenCap data for the final report and presentation. Develop MATLAB code to pull data from OpenCap downloads

Content:

Matlab code for data extraction:

```
%% Data Marker Upload - TRC

[file, path] = uigetfile({'*.xlsx;*.xls', 'Excel Files (*.xlsx, *.xls)'}, 'Select Excel File', 'C:\Users\lucyhockerman\Documents\MATLAB\MATLAB2\Client_OpenCap'

fullFilePath = fullfile(path, file);

% Turn off warning:

warning('off', 'MATLAB:table:ModifiedAndSavedVarnames');

% Read file:

data_angles = readtable(fullFilePath, MissingRule="omitrow");

data_angles.Properties.VariableNames = ["time",    "pelvis_tilt",    "pelvis_list",    "pelvis_rotation",    "pelvis_tx",    "pelvis_ty",    "pelvis_tz",    "hip_flexion_r",

 "ankle_angle_r",    "subtalar_angle_r",    "mtp_angle_r",    "hip_flexion_l",    "hip_adduction_l",    "hip_rotation_l",    "knee_angle_l",    "ankle_angle_l",    "su

 "lumbar_rotation",    "arm_flex_r",    "arm_add_r",    "arm_rot_r",    "elbow_flex_r",    "pro_sup_r",    "arm_flex_l",    "arm_add_l",    "arm_rot_l",    "elbow_fle


%% Knee Data:

figure(1);

plot(data_angles.time, data_angles.knee_angle_r, 'b-', 'LineWidth', 1.5);

xlabel('Time (s)');

ylabel('Knee Flexion Angle (degrees)');

title('Right Knee Flexion Angle');

grid on;

[x_peaks, y_peaks] = ginput(2); % change the number here

selected_angles = y_peaks;

% Calculate the average and standard deviation of the selected angles

average_angle = mean(selected_angles);

std_angle = std(selected_angles);

% Display the calculated average and standard deviation

fprintf('Average Knee Angle: %.2f degrees\n', average_angle);

fprintf('Knee Standard Deviation: %.2f degrees\n', std_angle);
```

```
%% Hip Data:

figure(2);

plot(data_angles.time, data_angles.hip_flexion_r, 'r-', 'LineWidth', 1.5)

xlabel('Time(s)');

ylabel('Hip Extension Angle (degrees)');

title("Right Hip Angle");

grid on;

% Max Hip Angle:

[x_peaks, y_peaks] = ginput(3); % change the number here

selected_angles = y_peaks;

% Calculate the average and standard deviation of the selected angles

average_angle = mean(selected_angles);

std_angle = std(selected_angles);

% Display the calculated average and standard deviation

fprintf('Average Max Hip Angle: %.2f degrees\n', average_angle);

fprintf('Hip Max Standard Deviation: %.2f degrees\n', std_angle);

% Min Hip Angle:

[x_peaks, y_peaks] = ginput(2); % change the number here

selected_angles = y_peaks;

% Calculate the average and standard deviation of the selected angles

average_angle = mean(selected_angles);

std_angle = std(selected_angles);

% Display the calculated average and standard deviation

fprintf('Average Min Hip Angle: %.2f degrees\n', average_angle);

fprintf('Hip Min Standard Deviation: %.2f degrees\n', std_angle);
```

Raw Data:

Trial	Number of (consistent) KNEE Peaks	Average Max Knee Angle (Degrees)	Knee Standard Deviation	Number of (consistent) HIP Peaks	Average Max Hip Angle (Degrees)	Average Min Hip Angle (Degrees)	Hip Standard Deviation Max	Hip Standard Deviation Min	Notes
NB_forward 1	1	63.7	18.62	1	25.58	-19.4	2.23	0	
NB_forward 2	1	54.52	8.1	1	21.55	-20.89	13.19	0	
NB_forward 3	1	66.34	7.00	1	23.23	-21.8	8.94	0	
NB_side 1	2	62.6	0.29	2	22.6	-25.4	0.74	3.73	
NB_side 2	2	75.04	3.3	2	27.28	-28.58	0.29	3.32	
NB_side 3	2	58.22	1.31	1	24.96	-22.42	0	1.80	Odd dip in first hip peak
BB_forward 1	1	53.3	12.39	1	26.63	-18.8	0	0	
BB_forward 2	1	36.05	14.10	2	18.75	-19.4	3.57	0	
BB_forward 3	1	60.8	0	1	23.69	-19.38	7.08	0	
BB_side 1	2	60.4	3.27	3	23.47	-18.03	2.61	0.07	
BB_side 2	2	64.01	0.29	3	19.67	-25.18	3.13	0.5	
BB_side 3	2	61.76	2.31	2	24	-22.03	1.18	3.39	
FB_forward 1	2	53.39	9.34	1	23.58	-18.92	0	0	
FB_forward 2	2	48.14	18.1	1	27.27	-18.97	0	0	
FB_forward 3	2	57.04	14.35	1	26.79	-20.99	0	0	
FB_side 1	2	59.58	2.31	2	22.86	-19.93	1.73	6.53	
FB_side 2	2	62.71	1.34	2	24.23	-23.12	10.43	1.73	
FB_side 3	2	55.56	3.05	3	26.72	-19.58	5.2	3.58	

Conclusions/action items: Use the same code and formula to gather client data

04/14/2025: Analyzing Client OpenCap Data

Title: Analyzing Client Subject OpenCap Data

Date: April 14, 2025

Content by: Lucy

Present: Kate, Sadie, Myself

Goals: Using the code and methods used to previously extract healthy subject data, repeat using client data.

Content:

Matlab code for data extraction:

```
%% Data Marker Upload - TRC

[file, path] = uigetfile({'*.xlsx;*.xls', 'Excel Files (*.xlsx, *.xls)'}, 'Select Excel File', 'C:\Users\lucyhockerman\Documents\MATLAB\MATLAB2\Client_OpenCap'

fullFilePath = fullfile(path, file);

% Turn off warning:

warning('off', 'MATLAB:table:ModifiedAndSavedVarnames');

% Read file:

data_angles = readtable(fullFilePath, MissingRule="omitrow");

data_angles.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r",
 "ankle_angle_r", "subtalar_angle_r", "mtp_angle_r", "hip_flexion_l", "hip_adduction_l", "hip_rotation_l", "knee_angle_l", "ankle_angle_l", "su
 "lumbar_rotation", "arm_flex_r", "arm_add_r", "arm_rot_r", "elbow_flex_r", "pro_sup_r", "arm_flex_l", "arm_add_l", "arm_rot_l", "elbow_fle


%% Knee Data:

figure(1);

plot(data_angles.time, data_angles.knee_angle_r, 'b-', 'LineWidth', 1.5);

xlabel('Time (s)');

ylabel('Knee Flexion Angle (degrees)');

title('Right Knee Flexion Angle');

grid on;

[x_peaks, y_peaks] = ginput(2); % change the number here

selected_angles = y_peaks;

% Calculate the average and standard deviation of the selected angles

average_angle = mean(selected_angles);

std_angle = std(selected_angles);

% Display the calculated average and standard deviation

fprintf('Average Knee Angle: %.2f degrees\n', average_angle);

fprintf('Knee Standard Deviation: %.2f degrees\n', std_angle);
```

```
%% Hip Data:

figure(2);

plot(data_angles.time, data_angles.hip_flexion_r, 'r-', 'LineWidth', 1.5)

xlabel('Time(s)');

ylabel('Hip Extension Angle (degrees)');

title("Right Hip Angle");

grid on;

% Max Hip Angle:

[x_peaks, y_peaks] = ginput(3); % change the number here

selected_angles = y_peaks;

% Calculate the average and standard deviation of the selected angles

average_angle = mean(selected_angles);

std_angle = std(selected_angles);

% Display the calculated average and standard deviation

fprintf('Average Max Hip Angle: %.2f degrees\n', average_angle);

fprintf('Hip Max Standard Deviation: %.2f degrees\n', std_angle);

% Min Hip Angle:

[x_peaks, y_peaks] = ginput(2); % change the number here

selected_angles = y_peaks;

% Calculate the average and standard deviation of the selected angles

average_angle = mean(selected_angles);

std_angle = std(selected_angles);

% Display the calculated average and standard deviation

fprintf('Average Min Hip Angle: %.2f degrees\n', average_angle);

fprintf('Hip Min Standard Deviation: %.2f degrees\n', std_angle);
```

Raw Data:

Trial	Number of (consistent) KNEE Peaks	Average Max Knee Angle (Degrees)	Knee Standard Deviation	Number of (consistent) HIP Peaks	Average Max Hip Angle (Degrees)	Average Min Hip An
NB_foward 1	1 (averaged 2)	53.7	11.71	(2 max, 1 min)	32.49	
NB_foward 2	1 (averaged 2)	54.62	14.45	(2 max, 1 min)	30.85	
NB_foward 3	1 (averaged 2)	53.29	18.06	(2 max, 1 min)	32.42	
NB_side 1	2 (averaged 3)	66	10.25	(2 max, 2 min)	33.07	
NB_side 2	2	74.1	3.3	(2 max, 2 min)	30.41	
NB_side 3	2	76.01	6.32	(3 max, 2 min)	34.7	
AFO_foward 1	1	68.31	0	(2 max, 1 min)	27.07	
AFO_foward 2	1	67.09	0	(2 max, 1 min)	29.27	
AFO_foward 3	1	70.6	0	(2 max, 1 min)	32.16	
AFO_side 1	2	71.14	0.67	(2 max, 2 min)	28.25	
AFO_side 2						
AFO_side 3	2	69.78	6.44	(2 max, 2 min)	28.39	
RB_foward 1	1 (averaged 2)	50.02	15.46	(2 max, 1 min)	32.86	
RB_foward 2	1 (averaged 2)	51.55	13.3	(2 max, 1 min)	32.7	
RB_foward 3	3	41.93	3.87	(1 max, 2 min)	48.03	
RB_side 1	2	72.12	4.13	(2 max, 2 min)	30.66	
RB_side 2	2	68.73	5.95	(2 max, 2 min)	34.18	
RB_side 3	2	72	5.62	(3 max, 2 min)	32.89	

Conclusions/action items: Plot both healthy subject and client data in visually appealing graphs

01/29 Library Session 1

Lucia Hockerman - Jan 29, 2025, 2:04 PM CST

Title: Library Session 1: Article searching, source evaluation and citation management

Date: January 29, 2025

Content by: Lucy Hockerman

Present: Kate, Maddie, Lucy, Sadie, Presley

Goals: Learn about library resources

Content:

I used google scholar to quickly find a research article about ankle support methods for preventing inversion.

Citation:

[1] S. Siegler, W. Liu, B. Sennett, R. J. Nobilini, and D. Dunbar, “The Three-Dimensional Passive Support Characteristics of Ankle Braces,” J Orthop Sports Phys Ther, vol. 26, no. 6, pp. 299–309, Dec. 1997, doi: 10.2519/jospt.1997.26.6.299.

When discussing with my team, people used PubMed and Google Scholar for their research.

How the technology works:

- Online Search Engines: index information gather from the internet and produce a results list. These engines tend to "hide" information to force the user to click around more.

- LLM Chatbots: trained on internet data, produce text based on your input

- Databases: directly include and index information sources, produce a results list based on your input

Demo: go to library.wisc.edu --> dropdown to databases --> browse by subject/type --> select subject

Begin search: astric (*) will create a wildcard, when you only put a space, an "AND" is assumed (use OR to expand search)

To filter results: change to a more current time frame, sort by cited by (highest), as an entry point: search for reviews as a secondary source

To view full text: find full text --> "find it" associated with UW --> read text

Evaluating sources: relevance, authority, quality, currency, Tip: read laterally!

Technical reports: take sometime to work through but have very in-depth information. Example: DTIC

Ways to get in touch: AskSEL@library.wisc.edu and more ways on canvas on the lecture slides

Conclusions/action items: Continue to research and find some in-depth and new articles using databases.

02/26 Ethics Lecture

Lucia Hockerman - Feb 26, 2025, 2:06 PM CST

Title: Ethics Lecture

Date: February 26, 2025

Content by: Lucy Hockerman

Present: Kate, Maddie, Lucy, Sadie, Presley

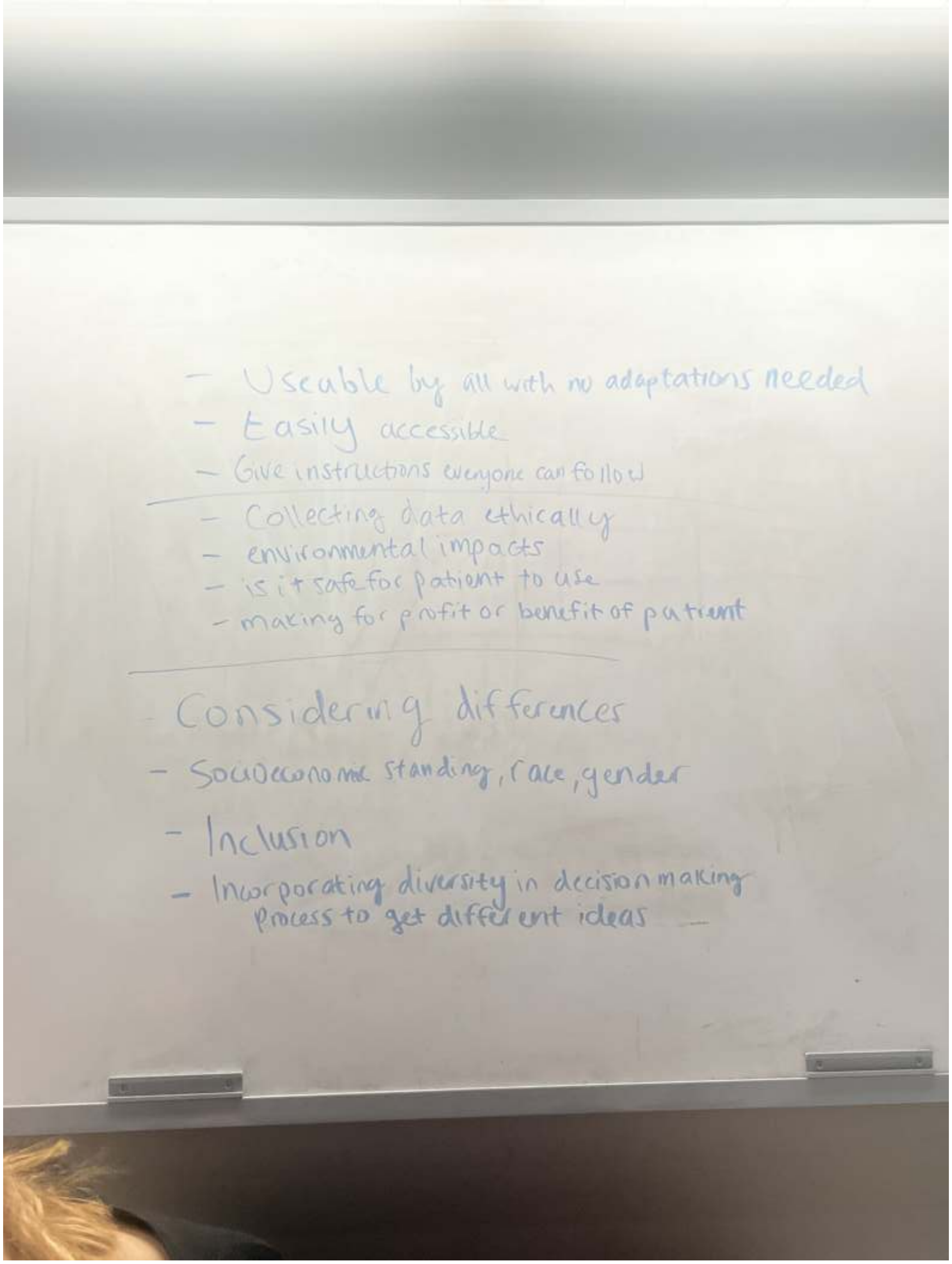
Goals: Learn about how to incorporate diversity and inclusion into design.

Content:

Group brainstorm 1: Diversity

Group brainstorm 2: Universal design

Group brainstorm 3: How does this relate to ethics



Broad diversity considerations: ethnicity, socioeconomic status, culture, experiences, skill sets

Designing broadly and inclusively - NOT for the "average user"

7 Principles of Universal Design:

1.) Equitable use

2.) Flexible Use

3.) Simple and Intuitive Use

4.) Perceptible information

5.) Tolerance for Error

6.) Low Physical Effort

7.) Size and space for approach and use

There is a Biomedical Engineering Code of Ethics: https://www.bmes.org/2025/cmbeconference/codeofconduct

Group design specific assignment:

Rise and Stride: Ethics Discussion

Date: February 26, 2025

What components of the design could be improved:

- Flexibility of Use: straps allow for the patient to customize effectiveness and comfort of the design
- Provide the patient with an assembly guide
- Patient-specific modeling
- Improve the ease of application. The current compression sleeves require significant strength to place over the ankle

Which of the 7 principles are you addressing:

- Flexibility of Use
- Low physical effort
- Tolerance for errors: address velcro wearing down

How can we make these improvements:

- Quick release straps
- Magnetic closures for the strapping mechanism
- Instruction videos
- Choose a elastic material for the straps
- Create a fixture to help assemble the brace and apply the compression sock
- Make the rigid support adaptable to any foot scan

Conclusions/action items: Continue to think about how we can make out s

03/12 Library Session 2

Lucia Hockerman - Mar 12, 2025, 2:03 PM CDT

Title: Library Session 2: Standards and Patents

Date: March 12, 2025

Content by: Lucy Hockerman

Present: Maddie, Lucy, Sadie, Presley

Goals: Learn about standards and patents and how to access them using online resources.

Content:

Standards: access through ASTM, ASABE, IEEE. In all other cases, check TechStreet Enterprise for titles and use Request a Standard form

- Other business databases recommendations: Data Axle Reference Solutions, IBISWorld Industry Reports, ProQuest One Business

Tips for more patents: look in the citation tab and key terms. CPC Classifications on the bottom of summary tab --> family options --> group by simple family

Conclusions/action items: Continue to research and find new patents and standards using new learned information.

03/19: Communication Tasks

Lucia Hockerman - Mar 19, 2025, 1:42 PM CDT

Title: Communication Tasks

Date: March 19, 2025

Content by: Lucy Hockerman

Present: Maddie, Lucy, Sadie, Presley, Kate

Goals: Prepare for show and tell and create and practice and elevator pitch

Content:

Show and Tell:

General structure: should be around 1 minute

1.) Attention grabber

2.) Introduction

3.) Value proposition

4.) Benefits

5.) Call to action

Tong Award:

General structure: 5 mins talking, 3 mins questions

Executive Summary: elevator pitch in a one page document (similar structure to general structure of elevator pitch. No citations!

Abstract: typically 150-300 words long. Complete this last so it includes all the necessary information, the entire report should be summarized. No citations!

Conclusions/action items: Write and practice elevator pitch with the team and put this into the google sheet.

04/02: Ethic Lecture

Lucia Hockerman - Apr 09, 2025, 1:24 PM CDT

Title: Ethics Lecture

Date: April 02, 2025

Content by: Lucy Hockerman

Present: Maddie, Lucy, Sadie, Presley, Kate

Goals: Discuss more about professional ethics

Content:

How do we define ethics?

- Moral principles that guide decision making and outline what is "right" and "wrong" based on honesty, respect, fairness, and integrity

Personal: morals, family values, social aspects

Professional: professionally integrated ethics codes, how your personal beliefs play a role in work environments

Where do ethics come from?

- Upbringing
- Culture
- Personal past experiences
- FDA
- Family, friends, professors

Ethical problem solving is similar to the design process

- Establish a need: questioning if it is an ethical action
- Understand the problem

Ethical Decision-Making Process:

- Awareness
- Stakeholders
- Options
- Analysis of options

Ethical tests

- Harm test: fewest negative consequences (both short and long term)
- Publicity test: Would you want your decision published online, or in the news?
- Reversibility test: how would you feel if someone you loved were affected adversely?
- Universality Test: if everyone were to use this solution, would that produce a just society?
- Respect for persons test: best response to the rights and dignity of others?
- Utilitarian tests
- Social justice test: does this option impact one population negatively

Ethics Case Study:

Consider the different perspectives on this case listed below, and discuss these questions in detail. Type your responses as a team.

1. **The Guidant VPs**: Most of the VP's at Guidant are very much against reporting the data to the FDA. (a) How might they continue to justify their case? (b) What would be the moral foundations of their perspective?
    a. The FDA's policies are "updated" to include less detailed disclosure of complications. It's better for the company to make money.
    b. If it helps some, it is worth leaving on the market
    c. Saves more lives than it takes (⅔)
    d. Don't want to destroy company reputation

2. **Patients and doctors**: Think about the position of those directly impacted: primarily patients who might be candidates for this surgery, and the doctors who use the device: (a) what arguments would those people want to ensure are considered by both the VPs and the design engineers about whether to report or not report the complications data? (b) What might be the ethical foundations of their perspective?
    a. Informed consent: the patient's life is at risk, and they are not willing to risk it if there is such a significant rate of complications and death. The doctors recommending the device to patients do not want to inflict harm on their patients. Also, unsuccessful surgeries and death would taint their image and prestige, and patients would stop coming to their practice.
    b. The doctors' personal morals of not wanting to put patients at risk and the fact they want to be successful doctors. The patients don't want to take risks with their health if they have family at home to take care of.

3. **The design engineers**: (a) What else can they say or do? (b) What arguments can they try to make, and to whom?
    a. The design engineers can contact the FDA directly or send an anonymous tip. Make a better design that works for more people.
    b. They can argue that if one device is mistrusted on the market, any new devices they invent will have a negative reputation with the medical device industry and practitioners. They make arguments to families and investors.

4. **The design engineers**: What options do they have? Generate a list of possible options (a minimum of 3 from the perspective of the design engineers), describe how each stakeholder is affected, then analyze them using the BME Code of Ethics (https://www.bmes.org/bmes2023-policies) and a couple of tests from the ethical decision-making system. Explain in detail the best option you would consider trying to act on.
    a. Write a protocol on what type of patients they can prescribe this treatment to and make the patients aware of the risk. They can outline a smaller subset of patients that are viable for the device.
    b. Quit - no more engineers = no more products
    c. Contact the FDA
    d. Start a new company with the "good" VP and use their new and current ideas in new products that are appropriately approved by the FDA.

Conclusions/action items: Write executive summary draft and continue to think about how ethics play a role in our project (specifically our testing plans)

04/09: Engineering Judgment

Lucia Hockerman - Apr 09, 2025, 2:00 PM CDT

Title: Engineering Judgment

Date: April 09, 2025

Content by: Lucy Hockerman

Present: Maddie, Lucy, Sadie, Presley, Kate

Goals: Discuss about what engineering judgment means to us, personally and as an engineer in the work place

Content:

Deesha Chadhad, Imperial College London: Three domains

(a): Attitudes: what do you feel and believe about a specific issue

(b): Behaviors: How you demonstrate and act upon your knowledge and attitudes while addressing a specific issue

(c): Cognitive: what you know about, and are able to do, to address a specific issue

* Filled out the survey with team

Conclusions/action items: Write executive summary draft and continue to think about how ethics play a role in our project (specifically our testing plans)

1/29/2025 - Library Session 1

SADIE ROWE - Jan 30, 2025, 10:22 AM CST

Title: Library Session 1: Article searching, source evaluation and citation management

Date: 1/29/2025

Content by: Presentation by Dave Bloom

Present: Sadie Rowe

Goals: Lear more about how to find & evaluate sources

Content:

- Online Search Engines: Google
  - index information gathered from crawlers
  - Produce a results list based on input
- LLM Chatbots (ChatGPT, Copilot, etc.)
  - Pattern matching
  - Trained on internet data
  - produce text based on your input
- Databases: PubMed, Google Scholar, etc.
  - Directly include and index information sources
  - Product a results list based on input
- Technical Reports: publish results of scientific or technical research
  - government provided
  - very detailed

Searching on databases like Scopus: very specific searching tools and filtering

Helpful document type: Review (2ndary source)

Conclusions/action items: Use tips from this lecture to find quality research sources

02/26/2025 - Diversity in Design

SADIE ROWE - Feb 26, 2025, 1:47 PM CST

Title: Diversity in Design Lecture Notes

Date: 2/26/2025

Content by: Sadie Rowe

Present: whole team

Goals: Participate in Diversity lecture

Content:

What are some factors to consider:

- Ethnicity
- Socioeconomic status
- Culture
- Experiences
- Skill Sets
-

What does universal design mean?

- Usable by all with no points of adaptation
  - or make multiple sizes/versions of the design
- Easily accessible
- Universal use
- Give instructions everyone can follow
- Designing for all possible users
- Not only for the average user

7 principles of universal design:

1. Equitable use

2. Flexibility in use

3. Simple and intuitive use

4. Perceptible information

5. Tolerance for error

6. Low Physical Effort

7. Size and space for approach and use

How does this relate to ethics?

- Collecting data ethically
- Considering environmental impacts
- Is it safe for patient use
- Making device for profit or for benefit of the patient

Conclusions/action items: Complete in-class activity.

02/26/2025 - Design Improvement Activities

SADIE ROWE - Feb 26, 2025, 2:05 PM CST

Title: Design Improvement Activities

Date: 2/26/2025

Content by: Entire Team

Present: Entire Time

Goals: Identify components of the design that could be more universal

Content:

What components of the design could be improved:

- Flexibility of Use: straps allow for the patient to customize effectiveness and comfort of the design
- Provide the patient with an assembly guide
- Patient-specific modeling
- Improve the ease of application. The current compression sleeves require significant strength to place over the ankle

Which of the 7 principles are you addressing:

- Flexibility of Use
- Low physical effort
- Tolerance for errors: address Velcro wearing down

How can we make these improvements:

- Quick release straps
- Magnetic closures for the strapping mechanism
- Instruction videos
- Choose a elastic material for the straps
- Create a fixture to help assemble the brace and apply the compression sock
- Make the rigid support adaptable to any foot scan

Conclusions/action items: Implement improvements into the design

03/12/2025 - Library Session 2

SADIE ROWE - Mar 12, 2025, 1:56 PM CDT

Title: Library Session 2

Date: 3/12/2025

Content by: Sadie Rowe

Present: N/A

Goals: Learn more about standards/patents

Content:

- Standards:
  - libraries have:
    - full text via database
      - ASTM
      - ASABE
      - IEEE
    - historical print collection
  - freely available online: ASSIST quick search, Every Spec, FDA, International Telecommunications Union, NASA, NPA, among others
- Market/Industry Sources
  - information on companies, industries, consumer trends with business databases
  - Library research guides to help you get started with these databases
    - company research
    - industry research
    - market research
  - Specific recommendations:
    - Data Axle reference solutions
    - IBISWorld Industry Reports
    - ProQuest One Business
- Patent and Prior art searching

Conclusions/action items: Search for standards/patents that apply to project

03/19/2025 - Brevity in communication

SADIE ROWE - Mar 19, 2025, 1:51 PM CDT

Title: Brevity in communication

Date: 3/19/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals:

Content:

- Short and efficient communication
- Capture attention
- generate interest
- leave a memorable impression

Crafting your pitch:

- Know your audience
- practice, practice, practice
- Be authentic
- Keep is simple
- Adapt and iterate

General Structure of Pitch:

- Attention grabber (hook to grab interest)
- Introduction
- Value proposition: what is the project trying to solve
    - target customer
    - how the product solved a specific problem
    - demonstrate what you have
    - don't give unnecessary background
- Benefits: unique features of your design
- Call to action: suggestions?
- Time: 1 minute

Dos and Don'ts:

- DO:
    - maintain eye contact
    - keep it concise and focused
    - tailor your pitch to different audiences
- DONTs:
    - don't overwhelm with unnecessary details

Executive Summary:

- Elevator pitch summarized into one page document

- Roadmap that highlights the most important points & key takeaways
- saying more with less
- No citations

Abstract:

- Clear, concise, and specific summary or work
- 150-300 words
- Write last
- No citations
- Structure:
    - background
    - objective
    - methods
    - results and analysis
    - discussion/conclusion
        - including future work

Conclusions/action items: Create executive summary with team.

04/02/2025 - Ethics Lecture

SADIE ROWE - Apr 02, 2025, 2:03 PM CDT

Title: Ethics Lecture

Date: 4/2/2025

Content by: Sadie, Kate, Lucy, Maddie, and Presley

Present: All

Goals: Take notes on ethics lecture and participate in class/group discussions

Content:

How do we define ethics?

- Moral principles that guide decision making and outline what is "right" and "wrong" based on honesty, respect, fairness, and integrity

Personal: morals, family values, social aspects

Professional: professionally integrated ethics codes, how your personal beliefs play a role in work environments

Where do ethics come from?

- Upbringing
- Culture
- Personal past experiences
- FDA
- Family, friends, professors

Ethical problem solving is similar to the design process

- Establish a need: questioning if it is an ethical action
- Understand the problem

Ethical Decision-Making Process:

- Awareness
- Stakeholders
- Options
- Analysis of options

Ethical tests

- Harm test: fewest negative consequences (both short and long term)
- Publicity test: Would you want your decision published online, or in the news?
- Reversibility test: how would you feel if someone you loved were affected adversely?
- Universality Test: if everyone were to use this solution, would that produce a just society?
- Respect for persons test: best response to the rights and dignity of others?
- Utilitarian tests
- Social justice test: does this option impact one population negatively

Ethics Case Study:

Consider the different perspectives on this case listed below, and discuss these questions in detail. Type your responses as a team.

1. **The Guidant VPs**: Most of the VP's at Guidant are very much against reporting the data to the FDA. (a) How might they continue to justify their case? (b) What would be the moral foundations of their perspective?
    a. The FDA's policies are "updated" to include less detailed disclosure of complications. It's better for the company to make money.
    b. If it helps some, it is worth leaving on the market
    c. Saves more lives than it takes (⅔)
    d. Don't want to destroy company reputation

2. **Patients and doctors**: Think about the position of those directly impacted: primarily patients who might be candidates for this surgery, and the doctors who use the device: (a) what arguments would those people want to ensure are considered by both the VPs and the design engineers about whether to report or not report the complications data? (b) What might be the ethical foundations of their perspective?
    a. Informed consent: the patient's life is at risk, and they are not willing to risk it if there is such a significant rate of complications and death. The doctors recommending the device to patients do not want to inflict harm on their patients. Also, unsuccessful surgeries and death would taint their image and prestige, and patients would stop coming to their practice.
    b. The doctors' personal morals of not wanting to put patients at risk and the fact they want to be successful doctors. The patients don't want to take risks with their health if they have family at home to take care of.

3. **The design engineers**: (a) What else can they say or do? (b) What arguments can they try to make, and to whom?
    a. The design engineers can contact the FDA directly or send an anonymous tip. Make a better design that works for more people.
    b. They can argue that if one device is mistrusted on the market, any new devices they invent will have a negative reputation with the medical device industry and practitioners. They make arguments to families and investors.

4. **The design engineers**: What options do they have? Generate a list of possible options (a minimum of 3 from the perspective of the design engineers), describe how each stakeholder is affected, then analyze them using the BME Code of Ethics (https://www.bmes.org/bmes2023-policies) and a couple of tests from the ethical decision-making system. Explain in detail the best option you would consider trying to act on.
    a. Write a protocol on what type of patients they can prescribe this treatment to and make the patients aware of the risk. They can outline a smaller subset of patients that are viable for the device.
    b. Quit - no more engineers = no more products
    c. Contact the FDA
    d. Start a new company with the "good" VP and use their new and current ideas in new products that are appropriately approved by the FDA.

Conclusions/action items: Complete design group assignment

01/30/2025 - Background FSHD Research

SADIE ROWE - Jan 30, 2025, 12:58 PM CST

Title: FSHD, Foot Drop, & background research

Date: 1/30/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Better understand the client condition and specific limitations that she experiences as a result

Content:

What is FSHD?

Facioscapulohumeral Muscular Dystrophy is an inherited disease and common form of muscular dystrophy. Some of the common side effects include, but are not limited to: Footdrop (when you are unable to extend to bend your foot upward) and Trendelenburg gait (occurs when the muscle in your thigh that allows you to move it out is weak, so you tend to sway toward the affected side)

Treatment options for **Footdrop:** condition where a person has difficulty lifting the front part of the foot (dorsiflexion), which leads to dragging the foot while walking

1. Braces & Splints: Ankle-foot orthosis (AFO) can help keep the foot in a neutral position and improve walking

2. Physical Therapy

3. Nerve Stimulation: functional electrical stimulation (FES) can help activate the muscles responsible for lifting

4. Medication

5. Surgery

Gait Cycle: 2 phases involving a combination of open and closed-chain activities

Stance phase: 60% of total gait cycle

1. Initial contact (heel strike)

2. Loading response (foot flat)

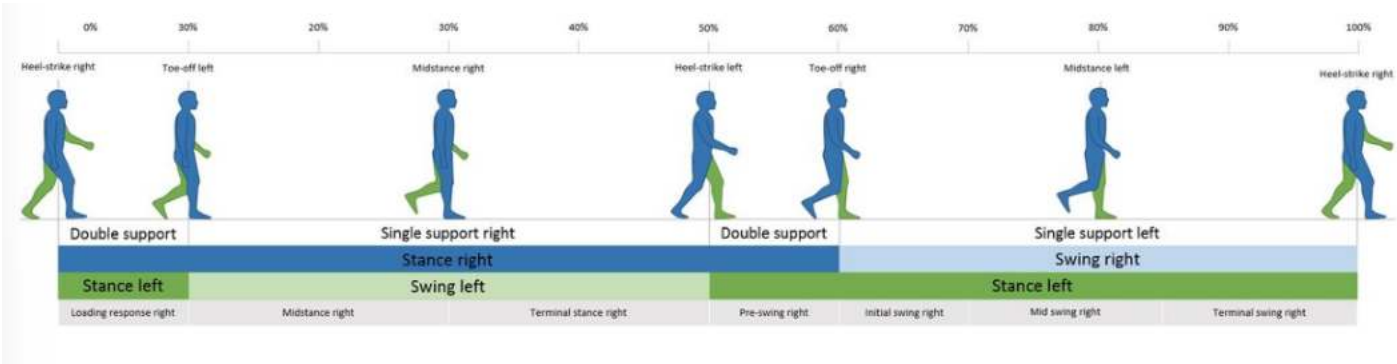
3. Mid-stance

4. Terminal stance (heel off)

5. Pre-swing (toe off)

Swing Phase: 40% of total gait cycle

1. Initial swing
2. Mid-swing
3. Late swing



Sources:

[1] "FSHD (Facioscapulohumeral Muscular Dystrophy)," Cleveland Clinic. Accessed: Jan. 29, 2025. [Online]. Available: https://my.clevelandclinic.org/health/diseases/facioscapulohumeral-muscular-dystrophy-fshd

[2] "The Gait Cycle," Physiopedia. Accessed: Jan. 29, 2025. [Online]. Available: https://www.physio-pedia.com/The_Gait_Cycle

Conclusions/action items: With this basic understanding of FSHD, current treatment methods, and a better understanding of the gait cycle, I can dive into more detailed research and learn about specific methods that AFO devices use to facilitate natural gate.

01/30/2025 - Mechanism and Design Analysis of Articulated Ankle Foot Orthoses for Drop-Foot

SADIE ROWE - Jan 30, 2025, 4:02 PM CST

Title: Mechanism and Design Analysis of Articulated Ankle Foot Orthoses for Drop-Foot

Date: 1/30/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Learn about existing AFO designs for drop-foot, limitations, and remaining design challenges

Search Term: Google Scholar: "AFO" AND "Drop foot"

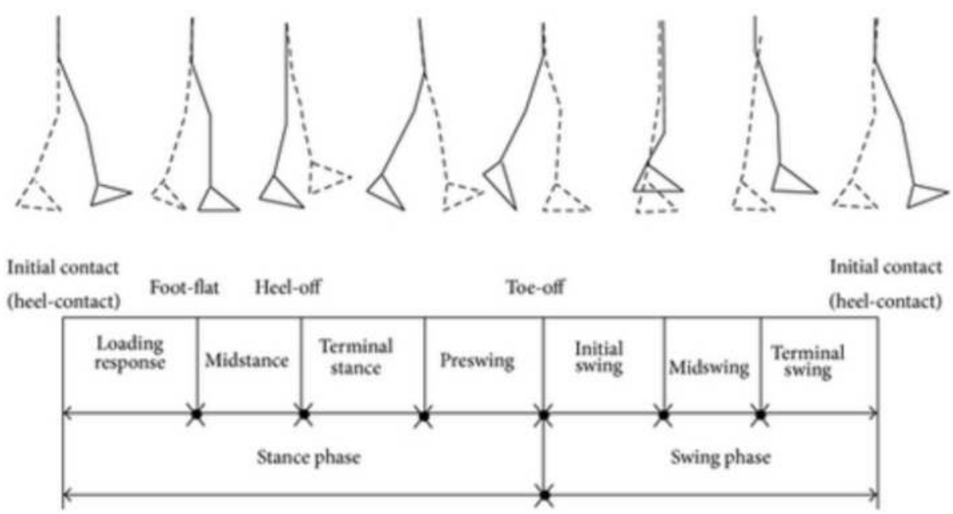
Citation: [1] M. Alam, I. A. Choudhury, and A. B. Mamat, “Mechanism and Design Analysis of Articulated Ankle Foot Orthoses for Drop-Foot,” *The Scientific World Journal*, vol. 2014, no. 1, p. 867869, 2014, doi: 10.1155/2014/867869.

Link: Mechanism and Design Analysis of Articulated Ankle Foot Orthoses for Drop-Foot - Alam - 2014 - The Scientific World Journal - Wiley Online Library

Content:

- Design & mechanism of AFO must ensure compactness, light-weight, low noise, & high efficiency

Phases of normal gait cycle:

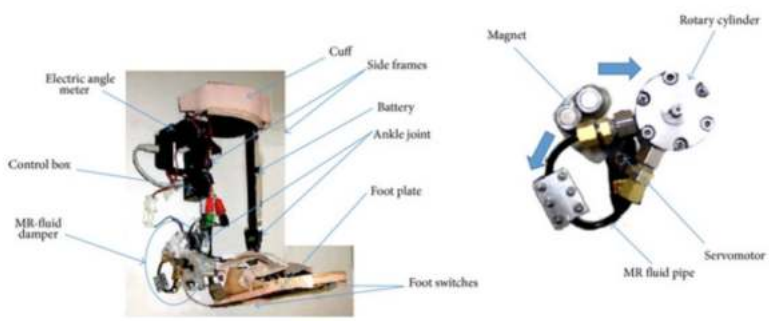


Types of ankle foot orthotic devices (AFO):

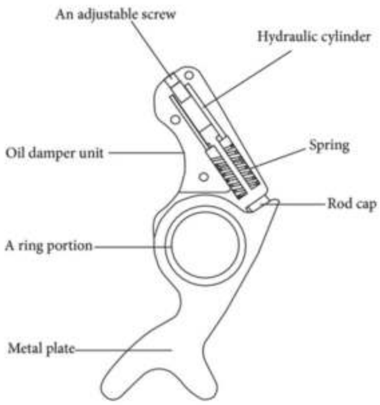
- Passive Devices: no electrical or electronic elements, no power source
  - may contain mechanical elements like dampers or springs to control motion of ankle-foot complex
  - most popular daily-wear device due to simplicity (& more compact)

    - 2 types: articulated & nonarticulated
        - Nonarticulated: single piece, thermoformable materials
            - encompass dorsal part of leg and bottom of foot
            - Range: rigid to flexible
            - Improves pathological gait, but restricts some movements
                - Ex: maintains clearance between forefoot & ground, but restricts plantarflexion mobility
        - Articulated: combination of light-weight thermoplastic/carbon composite shells and articulated joints
            - articulated joint designs: hinges, flexion stops, stiffness control elements, etc
            - AFOs w/ commercial joints are capable of preventing drop-foot by providing dorsiflexion assisting force OR locking ankle in a suitable position
                - inhibit other normal ankle movements
    - Power harvesting AFOs: passive AFOs that utilize energy from gait to provide assistive motion (bellow pump, passive pneumatic element, etc. are used for locking the foot or providing assistive torque)
- Semiactive devices: capable of varying flexibility of ankle joint by using computer control
- Active devices: contain onboard power source, control system, sensors, and actuators

Motion control elements successfully used in different AFOs:

- Spring-based system: Linear torsional springs control plantarflexion and dorsiflexion to prevent foot slap and assist ankle movement
- Series Elastic Actuators (SEA): Include elastic elements with DC motors for precise torque control, low impedance, and shock tolerance
- Magnetorheological (MR) fluid: Offers rapid response through viscosity changes when exposed to a magnetic field --> acting as dampers or brakes
    - 

    - Provides modulation of articulated joint stiffness and better ability to control motion
    - 2 of most promising AFO designs use this method
- Passive Pneumatic Elements: Lightweight & adaptable elements with variable elasticity for adjusting mechanical impedance
- Frictional Clutches: allow unidirectional motion w/ resistance in the other direction
- Oil dampers: hydraulic shock absorbers resist plantarflexion & absorb shock during heel strikes

- 

- increases stability, kinetics, and kinematics of pathological gait

- Artificial Pneumatic Muscles: pneumatic muscles mimic human muscles & provide torque for gait assistance
- Shape Memory Alloys: compact actuators with high power-to-weight rations (slow response time & mechanical inefficiencies

Important design considerations:

- For treatment of drop-foot: ideal AFO should compensate dorsiflexor muscle weakness by preventing unwanted plantarflexion motion without affecting normal movement
- Moderate resistance during loading (prevent foot-slap)
- No resistance during stance (free ankle motion)
- Large resistance to plantarflexion during swing phase (prevent drop-foot)
- Articulated ankle joint w/ initial angle adjustment in range of 0 to 8 degrees
    - dorsiflexion: no resistive moment & range of motion should be greater than 30 degrees from initial angle
    - plantarflexion: restrictive moment & adjustable
- Resistive moment during swing phase = 5*(resistive moment required in loading response)
- Proper maintenance of stiffness in ankle joint
- Compact
- Lightweight

Main functions of an AFO for drop-foot prevention:

a. provide moderate resistance during loading response to inhibit foot-slap

b. allow free dorsiflexion in stance phase

c. provide large resistance in swing phase to obstruct foot drop

Remaining issues:

- Many AFOs have only 1 degree of freedom
    - inversion & eversion limitation results in discomfort and unnatural gait
- Bulky designs (not intended for daily use)

Conclusions/action items:

- **Look into MR** (Magnetorheological Fluid) **AFOs**
- **Further research into existing methods of drop-foot prevention, specifically low-profile designs**
- **Paper citations to look into: 36 (https://pubmed.ncbi.nlm.nih.gov/15641008/)**

SADIE ROWE - Jan 30, 2025, 3:23 PM CST

Review Article

Mechanism and Design Analysis of Articulated Ankle Foot Orthoses for Drop-Foot

Morshed Alam, Imtiaz Ahmed Choudhury, and Azuddin Bin Mamat

1. Introduction

[Download](#)

The_Scientific_World_Journal_-_2014_-_Alam_-_Mechanism_and_Design_Analysis_of_Articulated_Ankle_Foot_Orthoses_for_Drop_Foot.pdf (1.69 MB)

01/31/2025 - Effects of Carbon Fiber vs. Plastic AFOs on Gait Outcomes and Energy Cost in Patients with Chronic Stroke

SADIE ROWE - Jan 31, 2025, 5:16 PM CST

Title: Effects of Carbon Fiber vs. Plastic AFOs on Gait Outcomes and Energy Cost in Patients with Chronic Stroke

Date: 01/31/2025

Content by: Sadie Rowe

Present: N/A

Goals: Better understand how different material use in AFOs impact economic factors as well as patient safety and outcomes

Search Term: "Carbon Fiber" AND "Cost" OR "Alternat*" AND "AFO"

Citation: [1] D. Rimaud, R. Testa, G. Y. Millet, and P. Calmels, "M EFFECTS OF CARBON VERSUS PLASTIC ANKLE FOOT ORTHOSES ON GAIT OUTCOMES AND ENERGY COST IN PATIENTS WITH CHRONIC STROKE," *Journal of Rehabilitation Medicine*, vol. 56, 2024, doi: [10.2340/jrm.v56.35213](10.2340/jrm.v56.35213).

Link: [View of Effects of carbon versus plastic ankle foot orthoses on gait outcomes and energy cost in patients with chronic stroke]()

Content:

Study compared the effects of a new, off-the-shelf carbon fiber ankle foot orthosis (C-AFO) with a custom-made plastic AFO (P-AFO) and no orthosis (No-AFO) on walking performance and energy cost in patients with chronic stroke

- Cost of Materials:
    - Plastic AFOs are widely used because of their relatively low cost, good aesthetics, and ease of cleaning
    - Composite materials (ex: carbon fiber) are usually less available & more expensive

- Off-the-Shelf vs. Custom Made: study used "off-the-shelf" composite AFO
    - Off-the-shelf are often less expensive (potential economic advantage compared to custom-made orthotics)
    - off-the-shelf C-AFOs can achieve similar positive results as custom-made P-AFOs
- Energy Cost of Walking:
    - study found that both C-AFOs and P-AFOs significantly reduced the energy cost of walking compared to no AFO
        - Could have long-term economic implications due to improved mobility and reduced need for assistance
    - reduction in energy cost (Cw) was observed with both AFOs compared to no-AFO
- Patient Safety & Outcomes:
    - Both C-AFOs and P-AFOs improved several gait parameters compared to no AFO1s
        - improvements included increased walking speed, distance, stride, & step length
- Reduced Foot Drop:
    - both types of AFOs were effective at improving the alignment of the ankle joint, promoting heel strike, & facilitating toe clearance
    - the ankle plantar flexion angle of the paretic limb decreased significantly with both AFOs
- Reduced Risk of Falls:
    - By improving walking speed and stability, AFOs can reduce this risk of falling

- AFOs can improve balance and symmetry
  - contributes to reducing the risk of falls

Study results:

- No Significant Difference Between AFO Types:
  - no significant differences in most outcome measures between the C-AFO and the P-AFO
    - the off-the-shelf composite AFO is just as effective as a custom-made plastic one for gait and energy cost
- Patient Satisfaction:
  - 60% of patients felt more comfortable walking with the C-AFO
  - 67% wished to keep the C-AFO at the end of study
  - Patients reported that they took bigger steps & had less fatigue when walking with the C-AFO compared to the P-AFO

Conclusions/action items:

- Conduct additional materials research regarding plastic vs. carbon fiber
- Determine client preferences for material type if applicable

02/02/2025 - Ankle Foot Orthosis (AFO) stiffness design for mitigation of ankle inversion injury

SADIE ROWE - Feb 02, 2025, 6:02 PM CST

Title: Ankle Foot Orthosis (AFO) stiffness design for mitigation of ankle inversion injury

Date: 02/02/2025

Content by: Sadie Rowe

Present: N/A

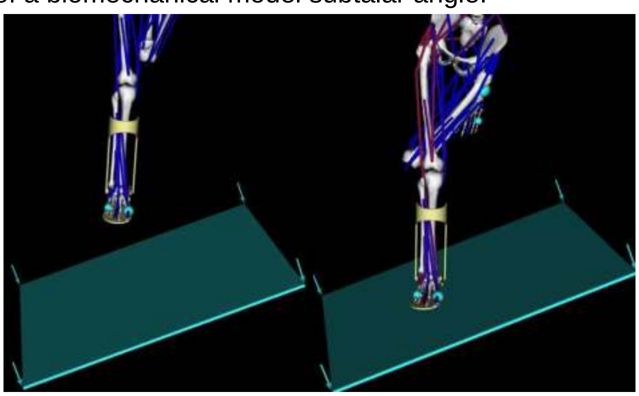
Goals: Learn about design characteristics tailored for prevention of ankle inversion in braces and AFOs.

Search Term: "Ankle inversion" AND "AFO"

Citation: [1] D. Teixeira, J. Milho, M. S. Carvalho, and M. A. R. Loja, “Ankle Foot Orthosis (AFO) stiffness design for mitigation of ankle inversion injury,” in *2019 IEEE 6th Portuguese Meeting on Bioengineering (ENBENG)*, Feb. 2019, pp. 1–4. doi: 10.1109/ENBENG.2019.8692490.

Link: https://ieeexplore.ieee.org/abstract/document/8692490

Content:

- Flexibility of an ankle and foot orthosis depend on the characteristics of this design, such as the thickness of the wall of the AFO, components around the ankle, stiffness, contours, etc.
  - to improve gait movement: must consider both selection of materials & material geometry
- Inversion angles greater than 25 degrees may cause injury to the ankle
  - angle used as a basis for conducting remainer of study
  - evaluation of the risk of a lesion by inversion of the ankle during freefall is based on the analysis of a biomechanical model subtalar angle:
  - 
  - Software used OpenSim

- Results showed that the higher the value of translational stiffness, the lower the resulting inversion angle was
- Multiple sets of values for each translational stiffness in directions x, y, and z can achieve subtalar angles less than 25 degrees
- In the table, injury safe configurations are marked with an asterisk (*)

Coordinate System:

Simulation number	X translational stiffness (N/m)	Y translational stiffness (N/m)	Z translational stiffness (N/m)	Subtalar angle (degrees)
1	34391.2	34391.2	34391.2	34.1
2	120608.8	34391.2	34391.2	26.2
3	34391.2	120608.8	34391.2	23.0*
4	120608.8	120608.8	34391.2	19.3*
5	34391.2	34391.2	120608.8	32.8
6	120608.8	34391.2	120608.8	25.7
7	34391.2	120608.8	120608.8	22.8*
8	120608.8	120608.8	120608.8	19.2*
9	5000.0	77500.0	77500.0	29.6
10	150000.0	77500.0	77500.0	20.8*
11	77500.0	5000.0	77500.0	33.7
12	77500.0	150000.0	77500.0	19.1*
13	77500.0	77500.0	5000.0	24.6*
14	77500.0	77500.0	150000.0	24.1*

* injury risk safe configurations.

Conclusions/action items:

- Consider use of this data when determining required stiffness of AFO in each direction
- Implement important data/design standards in PDS

SADIE ROWE - Feb 02, 2025, 5:44 PM CST


Ankle Foot Orthosis (AFO) stiffness design for mitigation of ankle inversion injury

[Download](#)

Ankle_Foot_Orthosis_AFO_stiffness_design_for_mitigation_of_ankle_inversion_injury.pdf (2.21 MB)

02/16/2025 - Review of Last Semester's Work

SADIE ROWE - Feb 16, 2025, 11:43 PM CST

Title: Review of Last Semester's Work

Date: 2/26/2025

Content by: Sadie Rowe

Present: N/A

Goals: Review last semester's work on project

Content:

- Problem statement: brace for teens that assists with ankle dorsiflexion, promoting safer walking, concealable, & flexible enough to allow functional ankle movement
  - client struggles with medial instability
  - Current AFOs are too bulky and constrictive
  - Similar to ankle brace
- Client Info: Debbie Eggleston - Advocate for FSHD
- Design & Development Process:
  - Preliminary Designs: Three initial designs were considered: a hinge design, a bungee brace, and a strap brace
  - Final Design: The final prototype combined elements of the bungee and strap braces, featuring a carbon fiber support and a bungee cord system with a lace lock mechanism for adjustability
  - Materials**:** The AFO uses a combination of nylon, polyester, and latex for the sleeve, carbon fiber-reinforced PLA for the medial support, and a bungee cord
  - Fabrication**:** The carbon fiber support was 3D printed, and other components were purchased and assembled
- Methods:
  - Carbon fiber attachment designed in SolidWorks
    - 3D printed using Bambu Labs printer
  - Lock lace designed in SolidWorks
    - 3D printed using Ulti maker printer
- Testing:
  - Bungee Cord Testing**:** Different bungee cord strengths were tested to determine the optimal tension for dorsiflexion support
  - SimulationXpress Analysis**:** SolidWorks simulation was used to analyze the structural integrity of the carbon fiber support under load
  - Gait Analysis**:** Runeasi, an IMU-based system, was used to assess the impact of the AFO on gait in a healthy individual, measuring dynamic instability, ground contact time, impact magnitude, and cadence
    - testing involved walking intervals with and without the brace, but doesn't summarize the results of this testing
- Challenges:
  - Balancing discreetness and functionality
  - Working with carbon fiber (cost and fabrication)

  - Designing the bungee cord system
  - Real-world testing and refinement (comfort, gait)
- Future Work:
  - Replace neoprene straps & compression sleeve with a slimmer, more cohesive design
  - Use of carbon fiber
  - Custom molding
  - Add gel padding to avoid pressure points
  - Testing on patient
  - Needs to fit inside a show
  - Less bulky & more comfortable

Conclusions/action items: Reviewing the team's report was very helpful in terms of better understanding their design choices, challenges, and testing procedures.

01/30/2025 - A usability study on the inGAIT-VSO: effects of a variable-stiffness ankle-foot orthosis on the walking performance of children with cerebral palsy

SADIE ROWE - Jan 30, 2025, 5:04 PM CST

Title: A usability study on the inGAIT-VSO: effects of a variable-stiffness ankle-foot orthosis on the walking performance of children with cerebral palsy

Date: 01/30/2025

Content by: Sadie Rowe

Present: N/A

Goals: Understand how sensor integration in an AFO device impacts personalized treatment, patient usability, with a focus on improving the health and safe mobility of children

Search Term: SCOPUS: "AFO" AND "Drop foot"

Citation: [1] L. van Noort, N. Van Crey, E. J. Rouse, I. Martínez-Caballero, E. H. F. van Asseldonk, and C. Bayón, "A usability study on the inGAIT-VSO: effects of a variable-stiffness ankle-foot orthosis on the walking performance of children with cerebral palsy," *Journal of NeuroEngineering and Rehabilitation*, vol. 21, no. 1, 2024, doi: 10.1186/s12984-024-01433-7.

Link: https://jneuroengrehab.biomedcentral.com/counter/pdf/10.1186/s12984-024-01433-7.pdf

Content:

Many traditional AFOS lock the ankle in place to maintain ground clearance during leg swing and lack in mimicking the dynamic, energy cycling, and impedance of the human ankle joint

- Their adaptability to individual needs is compromised due to the maintenance of static stiffness throughout the entire gate cycle
- This also prevents the AFO from addressing specific needs of an individual, which often change over time
- Passive assistive solutions hold a distinct advantage over powered devices as they eliminate the need for motors and batteries
  - reduced cost, weight, & complexity
- Unable to customize the shape of the torque-angle relationship to a specific user's needs & capabilities

Commercially available Passive AFOS:

- Neuro Swing
- Nexgear Tango
- Ultraflex AFO Joint

Variable Stiffness Orthosis (VSO): quasi-passive AFO that allows for customizable torque-angle relationships & step-to-step motorized adjustment of its average stiffness:

- inGAIT-VSO: pediatric version of the VSO: offers quick manual adjustment of ankle stiffness through a spring support mechanism
  - enables clinicians to customize stiffness for individual gait needs

Unique features of design:

- Cam Profile: interchangeable component that shapes the torque-angle relationship
- Manual adjustment: Stiffness can be adjusted without replacing components
    - increased flexibility in both dorsiflexion & plantarflexion
- Sensor integration: magnetic encoders to measure ankle angles & force-sensitive resistors embedded in the insoles to detect heel strike & toe-off events
- Data Capture: Sensor data is logged at 100 Hz (use of microcontroller)

Table 1 Main technical features of the inGAIT-VSO

Type of device	Passive
Weight (kg)	0.5–1 depending on the size
Stiffness range DF (Nm/deg)	0.39–3.43
Stiffness range PF (Nm/deg)	0.28–1.16
Range of motion (deg)	Adaptable, with a maximum of 35 DF, 30 PF, 15 AI and 75 AE
Max voltage (V) used by electronics	5
Data logging frequency (Hz)	100
Battery life with touchscreen on (h)	3.5
Recommended user's height (m)	1.1–1.75
Maximum user's weight (kg)	60

DF dorsiflexion, *PF* plantarflexion, *AI* ankle inversion, *AE* ankle eversion

Conclusions/action items:

- Conduct further research on passive AFO methods & specific types of joints used in these designs
- Learn more about interchangeable shoes & ankle height modulation in AFOs

SADIE ROWE - Jan 30, 2025, 4:16 PM CST

Download

s12984-024-01433-7.pdf (1.75 MB)

02/11/2025 - Changes of Ankle Motion and Ground Reaction Force Using Elastic Neutral AFO in Neurological Patients with Inverted Foot During Gait

SADIE ROWE - Feb 11, 2025, 10:00 AM CST

Title: Changes of Ankle Motion and Ground Reaction Force Using Elastic Neutral AFO in Neurological Patients with Inverted Foot During Gait

Date: 2/11/2025

Content by: Sadie Rowe

Present: N/A

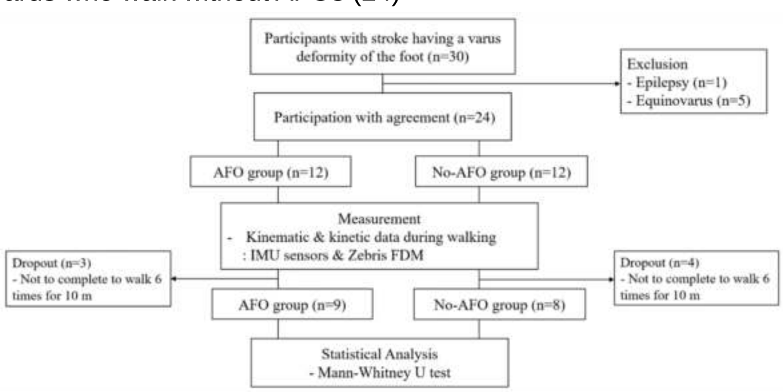
Goals: Understand unique elastic design for AFO designed to prevent ankle inversion

Search Term: Google Scholar: "AFO" AND "ankle inversion"

Link: https://www.mdpi.com/2076-0825/13/12/526

Citation: [1] D.-J. Park and Y.-I. Hwang, "Changes of Ankle Motion and Ground Reaction Force Using Elastic Neutral AFO in Neurological Patients with Inverted Foot During Gait," *Actuators*, vol. 13, no. 12, Art. no. 12, Dec. 2024, doi: 10.3390/act13120526.

Content:

- Study conducted to analyze changes in kinematic and kinetic gait data in stroke patients with ankle varus
    - 30 stroke patients with a varus deformity of the foot
    - 2 groups: one group already using AFOs due to severe ankle varus (12) & another with ankle varus who walk without AFOs (24)
    - 

- Elastic Neutral AFO (EN-AFO): assist movement without restricting ankle motion
    - composed of velcro straps, fabric, and an elastic band that wraps around the lower leg and forefoot
    - thin plastic piece attached in area around the second toe

Figure 3. The EN-AFO device in use. (a) Velcro straps; (b) fabric belt with elastic reinforcement; (c,d) elastic bands securing the lower leg and forefoot.

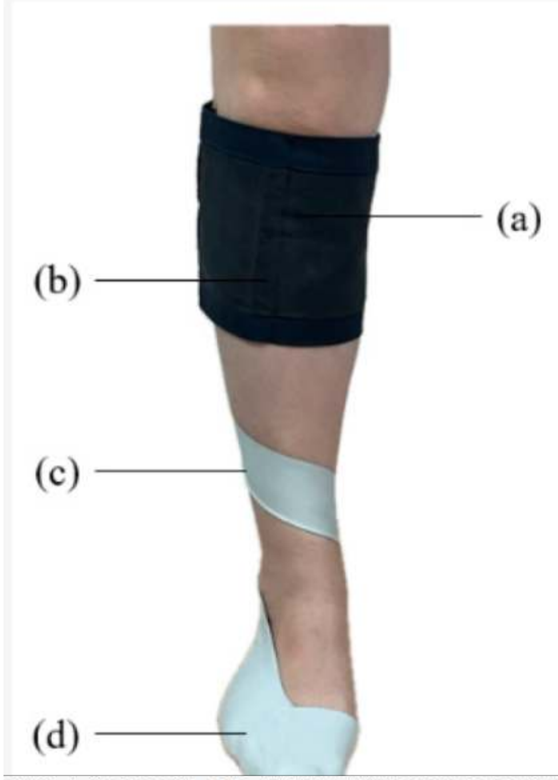
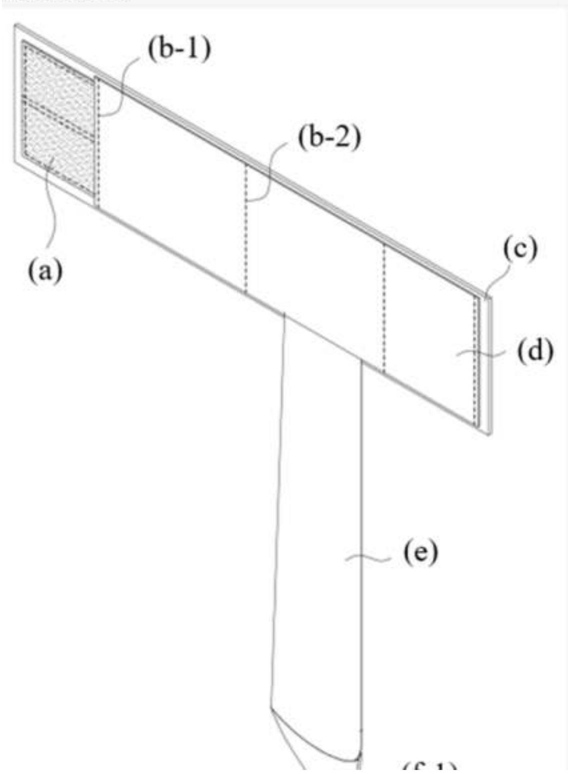
- 

Figure 4. The inner side of the EN-AFO. (a) Velcro strap; (b-1,b-2) joint between elastic band and fabric, (c) fabric, (d) the elastic support, (e) the elastic band wearing the lower leg and forefoot, (f-1,f-2) stiches in the shape of an overshoe in an area where thin plastic was attached. (Cited from Hwang and Park (2021) [10]).



- Noraxon MyoMOTION motion analysis system was used to analyze kinematic variables
- Results:
  - Significant kinematic changes primarily in the No-AFO group compared to the AFO group

- Group without AFO showed overall improvements in kinematic gait patterns on both the affected and less-affected sides compared to the AFO group
  - EN-AFO may be effective for patients who experience ankle inversion but can walk without an AFO
  - During the swing phase, minimal ankle dorsiflexion on the affected side decreased, and maximal ankle inversion on the less-affected side significantly decreased

Conclusions/action items:

- Discuss elastic design with group (consider use of thicker elastic as opposed to bungee cord)

- Refer to paper for additional details about EN-AFO construction

---

SADIE ROWE - Feb 11, 2025, 10:00 AM CST


actuators

MDPI

Article

Changes of Ankle Motion and Ground Reaction Force Using Elastic Neutral AFO in Neurological Patients with Inverted Foot During Gait

[Download](#)

actuators-13-00526.pdf (8.28 MB)

01/21/2025 - Enhancing Economic and Environmental Sustainability Benefits Across the Design and Manufacturing of Medical Devices: A Case Study of Ankle Foot Orthosis

SADIE ROWE - Jan 31, 2025, 4:45 PM CST

Title: Enhancing Economic and Environmental Sustainability Benefits Across the Design and Manufacturing of Medical Devices: A Case Study of Ankle Foot Orthosis

Date: 1/31/2025

Content by: Sadie Rowe

Present: N/A

Goals: Better understand the economic and environmental impacts of AFO designs and manufacturing processes and potential enhancements described

Search Term: "Environmental impact of AFO design"

Citation: [1] A. Mirkouei, B. Silwal, and L. Ramiscal, “Enhancing Economic and Environmental Sustainability Benefits Across the Design and Manufacturing of Medical Devices: A Case Study of Ankle Foot Orthosis,” presented at the ASME 2017 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers Digital Collection, Nov. 2017. doi: 10.1115/DETC2017-68427.

Link: Enhancing Economic and Environmental Sustainability Benefits Across the Design and Manufacturing of Medical Devices: A Case Study of Ankle Foot Orthosis | IDETC-CIE | ASME Digital Collection

Content:

- AFO fabrication process is time-consuming and the cost to custom-make an AFO is substantial
  - Recent advancements to reduce process: use of a laser scanner to generate CAD models of a patient's foot to design & fabricate the mold

Why make the design more sustainable

- Brundtland Commission (1987): “meet the needs of the present without compromising the ability to meet the needs of future generations”
  - sustainability concerns have arisen regarding:
    - economic (total cost)
    - environmental (energy used)
    - social (human health)
  - reduction of energy used in manufacturing is essential to mitigating GHG emissions
  - Additive manufacturing (AM) vs. subtractive manufacturing (SM)
    - AM has shorter lead time (ex: CAD model) & generally reduced material wastes while promoting flexibility in manufacturing operations
    - Available AM processes for AFO fabrication:

- **Table 1. Available AM processes for AFO fabrication**

Categories	Technologies	Materials
Material Extrusion	Fused Deposition Modeling	Thermoplastics
Powder Bed Fusion	Selective Laser Sintering	Polyamides, Polymer
Vat Photo-polymerization	Stereolithography	Photopolymer
Material Jetting	Polyjet, Inkjet	Photopolymer, Wax

International Committee of Red Cross recognizes 4 major types of AFOs

1. Anti-Talus AFOs: poor stabilization of the subtalar joint and block ankle motion, especially dorsiflexion

2. Flexible AFOs: poor stabilization of the subtalar joint, however, provide dorsiflexion assistance

3. Tamarack Flexure Joints: provide subtalar stabilization while allowing free ankle dorsiflexion

4. Rigid AFOs: block ankle movements, including stabilizing the subtalar joint and controlling the forefoot adduction and abduction

Decision-making framework to facilitate sustainable design & AM manufacturing:

1. NURBS Technique: non-uniform rational b-splines

used to drive decisions about material geometry and manufacturing process selection (NURBS surface & parametric design methods are useful to design & develop and STL file for constructing different types of organic 3D shapes). Enables parametric design, allowing user-specific foot measurements to generate 3D CAD models

$$P(u,v) = \sum_{i=0}^{m} \sum_{j=0}^{n} N_{i,p}\ (u) * N_{j,q}\ \ (v) * pP_{i,j}$$

- NURBS is a mathematical modeling technique widely used in CAD. It provides a powerful and flexible way to create & manipulate complex, smooth, and organic 3D shapes
    - The shape of a NURBS curve or surface is influenced by control points, which act like "handles" to adjust its geometry
    - Knot vectors define how the control points influence the curve or surface
    - uses B-spline functions to combine polynomial segments smoothly
    - allows each control point to have an associated weight, offering additional control over the shape of the curve or surface

2. Build time calculation: Main parameters are height, volume, outside surface area, support height and volume, and base area. Quantifies processing time based on design parameters such as height, volume, and surface area

2. Energy used calculation: total energy (Et) used is the sum of total machine energy (Eb) and total post-processing energy used (Ep). The rated power of the machine (PFDM) is the max power that the machine can be used at a specified ambient temp under continuous operation

$$E_t = E_b + E_p$$

$$E_b = T_b * P_{FDM}$$

$$E_p = T_p * P_p$$

3. Energy Usage: Evaluates total energy consumption during build and post-processing phases

4. Techno-Economic Analysis: Assesses total production cost, including material, energy, and labor costs. Material costs are determined by the volume and unit price of raw and support materials

5. Life Cycle Assessment: Evaluates the environmental impact of AFO production using cradle-to-gate analysis & analyzes emissions and energy consumption for material production, transportation, and manufacturing

6. Environmental metrics: Applies emission factors for CO2, CH4, and N2O to calculate global warming potential over a 100-year horizon

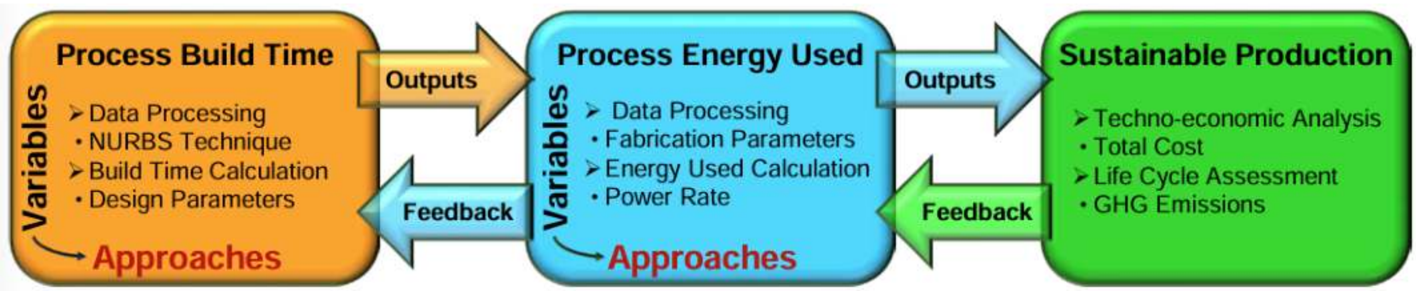


Figure 1. A knowledge-based multi-criteria decision making framework

AFO fabrication assumptions:

1. The pre-processing is assumed half an hour.

2. The post-processing ignored in this study.

3. The rated power of FDM machine is assumed 23 kW.

4. The labor cost is ignored in the cost calculation.

5. The price of electricity is assumed $0.2/kWh.

6. The density of ABS and ASA are assumed 1.07E-6 kg/mm3.

2 Parts considered in study: part 1 in child sized, and part 2 is adult sized (both designs used novel non-uniform rational b-splines (NURBS) to design the AFOs for developing 3D CAD models)

Table 2. Ankle foot orthosis attributes

Case Scenario	Part 1	Part 2
Material	ABS	ASA
Machine	uPrint SE Plus	Fortus 450mc
Material Volume (mm^3)	74,725	237,235
Support Volume (mm^3)	14,912	48,260
Build Time (hr)	7.3	24.2

Table 4. Cradle-to-gate GWP over 100-year time horizon for the AFO fabrication

Substance	Emission Factor	Part 1 (kg CO_2 eq.)	Part 2 (kg CO_2 eq.)
EI_e	7.40E-01	1.33E+02	4.16E+02
EI_m	3.77E+00	3.01E-01	9.57E-01
EI_t	2.50E-04	4.00E-03	1.27E-02
Total	-	1.34E+02	4.17E+02

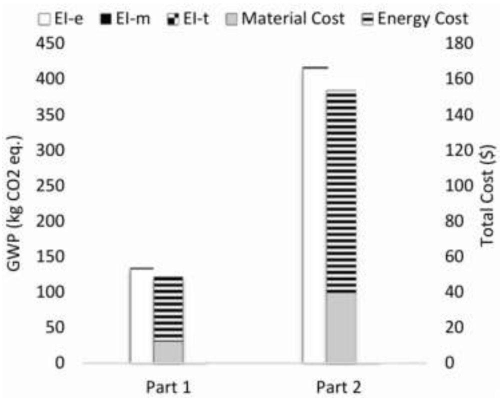


Figure 4. Cradle-to-gate GWP for AFO fabrication, using AM FDM process

Results and Takeaways from paper:

- Energy consumption causes the highest environmental impact (99%) in both parts
  - direct relation with AM process time and indirect relation with design parameters
- Optimal & sustainable AFO design: focus on reducing the build time to enhance environmental sustainability

Conclusions/action items:

- Look into NURBS technique: do we already have the tools to use it?
- How is this technique different than 3D scanning for representation in CAD?
- Consider implementing a similar methodology to monitor economic & environmental impact of the design & manufacturing techniques

SADIE ROWE - Jan 31, 2025, 1:18 PM CST

Proceedings of the ASME 2017 International Design Engineering Technical Conferences and
Computers and Information in Engineering Conference
IDETC/CIE 2017
August 6-9, 2017, Cleveland, Ohio, USA

DETC2017-68427

Enhancing Economic and Environmental Sustainability Benefits across the Design and Manufacturing of Medical Devices: A Case Study of Ankle Foot Orthosis

Amin Mirkouei* and Bishal Silwal
Department of Mechanical Engineering
Georgia Southern University
Statesboro, GA, USA

Lawrence Ramiscal
Department of Physical Therapy
Augusta University
Augusta, GA, USA

ABSTRACT

Government and societal interests in additive manufacturing have increased scrutiny on process analysis, cross-cutting sustainability, and integrated decision-making methods to address commercialization and sustainability challenges. One of the key challenges is the absence of standardized metrics to assess design parameters and manufacturing practices. The primary objective of this research is to create a knowledge-based multi-criteria decision-making framework for enhancing sustainability across the design and fabrication of medical devices. The motivation behind this study lies in the inherent limitations of the existing methods. The proposed framework herein improves the traditional approaches by integrating extensive sharing of information and feedback among all design and manufacturing steps, and consequently coupling the economic and environmental sustainability dimensions. The framework includes sets of qualitative (e.g., data processing and design analysis) and quantitative (e.g., build time and energy use analyses) methods to assess transforming the raw material into optimal and sustainable final products. As an application of this study, optimal and sustainable approaches for the developing and competitive market of Orthotic and Prosthetic, particularly Ankle Foot Orthosis (AFO), is examined. Decision makers, such as managers and manufacturers, will benefit from the integrated methods in the proposed framework. The results indicate the framework offers a promising approach to address existing sustainability challenges in the AFO industry.

1. INTRODUCTION

1.1. Motivation and Challenges

The additive manufacturing (AM) industry generated over $5 billion from the product sales and support in 2015, and it is expected to grow over $26 billion by the year 2021 [1]. The growing availability of AM or three-dimensional (3D) printing has made it possible for end-users to fabricate devices tailored and to address their individual needs. AM technologies provide many sustainability benefits, such as reducing the mass and energy consumption that contribute significantly to greenhouse gases (GHG) and global warming [2]. Recently, AM processes appear as promising due to the ability of the technology to produce customized, application-specific tools for the customer needs [3]. The integration of computer-aided design (CAD) and AM in the manufacturing of parts and tools (e.g., medical devices) could contribute by improving the process characteristics (e.g., build time and cost) and social benefits (e.g., better fitting and performing, and improved overall customer comfort) [3]. However, it has not yet been commercialized due to the existing AM challenges. The major limitations of AM are [4,5]: (a) improvements in surface finish, (b) developments in detail resolution by thinner layers, (c) improvements of material properties and range, (d) eliminations of rework and cut down on build time, (e) total energy used and cost reductions, and (f) validation by the governing organization.

The need for this study derives from the numerous variables and limitations in design and fabrication of equipment/devices. A novel decision support plan is crucial to recognize all variables, and structure an optimal and sustainable process to address existing challenges in the design and manufacturing segments. This study focuses on Orthotic and Prosthetic (O&P) devices, particularly Ankle Foot Orthoses (AFOs). AFOs are lower limb orthoses made to assist people with ankle and foot dysfunctions [6]. The AFO industry can take benefits of innovations over

* Corresponding Author:
amirkouei@georgiasouthern.edu (Mirkouei, A.)

Download

v004t05a005-detc2017-68427.pdf (1.67 MB)

01/30/2025 - Customized passive-dynamic ankle–foot orthoses can improve walking economy and speed for many individuals post-stroke

SADIE ROWE - Feb 04, 2025, 5:30 PM CST

Title: Customized passive-dynamic ankle–foot orthoses can improve walking economy and speed for many individuals post-stroke

Date: 01/30/2025

Content by: Sadie Rowe

Present: N/A

Goals: Assess how stiffness-customized passive-dynamic ankle-foot orthoses (PD-AFOs) influence the health and walking function of post-stroke individuals by evaluating improvements in mechanical cost-of-transport, self-selected walking speed, and gait biomechanics compared to no AFO and standard care devices.

Search Term: "AFO" and "Passive

Citation: [1] J. T. Skigen *et al.*, “Customized passive-dynamic ankle–foot orthoses can improve walking economy and speed for many individuals post-stroke,” *Journal of NeuroEngineering and Rehabilitation*, vol. 21, no. 1, 2024, doi: 10.1186/s12984-024-01425-7.

Link: Customized passive-dynamic ankle–foot orthoses can improve walking economy and speed for many individuals post-stroke

Content:

Article Purpose: PD-AFOs are prescribed to address plantar flexor weakness during gait, which is commonly observed after strike

- limited evidence is available to inform prescription guidelines for bending stiffness, so this article assessed the extent to which PD-AFOs that are customized to match an individual's level of plantar flexor weakness influence their walking function
- Stiffness-customized PD-AFOs can improve the mechanical cost-of-transport and self-selected walking speeds

What is a passive-dynamic ankle-foot orthosis (PD-AFO)?

- A type of unpowered orthotic device that can be used to mitigate the negative effects on gait caused by weakened plantar flexors
-
- PD-AFOs rely on the natural dynamics of the wearer's gait and the mechanical properties of the device to provide assistance
- PD-AFOs mimic many of the functions of healthy plantar flexors because they have a spring-like bending stiffness which provides resistance to help control shank forward rotation during stance-phase dorsiflexion
- Patients came in for an initial visit to collect baseline data
    - the data collected in visit 1 was used to customize the PD-AFO for each participant
    - Visual 3D software was used to calculate each participant's net peak paretic plantar flexion movement during stance

- Software: C-motion
- theory underlying the stiffness prescription model used is that the PD-AFO stiffness is intended to “make up for” the lost paretic ankle plantar flexion moment during stance
  - lost moment defined as the difference between a participant’s unassisted plantarflexion moment and a scaled, speed matched typical value
  - difference was divided by 12° (typical ankle dorsiflexion excursion during the period of interest
- Each PD-AFO was manufactured at the University of Delaware's center for Composite materials
  - made from carbon fiber pre-impregnated with resin
  - fit of footplate was further modified during a second visit

Fig. 1 Stiffness-customized carbon fiber PD-AFO

Mechanical Cost of Transport (COT): COT is the amount of energy required to move a unit of body mass over a specific distance. COT was calculated per limb for each condition as sum of positive limb work (hip, knee, ankle, and distal foot, all normalized by body mass), summed with the absolute value of negative limb work over the gait cycle, & scaled by stride length. The COT of both limbs was combined to calculate the total COT for each participant in each condition

- Hypothesis that stiffness-customized PD-AFOs would reduce COT was confirmed through the study: the average COT was significantly lower when participants wore the PD-AFO compared to walking with no AFO or a standard or care AFO
- Some individuals whose walking efficiency was already high without an AFO did not experience reduced COT
- Participants who already used a passive-dynamic AFO showed minimal improvement with the customized PD-AFO

Self-Selected Walking Speeds (SSWS): SSWS represents the speed of a person's comfortable and efficient pace for traveling over a specific distance. SSWS values for each condition were determined entirely from overground walking through the 10-m walk tests

- Hypothesis that the PD-AFOs would improve SSWS was also supported on a group level
  - participants generally walked faster with the PD-AFO than with no AFO
- Significant variability: SSWS results less consistent than COT

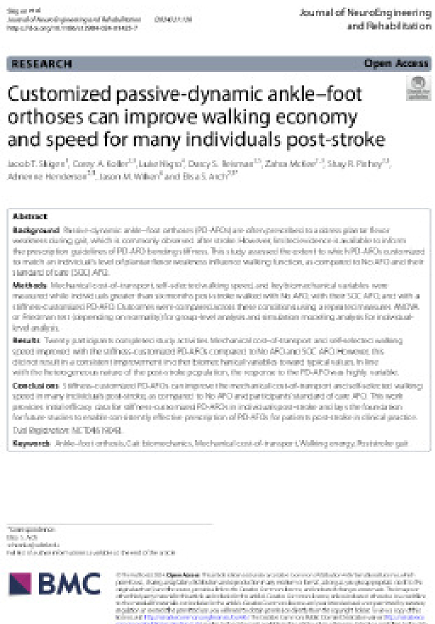
Biomechanical Impact:

- No significant improvements in peak dorsiflexion angles or hip power
  - could be due to insignificant engagement of the spring-like mechanism of the PD-AFO

Conclusions/action items:

- Determine what device the client is using for support currently
- Look into devices/mechanisms that directly support/facilitate dorsiflexion
- Research carbon fiber & alternatives for use in a design

SADIE ROWE - Jan 30, 2025, 5:29 PM CST


Journal of NeuroEngineering and Rehabilitation

RESEARCH Open Access

Customized passive-dynamic ankle–foot orthoses can improve walking economy and speed for many individuals post-stroke

Abstract

BMC

Download

s12984-024-01425-7.pdf (1.35 MB)

3/11/2025 - Standard Work Design Assembly Research

SADIE ROWE - Mar 11, 2025, 11:20 PM CDT

Title: Standard Work Design Assembly Research

Date: 3/11/2025

Content by: Sadie Rowe

Present: N/A

Goals: Learn about common formatting/practices for standard work documents. The eventual goal is to make a document/guide to fabricate our device for any individual (with access to specified tools)

Link: https://www.learnleansigma.com/guides/standard-work/

Citation: [1] “Guide: Standard Work » Learn Lean Sigma.” Accessed: Mar. 11, 2025. [Online]. Available: https://www.learnleansigma.com/guides/standard-work/

Content:

SWIs: Standard Work Instructions

- beneficial for processes demanding consistent and reproducible outcomes
- play a crucial role in enhancing safety and quality by reducing defects and increasing efficiency
- Completed with visual aids/technical drawings
  - "What"
  - "Why"
  - "How"
- minimize errors and ensure smooth operation
- accessible to everyone who is expected to follow
- updated as process changes/evolves

SWI vs SOP (standard operating procedure):

- SOPs are more general and overarching
  - provide high-level view of procedures
  - quality control, compliance, etc.
- SWIs are much more detailed and task specific
  - granular step-by-step guide
  - designed to remove ambiguity or variation in performing a task

Steps to implement an SWI:

1. Identify the task: complex enough to require instructions

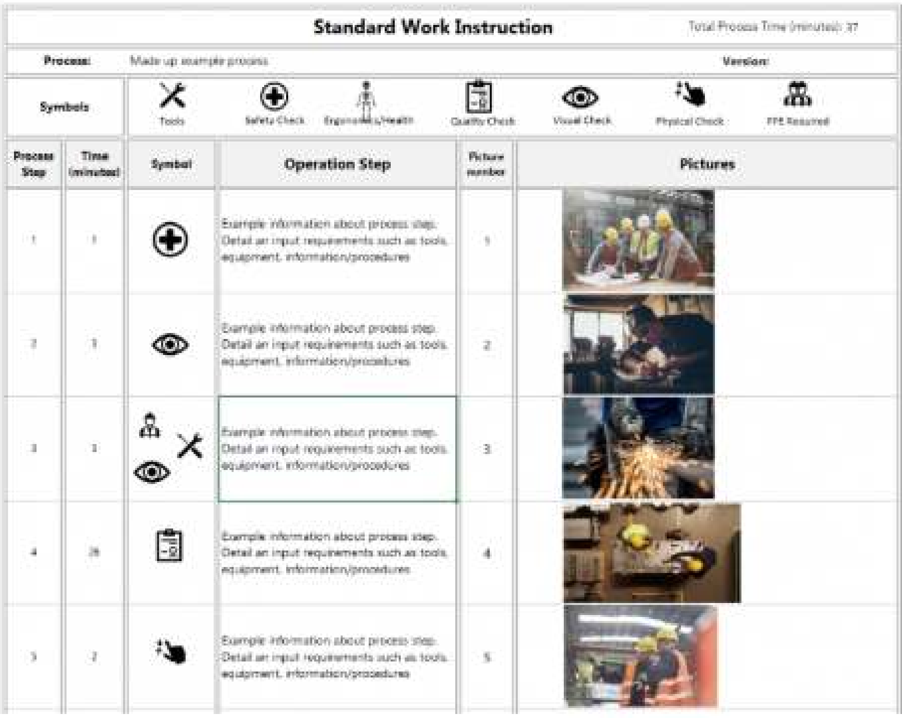
2. Gather information: document nuances of the task & understand where things can go wrong

3. Draft SWI: should be clear & concise, simple language, technical terms explained, incorporation of visual aids

4. Review and Test: review by various stakeholders to ensure SWI is practical and understandable

5. Finalize and Distribute

Example SWI:



Standard Work Instruction — Total Process Time (minutes): 37

Process: Made up example process — Version:

Symbols: Tools, Safety Check, Ergonomics/Health, Quality Check, Visual Check, Physical Check, PPE Required

Process Step	Time (minutes)	Symbol	Operation Step	Picture number	Pictures
1	1		Example information about process step. Detail an input requirements such as tools, equipment, information/procedures	1	
2	1		Example information about process step. Detail an input requirements such as tools, equipment, information/procedures	2	
3	3		Example information about process step. Detail an input requirements such as tools, equipment, information/procedures	3	
4	28		Example information about process step. Detail an input requirements such as tools, equipment, information/procedures	4	
5	2		Example information about process step. Detail an input requirements such as tools, equipment, information/procedures	5	

Conclusions/action items: Determine if an SWI document would be useful to make design more universal, or if a more complicated method of documentation would be preferred given complication involved in the CAD design/fabrication process.

02/18/2025 - 3D Scanning Research

Title: 3D Scanning Research

Date: 2/18/2025

Content by: Sadie Rowe

Present: N/A

Goals: Better understand 3D scanning options available through Makerspace

Link: https://making.engr.wisc.edu/equipment/3d-scanners/

Content:

Available Equipment Make:

- Creaform Handyscan 700: give sub-millimeter resolution scans that are professional grade
  - Hand-held 3D scanner with turntable
  - Automatic mesh output: no complicated alignment or point cloud processing
  - Metrology-grade measurements
    - accuracy up to 0.030 mm
    - resolution up to 0.050 mm
    - no rigid set-up required
  - Creaform VX Elements software is the best tool for post-processing the mesh
    - can be imported into CAD packages
    - software only available on a couple powerful Makerspace laptops (can borrow)
  - 3D Scanning has 2 parts:
    - Part 1: Scan (1-2 hours for a small part)
    - Part 2: Post-processing the scan (mesh) using Creaform's VX Elements (minimum 1-2 for small part)
      - similar to CAD or FEA package: training required
      - Makerspace can help train on the software
- Creaform Academia 50 - Creaform ACADEMIA
  - Hand-held 3D scanner with turntable
  - Accuracy: up to 0.250 mm
  - Mesh resolution: 0.500mm
  - Measurment resolution: 0.250 mm
  - Scanning and mesh editing software: VX Elements
    - only available on Makerspace computers
  - Can also use own software like DesignX
- EinScan SP
  - Bench-top 3D Scanner with Turntable
  - Dual Scan modes:
    - Auto scanning
    - Fixed scanning
    - Accuracy: 0.05 mm
    - 0.17mm point distance
  - scanning software: Mesh Mixer
    - installed on CAE computer next to scanner
    - can install on personal laptop
- Structure
  - Ipad and mount
  - Accuracy: 1 mm
  - All scanning software is built into the iPad (checked out from Makerspace)
  - Email .stl file through app
    - can be opened and edited using Mesh Mixer (free software) or other editing software
      - installed on all CAE computers in Makerspace

Directly from Makerspace Website:

Type of Equipment	Make	Model
3D Scanning / Sensors	Creaform Handyscan 700	https://www.creaform3d.com/sites/default/files/assets/brochures/files/handyscan3d_brochure_en_h
3D Scanning / Sensors	Creaform Academia 50	https://www.creaform3d.com/en/education/teaching#section-1||Creaform Academia 50
3D Scanning / Sensors	Einscan SP	https://www.einscan.com/desktop-3d-scanners/einscan-sp/||Einscan SP
3D Scanning / Sensors	Structure	https://structure.io/structure-sensor/original#faq||Structure Sensor

Conclusions/action items: Meet with Jesse & team to discuss project specifics and 3D scanning options futher.

02/18/2025 - Dragon Skin Silicone Molding Research

SADIE ROWE - Feb 18, 2025, 8:51 PM CST

Title: Silicone Molding Research

Date: 2/18/2025

Content by: Sadie Rowe

Present: N/A

Goals: Learn more about silicone molding techniques for use as an alternative fabrication plan (if 3D scanning does not work). Determine if Dragon Skin silicone could be used to create a mold of the client's foot.

Link: https://www.smooth-on.com/product-line/dragon-skin/

Citation: [1] “Dragon Skin™ Series, High Performance Silicone Rubber,” Smooth-On, Inc. Accessed: Feb. 18, 2025. [Online]. Available: https://www.smooth-on.com/product-line/dragon-skin/

Content:

- Low viscosity formulation, high performance
- Skin Safe
- High tensile strength
- 663% elongation stretch: don't need to cut a seam to remove foot from mold after silicone has been formed
- Process: Mix 1A and 1B in a 1:1 ration by weight or volume
  - will then need to mix thoroughly for 3 minutes before using
  - uniform flow will help minimize trapped air
  - no need for gram scales or precise weight measurements
- Pot life of 15 min
- Cure time of 75 min at room temperature
  - negligible shrinkage
- Can be thickened or thinned to different consistencies
- Can not be used with other tin or platinum based silicone
- Room needs to have proper ventilation
- Need to wear safety glasses, long sleeves, and rubber gloves to minimize contamination risk. Wear vinyl gloves only, rubber gloves will inhibit the cure of the rubber
- Can use a release agent if necessary
- Depending on specific silicone chosen, there are different levels of viscosity, tensile strengths, young's modulus, and shrinkage

- Options:

Select a Product Below	Hardness	Pot Life	Cure Time
Dragon Skin™ 10 VERY FAST	10 A	4 mins	30 mins
Dragon Skin™ 10 FAST	10 A	8 mins	75 mins
Dragon Skin™ 10 MEDIUM	10 A	20 mins	5 hrs
Dragon Skin™ 10 SLOW	10 A	45 mins	7 hrs
Dragon Skin™ 10 NV	10 A	15 mins	75 mins
Dragon Skin™ 10 AF Anti Fungal	10 A	20 mins	5 hrs
Dragon Skin™ 15	15 A	40 mins	7 hrs
Dragon Skin™ 20	20 A	25 mins	4 hrs
Dragon Skin™ 20 NV	20 A	6 mins	30 mins
Dragon Skin™ 30	30 A	45 mins	16 hrs
Dragon Skin™ FX- Pro™	2 A	12 mins	40 mins

Conclusions/action items: Present information to team and further explore the different types of silicone available if this method is chosen

02/18/2025 - Eco Flex Silicone Molding Research

SADIE ROWE - Feb 18, 2025, 8:52 PM CST

Title: Silicone Molding Research

Date: 2/18/2025

Content by: Sadie Rowe

Present: N/A

Goals: Learn more about silicone molding techniques for use as an alternative fabrication plan (if 3D scanning does not work)

Link: https://www.smooth-on.com/product-line/ecoflex/

Citation: [1] "Ecoflex^{TM} Series, Super-Soft, Addition Cure Silicone Rubbers," Smooth-On, Inc. Accessed: Feb. 18, 2025. [Online]. Available: https://www.smooth-on.com/product-line/ecoflex/

Content:

Eco flex Silicone: skin safe applications

- Can be used as cushioning for orthopedic and orthic devices to be worn on the body
- Can be used for life casting
  - creation of 3D mold --> apply silicone directly onto skin to capture fine details

Types of Silicone:

- Ecoflex 00-10
  - Hardness 00-10
  - Cure time: 4 hours
  - Pot life: 30 mins
- Ecoflex 00-20
  - Hardness: 00-20
  - Cure time: 4 hours
  - Pot life: 30 mins
- Ecoflex 00-30
  - Hardness: 00-30
  - Cure time: 4 hours
  - Pot life: 45 mins
- Ecoflex 00-50
  - Hardness: 00-50

  - Cure time: 3 hours
  - Pot life: 18 mins
- Ecoflex 5:
  - Hardness: 5A
  - Cure time: 5 mins
  - Pot life: 1 min
- Ecoflex GEL
  - Hardness: 000-35
  - Cure time: 2 hours
  - Pot life: 15 mins
- Ecoflex GEL 2:
  - Hardness: 000-34
  - Cure time: 50 mins
  - Pot life: 20 mins

Seems to be easy preparation:

EX: How to make a silicone mold (EXL Ecoflex 00-35):

- Parts A and B are mixed 1:2 by weight or volume
- Allow mixture to cure at room temperature and watch for shrinkage
- Add pigment (if needed)
- Pour mixture into mold
- Allow silicone to cure (dependent on type of silicone)
- Remove with release solvent slowly
- NOTE: proportions might need to be adjusted as needed

Conclusions/action items: Revisit if 3D scanning is not a viable option

03/18/2025 - Foam Attachment Methods

SADIE ROWE - Mar 18, 2025, 3:44 PM CDT

Title: Foam Attachment Methods

Date: 3/18/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Research Potential methods for foam attachment

Link: https://gluesavior.com/what-glue-sticks-to-fabric/

Citation: [1] S. Graham, "What Glue Sticks to Fabric: A Comprehensive Guide," Glue Savior. Accessed: Mar. 18, 2025. [Online]. Available: https://gluesavior.com/what-glue-sticks-to-fabric/

Content:

Most common fabric adhesives: fabric glue, super glue, epoxy, hot glue, spray adhesive, permanent craft adhesive

- Fabric Glue: specially formulated glue designed for work with fabric
  - often used to attach embellishments to clothing
  - variety of formulas available: washable & permanent
  - Different forms: liquid and stick form
  - Application: applied with brush or nozzel
  -

TYPE OF FABRIC GLUE	DRYING TIME	WASHABILITY
Permanent Liquid Fabric Glue	Dries in 24 hours	Machine washable
Washable Liquid Fabric Glue	Dries in 24 hours	Hand washable
Stick Fabric Glue	Dries in minutes	Hand washable

- Super Glue (cyanoacrylate adhesive): fast drying and highly sticky adhesive
  - not all super gules are compatible with fabric (look for fabric-safe blend)
  - Tips for application:
    - apply sparingly
    - use a clamp
    - test first
    - work in a well-ventilated area
    - don't use on stretchy fabrics
    - excess glue will cause the fabric to harden and become brittle
- Epoxy: two-part adhesive that sets through a chemical reaction and creates a very strong bond with the fabric
  - ideal for heavy fabrics to bond to a range of materials: metals, plastics, ceramics, and wood
  - waterproof and heat resistant
  - can be messy to work with (need gloves for application)

    - Application: mix 2 components of epoxy together and apply to fabric with a brush
- Glue guns dry quickly and forms strong bonds
    - can limit fabric flexibility
    - will not hold up well in the was
    - Application: heat up glue and apply directly onto fabric
- Spray adhesive:
    - PROS:
        - can be applied evenly
        - good for 3D shape (sprayed on fabric, then pressed onto object
    - CONS:
        - can be messy
    - Types:

PERMANENT CRAFT ADHESIVE	WORKS BEST ON	DRYING TIME	WASHABILITY
Aleene's Fabric Fusion	Fabric, felt, canvas, burlap	24 hours	Machine washable
Gorilla Super Glue	Leather, plastic, metal, fabric	10-30 seconds	Not recommended
Beacon Fabri-Tac	Fabric, lace, ribbon, leather, suede	24 hours	Machine washable
3M Super 77 Multipurpose Adhesive	Fabric, foam, plastic, metal, wood	15 seconds	Not recommended

        - 3M Super 77 Multipurpose adhesive: strong fast-binding option
            - compatible with foam
    - Fusible Adhesive: type of adhesive that is activated by heat
        - comes in the form of a sheet or web
        - Fabric-to-fabric
        - Application: applied to fabric with an iron

General Properties of different glues:

- Drying times:

TYPE OF GLUE	DRYING TIME
Fabric Glue	24 hours
Super Glue	10-20 seconds
Epoxy	5 minutes to 24 hours
Hot Glue	10-20 seconds
Spray Adhesive	30 seconds to 1 minute
Permanent Craft Adhesive	1-2 hours
Fusible Adhesive	Time varies depending on the adhesive type

- Washability:
GLUE TYPE	WASHABILITY
Fabric Glue	Machine washable
Super Glue	Not recommended for washing
Epoxy	Not recommended for washing
Hot Glue	Not recommended for washing
Spray Adhesive	Machine washable
Permanent Craft Adhesive	Machine washable
Fusible Adhesive	Machine washable

- Flexibility:
TYPE OF GLUE	FLEXIBILITY
Fabric Glue	Very flexible, designed specifically for fabric
Epoxy	Often not very flexible, may crack or break when bent
Hot Glue	Moderately flexible, can become brittle over time
Permanent Craft Adhesive	Flexible when dry, but may become brittle over time
Fusible Adhesive	Very flexible, designed to bond two separate fabrics together

- Clarity: Will glue be visible or blend in with fabric?
  -

GLUE TYPE	CLARITY
Fabric Glue	Most fabric glues dry clear, making them a great choice for projects where the glue will be visible.
Super Glue	Super glue dries clear, but it can create a noticeable hardness in the fabric.
Epoxy	Epoxy dries clear, but it can create a noticeable hardness in the fabric.
Hot Glue	Hot glue dries with a slight yellow tint and can be very noticeable on light-colored fabrics. It's best used for projects where the glue won't be visible or for darker-colored fabrics.
Spray Adhesive	Spray adhesive can create a tacky surface that may not be completely clear, so it's best used for projects where the glue won't be visible.
Permanent Craft Adhesive	Permanent craft adhesive dries clear and is a good choice for projects where the glue will be visible.
Fusible Adhesive	Fusible adhesive is completely clear and won't be visible on the fabric.

Conclusions/action items: Look into 3M Super 77 adhesive, as it seems promising for attachment of foam to a hard surface, like the CF-PLA composite rigid supports

03/18/2025 - 3M Super 77 Adhesives

SADIE ROWE - Mar 18, 2025, 6:08 PM CDT

Title: 3M Super 77 Adhesives

Date: 3/18/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Learn more about 3M Super 77 Adhesive as a method of fabric/foam attachment onto rigid supports

Link: https://www.3m.com/3M/en_US/p/d/b40071862/

Citation: [1] “3M™ Super 77™ Multipurpose Spray Adhesive Aerosol.” Accessed: Mar. 18, 2025. [Online]. Available: https://www.3m.com/3M/en_US/p/d/b40071862/

Content:

Properties:

- Multipurpose adhesive
- Fast, aggressive tack for strong, permanent bonding
- Designed for use on carons or foam
- High solids content: supports low soak-in property: adequate time to best fit for application
- Versatile & fast drying
- Spray formula
- Bonds to wide range of lightweight materials, like: paper, paperboard, fabric, foam, etc.

Purchasing details from Uline: https://www.uline.com/BL_8103/3M-Super-77-Adhesives

- 3 forms:
    - Super 77:
        - Model #: S-515
        - Cost: $28/can
    - Low VOC (volatile organic compounds): Meets VOC regulations in CO, CT, DE, IL, IN, MA, MD, ME, MI, NH, NJ, NY, OH, PA, RI, UT, VA, and Dist. of Columbia
        - means that the product has a reduced level of VOCs, making it safer for both human health and the environment compared to regular products with higher VOC content
        - Model #: S-24722
        - Cost: $28/can
    - Ultra low VOC: compliant with VOC regulations in all 50 states
        - meets CARB/OTC requirements
        - designed to have minimal VOC emissions, making them even safer and more environmentally friendly
        - Model #: S-22030
        - Cost: $24/can
    - Bulk Pail: for large surface areas/industrial manufacturing

Conclusions/action items: Discuss adhesive options with team and order necessary materials before spring break

02/18/2025 - IMU Testing

SADIE ROWE - Feb 18, 2025, 9:23 PM CST

Title: IMU Testing Research

Date: 2/18/2025

Content by: Sadie Rowe

Present: Sadie

Goals: Gain a better understanding of what IMU testing is and how it can be applied to the project via evaluation of Ankle inversion angles and dorsiflexion motion

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC8434290/

Citation: [1] M. Sharifi Renani, A. M. Eustace, C. A. Myers, and C. W. Clary, "The Use of Synthetic IMU Signals in the Training of Deep Learning Models Significantly Improves the Accuracy of Joint Kinematic Predictions," *Sensors (Basel)*, vol. 21, no. 17, p. 5876, Aug. 2021, doi: 10.3390/s21175876.

Content:

- **IMU:** Inertial measurement unit that measures motion using accelerometers, gyroscopes, and sometimes magnetometers to track position, velocity, and orientation
    - Used to measure movement mechanics, including joint angles and kinetics
    - Provide a portable alternative to traditional motion capture systems
    - Integrate the rotational velocity and linear acceleration data from each limb segment coupled with orientation data (from magnetometer) to make estimations about limb segment positions and orientations
- Current gold standard passive-marker motion capture (MOCAP) systems require technical expertise to generate reliable data
    - MoCap: uses optical systems with cameras or marker-based systems to track the positions of makers placed on a subject's body
- Open Sim: analysis tool
    - can be used to generate simulated IMU data for comparison
    - simulated IMU data: IMU signals that are generated based on existing motion capture data rather than being directly recorded from a physical IMU sensor
    - takes motion capture (Mocap) data and applies this data to a virtual human model with defined joint mechanics and muscle structures, then it calculates that angular velocities and accelerations those virtual IMUs would record based on the movement data

Article: The Use of Synthetic IMU Signals in the Training of Deep Learning Models Significantly Improves the Accuracy of Joint Kinematic Predictions

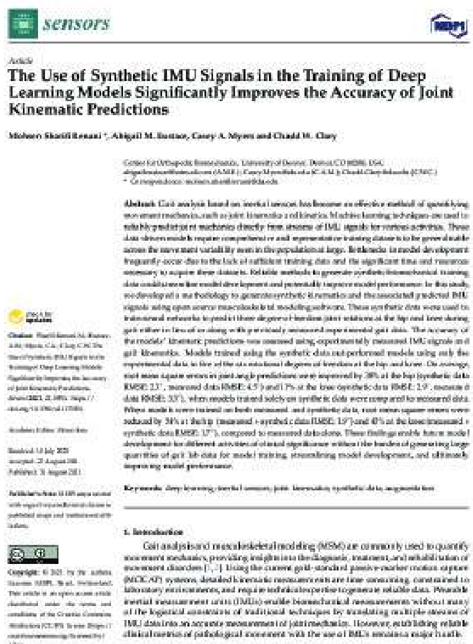
- Study aimed to determine if synthetic IMU data could improve the accuracy of joint kinematic predictions during gait analysis (using deep learning models)
- Procedure:
    - Experimental data - 30 subjects: performed gait trials while wearing IMUs and motion capture markers

    - Synthetic IMU data - use of musculoskeletal modeling software (Open Sim) to simulate IMU signals based on augmented gait kinematics
        - using Open Sim, researcher can simulate how IMU sensors would behave if they had been placed on the body during recorded motion
- Findings:
    - Adding synthetic IMU data significantly improved prediction accuracy
        - Models trained with both real and synthetic data had up to 54% lower error at the hip and 45% lower at the knee compared to those trained on real data alone
    - Synthetic IMU data alone performed comparably to real data for most kinematic predictions
    - Synthetic IMU data can reduce reliance on large motion capture datasets, making gait analysis models easier to develop

Conclusions/action items: Continue to research IMUs, MoCap, and OpenSim

---

SADIE ROWE - Feb 18, 2025, 9:24 PM CST


sensors

Article

The Use of Synthetic IMU Signals in the Training of Deep Learning Models Significantly Improves the Accuracy of Joint Kinematic Predictions

[Download](#)

sensors-21-05876.pdf (2.04 MB)

02/22/2025 - OpenCap: Human movement dynamics from smartphone videos

SADIE ROWE - Feb 23, 2025, 10:33 AM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

SADIE ROWE - Feb 23, 2025, 10:33 AM CST

PLOS COMPUTATIONAL BIOLOGY

RESEARCH ARTICLE

OpenCap: Human movement dynamics from smartphone videos

Abstract

Author summary

Download

ulrich2023_opencap.pdf (2.04 MB)

02/24/2025 - SolidWorks Simulation Testing

SADIE ROWE - Feb 24, 2025, 8:25 PM CST

Title: SolidWorks Simulation Testing (FEA)

Date: 2/24/2025

Content by: Sadie Rowe

Present: N/A

Goals: Understand the process of FEA testing in solidworks

Link: https://help.solidworks.com/2020/English/SolidWorks/cworks/c_Analysis_Steps.htm

Citation: [1] "Overview of SOLIDWORKS SimulationXpress - 2021 - SOLIDWORKS Help." Accessed: Feb. 24, 2025. [Online]. Available:
https://help.solidworks.com/2021/English/SolidWorks/cosmosxpresshelp/c_Overview_of_SOLIDWORKS_SimulationXpress.htm

Content: To effectively evaluate the rigidity of the design and ensure its ability to meet force and torsional requirements established in the PDS, Finite Element Analysis (FEA) will be conducted via SolidWorks.

- SolidWorks SimulationXpress Analysis Wizard is an easy-to-use portfolio of structural analysis tools that utilize FEA to predict a design's real-world physical behavior through virtual testing of CAD models
  - The portfolio provides linear and non-linear static and dynamic analysis capabilities which will allow the team to evaluate design requirements without physical destruction of prototype parts
  - Use of SimulationXpress will help to reduce cost and time by eliminating the need for expensive and time-consuming mechanical tests.
- SimulationXpress Analysis Wizard can be accessed directly from the Tools menu in SolidWorks
  - Before starting the analysis, the preferred unit system will be selected
  - A force of 266N will then be applied along the inside of the rigid support
  - The material, CF-PLA composite, will be registered in SolidWorks, and the simulation will be executed
  - Based on the results, further adjustments will be made to optimize the part's performance.

Procedure:

- Create a study defining its analysis type and options.
- If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.
- Define material properties. This step is not required if material properties were defined in the CAD system. Fatigue and optimization studies use referenced studies for material definitions.
- Specify restraints and loads. Fatigue and optimization studies use referenced studies for restraints and loads. Drop test studies do not allow you to define restraints and loads other than what is specified in the setup.
- The program automatically creates a shell mesh for surfaces and sheet metals with uniform thicknesses. For sheet metals, right-click on shell icon and select Treat as Solid to mesh with solid elements
- The program automatically meshes structural members with beam elements.
- The program automatically creates a mixed mesh when different geometries (solid, shell, structural members etc.) exist in the model.
- Define component contact and contact sets.
- Mesh the model to divide the model into many small pieces called elements. Fatigue and optimization studies use the meshes in referenced studies.

- Run the study.
- View results.

Conclusions/action items: FEA in SolidWorks will be used to ensure that the rigid components of the support can withstand a force of 266N, as specified in the PDS and that moment-ankle characteristics remain within a torque range of ±30 Nm without causing deformation of the rigid support

03/18/2025 - Measurement of Human Ankle Stiffness Using the Anklebot

SADIE ROWE - Mar 18, 2025, 6:32 PM CDT

Title: Measurement of Human Ankle Stiffness Using the Anklebot

Date: 3/18/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Learn more about the Anklebot mechanism of evaluating ankle stiffness and how similar principles could be used in our testing. Was directed to this paper by: Professor Peter Gabriel Adamczyk

Link: https://ieeexplore.ieee.org/abstract/document/4428450?casa_token=QaXPBEF41toAAAAA:QfvAGh4yB5ykLmZBty4j4sINXRpEsYeG28R-Q8YXtSBTnh5LY7SIAfwyDSbNGhL13myITzF5-w

Citation: [1] A. Roy *et al.*, "Measurement of Human Ankle Stiffness Using the Anklebot," *2007 IEEE 10th International Conference on Rehabilitation Robotics*, Noordwijk, Netherlands, 2007, pp. 356-363, doi: 10.1109/ICORR.2007.4428450. keywords: {Anthropometry;Humans;Rehabilitation robotics;Medical treatment;Nervous system;Protocols;Mechanical engineering;Muscles;Diseases;Manufacturing},

Content:

Study Motivation:

- Stroke is a leading cause of permanent disability
- Rehabilitation seeks to restore function through physical therapy
- Ankle stiffness is an important biomechanical factor in locomotion
    - Modulation of ankle stiffness is the primary mechanism for adjusting leg stiffness under various circumstances
    - Ankle stiffness is critical for controlling body momentum during the single support phase of gait
    - Ankle impedance is important for shock absorption and may be related to spasticity
- Ankle stiffness has been measured using perturbations of torque or angular displacement
    - Estimates of ankle stiffness are sensitive to experimental conditions:
        - Loading, posture, and inter-limb orientation
        - Perturbation conditions (active vs. passive, pulse-type vs. ramp-type, magnitude)
        - Physiological conditions (maximal vs. sub-maximal muscle contraction)
    - The Anklebot can be used to estimate intrinsic ankle properties, such as passive stiffness.

- Study presents a simple method to estimate ankle stiffness using the Anklebot

What is the Anklebot?

- robot developed at MIT to rehabilitate the ankle following stroke

- designed to address issues like footdrop
- allows a normal range of motion in all three degrees of freedom of the foot
- provides active assistance in dorsi-plantar flexion and inversion-eversion
- Anklebot provides information about ankle kinematics and torques
- Ankle angles in dorsi-plantarflexion estimated using equations based on the geometry of the device and sensor outputs
- torque is computed from sensor current information
- Anklebot accurately and repeatably estimates angles in dorsi-plantarflexion

Theoretical Methodology:

- Ankle stiffness estimated by: applying static displacements and measuring the resultant angular displacements
- linear mapping between static ankle torques and displacements yields an estimate of static passive ankle stiffness.

Results:

- Ankle stiffness appears to be different for dorsiflexion and plantarflexion
- Mean static stiffness in dorsiflexion was lower than in plantarflexion.
- Stiffness estimates were compared with those obtained in previous studies and found to be comparable.

Conclusion:

- Anklebot prototype can be used as a clinical measurement tool to estimate ankle stiffness

- Initial results from healthy individuals indicate that the device can acquire an accurate estimate of ankle stiffness

Conclusions/action items: Could anything from this paper be used for our analysis of ankle stiffness?

SADIE ROWE - Mar 18, 2025, 6:13 PM CDT

Measurement of Human Ankle Stiffness Using the Anklebot

Download

Measurement_of_Human_Ankle_Stiffness_Using_the_Anklebot.pdf (3.19 MB)

02/08/2025 - Brainstorming Sketches

SADIE ROWE - Feb 08, 2025, 12:26 PM CST

Title: Brainstorming Design Sketches

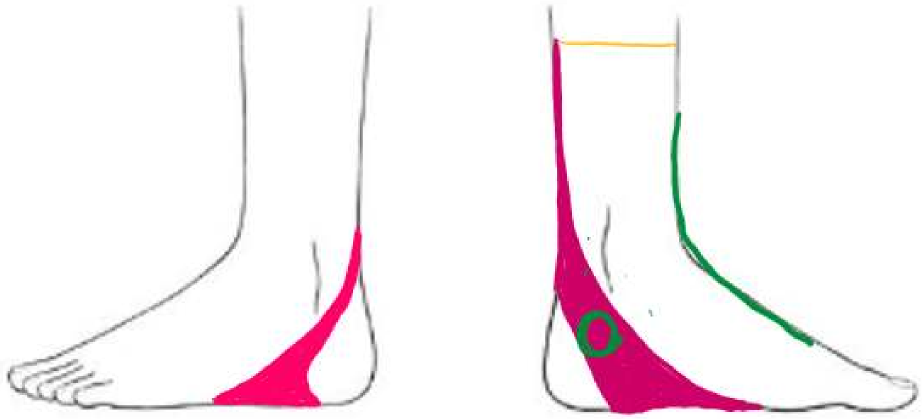
Date: 2/8/2025

Content by: Sadie Rowe

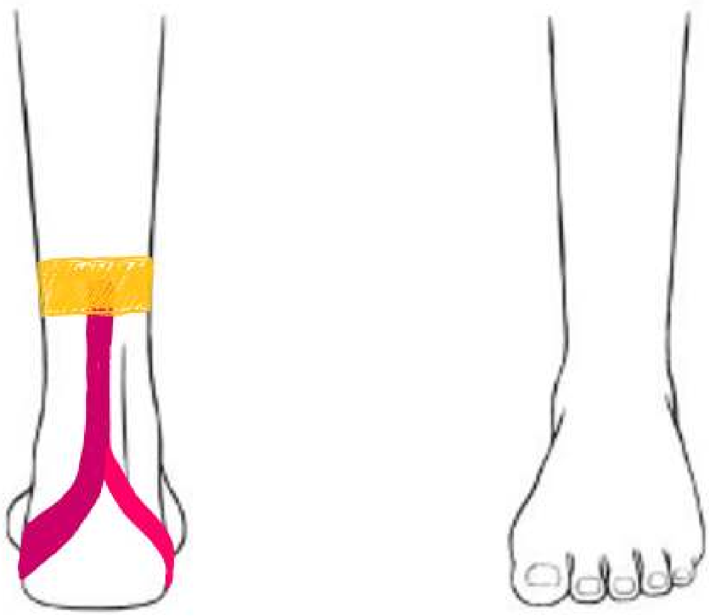
Present: Sadie Rowe

Goals: Create brainstorming sketch

Content:



Side Views



Front/Back View

Conclusions/action items: Add hinge and dimensions for design matrix sketch

02/08/2025 - Design Matrix Sketch

SADIE ROWE - Feb 08, 2025, 12:38 PM CST

Title: Design Matrix Sketch

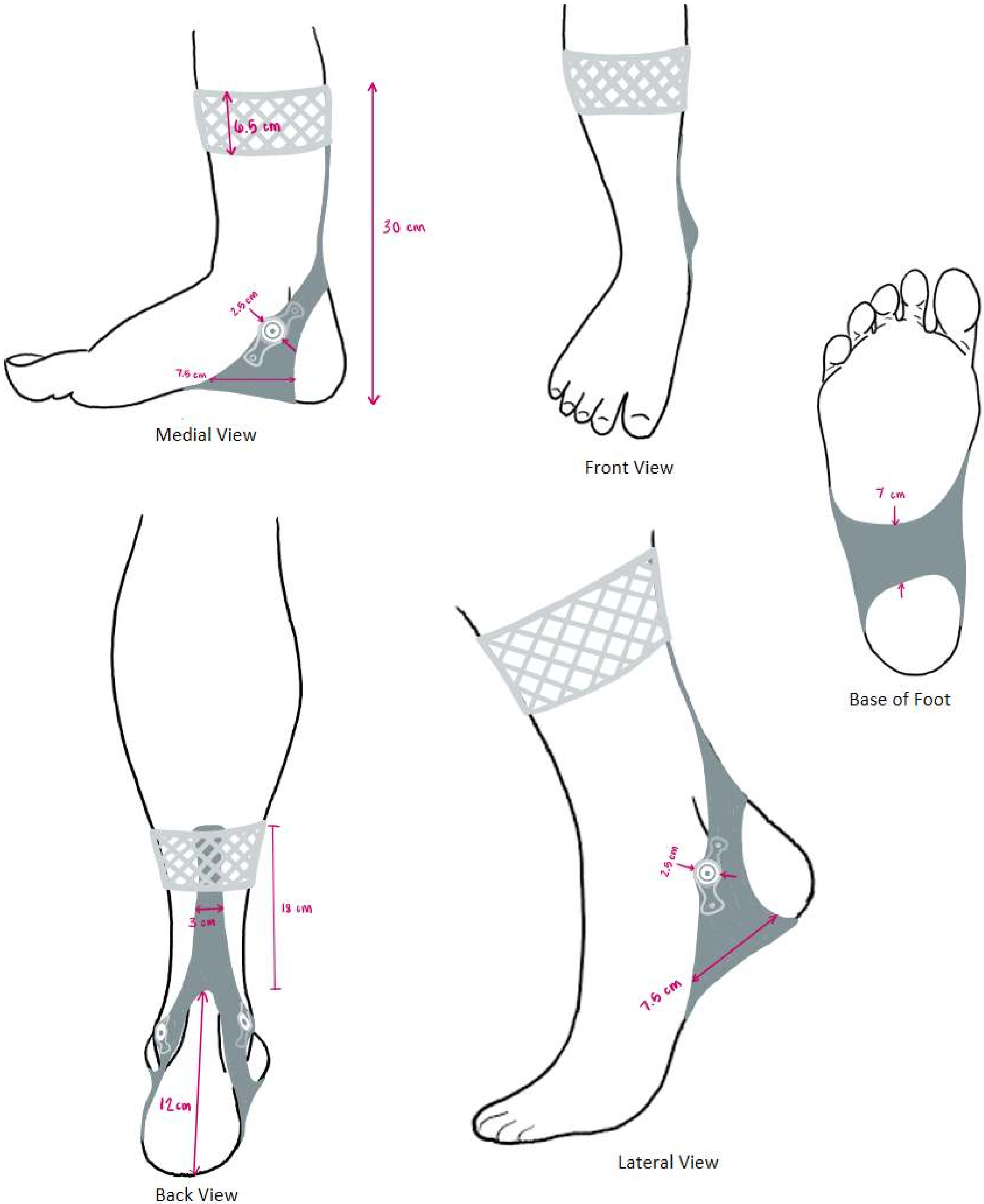
Date: 2/8/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Edit original brainstorming sketch and make more detailed design sketch with dimentions for the design matrix

Content:



Conclusions/action items: Add to design matrix.

3/11/2025 - Foam Lining Design Ideas

SADIE ROWE - Mar 11, 2025, 11:42 PM CDT

Title: Foam Lining Design ideas

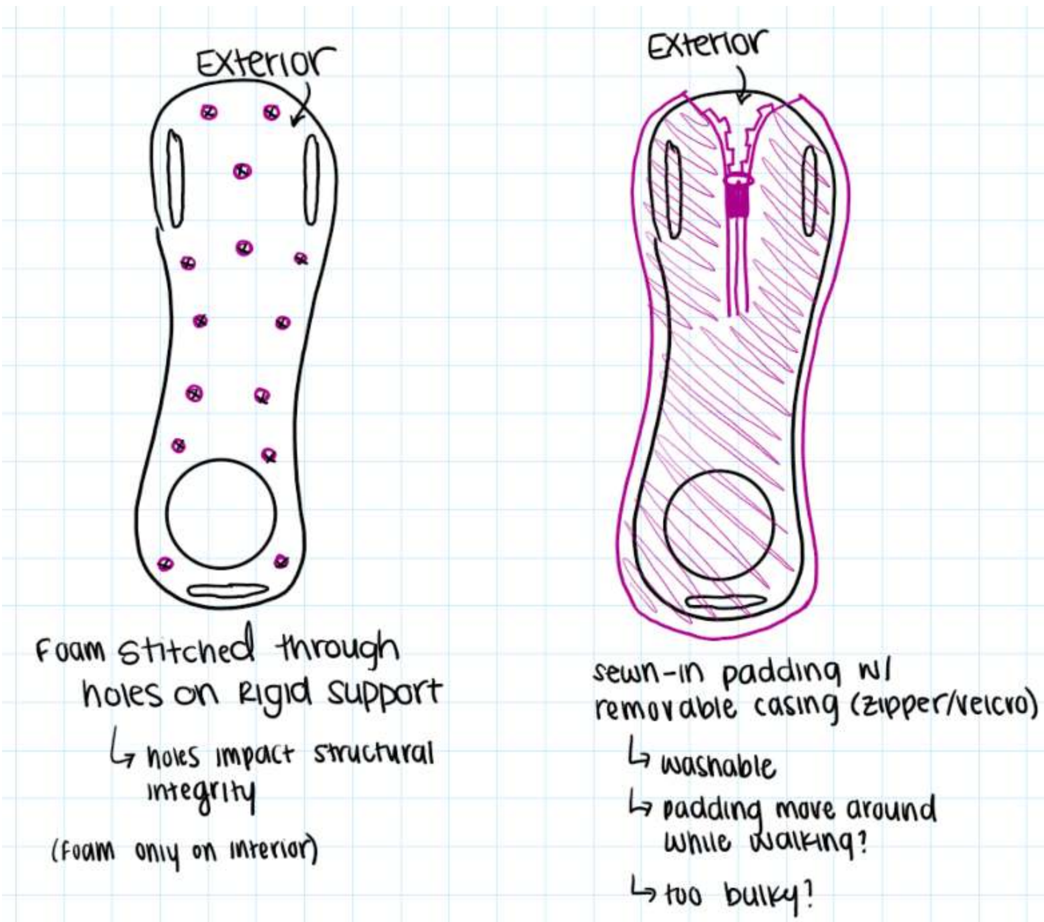
Date: 3/11/2025

Content by: Sadie Rowe

Present: N/A

Goals: Brainstorm methods of foam attachment if adhesive is not a viable option (placement and size)

Content:



Left side:

- Foam lines interior
- Attached via stitched through small holes in rigid plate

Right Side:

- Foam sewn into a removable fabric pocket
- Pocket would encase entire rigid support

Conclusions/action items: Design design ideas with team.

3/11/2025 - FEA Testing Outline

SADIE ROWE - Mar 11, 2025, 11:06 PM CDT

Title: FEA Testing Outline

Date: 3/11/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Summarize goals and big-picture steps of FEA testing

Content:

- Finite Element Analysis (FEA) in SolidWorks
    - Used to evaluate design rigidity and ensure compliance with force and torsional requirements in the PDS
    - Conducted via SolidWorks SimulationXpress Analysis Wizard
        - a structural analysis tool for virtual testing
    - Provides linear and non-linear static and dynamic analysis to assess design performance without physical prototype destruction
    - Helps reduce cost and time by eliminating expensive mechanical tests
- Force and Torsional Testing
    - Ensures rigid support components can withstand 266N force
        - as specified in the PDS
    - Verifies moment-ankle characteristics remain within a torque range of ±30 Nm without deformation
- Fatigue and Cyclic Loading Testing
    - Simulates forces and motions experienced during the stance phase of walking
        - heel strike to toe-off
    - Evaluates cyclic load effects to determine performance characteristics of the orthotic device
    - Ensures compliance with PDS and ISO Standard 2267:2024
- Simulation Setup in SolidWorks
    - 1: Access SimulationXpress from the Tools menu in SolidWorks
    - 2: Select the preferred unit system before starting the analysis
    - 3: Apply fixtures and loads according to design parameters on the rigid support
    - 4: Register CF-PLA composite material in SolidWorks
    - 5: Execute the simulation and make further adjustments based on results to optimize performance

Conclusions/action items: Write detailed testing procedure for final report and conduct testing

3/11/2025 - Comfortability Testing Outline

SADIE ROWE - Mar 11, 2025, 11:05 PM CDT

Title: Comfortability Testing outline

Date: 3/11/2025

Content by: Sadie Rowe

Present: N/A

Goals: Summarize goals and big-picture steps of comfortability testing

Content:

- Design and Fit Requirements
  - The AFO must maintain a low profile and fit within a standard shoe without requiring specialized footwear
- Comfortability Testing Protocol
  - A participant will walk at a normal pace for 5 minutes while wearing the brace
  - After walking, participants will rate their comfort level on a 1-10 scale:
    - 1 = Extreme discomfort
    - 10 = No discomfort
  - Participants will assess factors such as:
    - Pressure points
    - Stability
    - Ease of dorsiflexion
    - Ankle stiffness
    - Overall sensation
- Assessment and Design Improvement
  - This subjective assessment will identify areas for improvement
  - Ensures the device meets functionality and comfort standards before client evaluation
  - Results will guide design alterations before the final client presentation
  - Further customizations will be made as necessary

Conclusions/action items: Conduct testing on team members to determine necessary design changes. Write detailed testing protocol

3/11/2025 - IMU and Motion Capture Testing Outline

SADIE ROWE - Mar 11, 2025, 11:04 PM CDT

Title: IMU and Motion Capture Testing Outline

Date: 3/11/2025

Content by: Sadie Rowe

Present: N/A

Goals: Document goals and big-picture steps of IMU/Motion Capture Testing

Content:

- Assessment of AFO Design Performance
    - Testing conducted via Inertial Measurement Units (IMUs) and Motion Capture (MoCap) via OptiTrack
        - OptiTrack provides high-precision motion tracking with less than 0.2 mm measurement error across large areas
    - IMUs integrate with MoCap for comprehensive human movement analysis
    - Tests will quantify motion parameters while wearing the AFO, including:
        - Plantarflexion and dorsiflexion range of motion
        - Ankle inversion stability
- Ankle Inversion Testing
    - Participant walks along a straight path toward MoCap cameras, tracking movements in the coronal plane
    - IMU sensors on the ankle measure the angle of inversion during gait
    - Results confirm if ankle inversion stays below 25 degrees, meeting PDS stability requirements
- Dorsiflexion Testing
    - Goniometer measurement establishes maximum dorsiflexion and plantarflexion angles from resting foot position
    - Participant walks along a straight path parallel to MoCap cameras, tracking gait in the sagittal plane
    - OptiTrack software verifies if the design allows at least 30 degrees of dorsiflexion from neutral position
    - Ensure adequate foot clearance during the swing phase of gait

Conclusions/action items: Find time to practice testing procedure and work through kinks with team prior to client testing. Write detailed procedure for client visit

3/17/2025 - MTS Testing Results/Pictures

SADIE ROWE - Mar 18, 2025, 3:09 PM CDT

Title: MTS Testing Results/Pictures

Date: 3/17/2025

Content by: Sadie Rowe

Present: Sadie, Kate, Maddie, and Presley

Goals: Document MTS testing results and location of failure on each rigid support

Content:

MTS Testing Set-up:

50% Fill: Failure above 270 N

35% Fill: Failure at 260 N

15% Fill: Failure above 260 N

Conclusions/action items: Next steps include analyzing the MTS data and creating graphs to visualize stress - strain curves of each infill.

4/21/2025 - Hip Flexion Gait Analysis

Title: OpenCap Hip Flexion Angle Analysis

Date: 4/21/2025

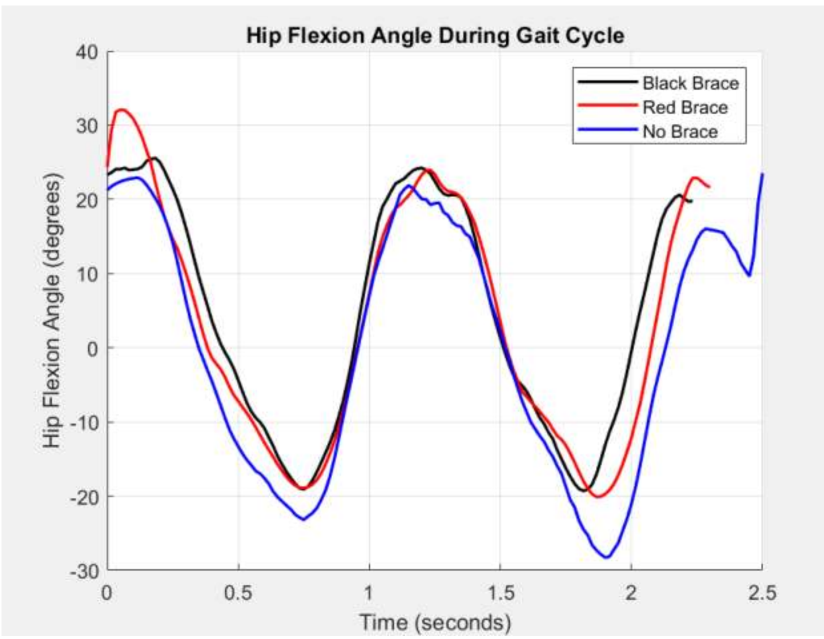
Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Document coding and data analysis of Open Cap Data

Content:

Plot:



MATLAB Code:

```
clc,clear;

%% Code for each

% BLACK BRACE:

data_anglesBB = readtable('BBSidewalk1mot.xlsx', MissingRule="omitrow");

data_anglesBB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu

% figure;

% plot(data_anglesBB.time, data_anglesBB.knee_angle_r, 'b-', 'LineWidth', 1.5);

% xlabel('Time (s)');

% ylabel('Knee Flexion Angle (degrees)');

% grid on;


% RED BRACE (shortest file - everything has to line up to this one)

data_anglesRB = readtable('RBSidewalk3.mot_EXCEL.xlsx', MissingRule="omitrow");
```

```
data_anglesRB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu
%figure;
% plot(data_anglesRB.time, data_anglesRB.knee_angle_r, 'b-', 'LineWidth', 1.5);
% xlabel('Time (s)');
% ylabel('Knee Flexion Angle (degrees)');
% grid on;

% NO BRACE
data_anglesNB = readtable('NBSidewalk1mot.xlsx', MissingRule="omitrow");
data_anglesNB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu
% figure;
% plot(data_anglesNB.time, data_anglesNB.knee_angle_r, 'b-', 'LineWidth', 1.5);
% xlabel('Time (s)');
% ylabel('Knee Flexion Angle (degrees)');
% grid on;

%% Offset - match up all 3 data sets to the same point
% Shortest: set offset to 1
% Others: (set offset to the length of its signal - shortest signal length) + 1
BBoffset = 127;
RBoffset = 1;   % set offset for shortest signal to 1, adjust the rest roughly by its signal length - the shortest signal length + 1
NBoffset = 187;
time = data_anglesNB.time; % taking the longest sample and temporarily storing time?
% Going from offset to the height (bottom of columns) & taking this for all columns:
data_anglesBB = data_anglesBB(BBoffset:height(data_anglesBB), :);
data_anglesRB = data_anglesRB(RBoffset:height(data_anglesRB), :);
data_anglesNB = data_anglesNB(NBoffset:height(data_anglesNB), :);

%% Plotting:
figure;
hold on;
% plot(time, knee angle data)
% dimensions need to match
% this won't run unless all the dimensions match
% need to see how long arrays are  and plot the time indicies from (1:number of rows)
plot(time(1:135), data_anglesBB.hip_flexion_r, 'k-', 'LineWidth', 1.5);
plot(time(1:139), data_anglesRB.hip_flexion_r, 'r-', 'LineWidth', 1.5);
```

```
plot(time(1:156), data_anglesNB.hip_flexion_r, 'b-', 'LineWidth', 1.5);

xlabel('Time (seconds)');

ylabel('Hip Flexion Angle (degrees)');

title('Hip Flexion Angle During Gait Cycle');

xlim([0 2.5])

legend('Black Brace','Red Brace', 'No Brace')

grid on;

hold off;
```

Conclusions/action items: Discuss Results with team

4/21/2025 - Subtalar Angle Gait Analysis

Title: OpenCap Hip Flexion Angle Analysis

Date: 4/21/2025

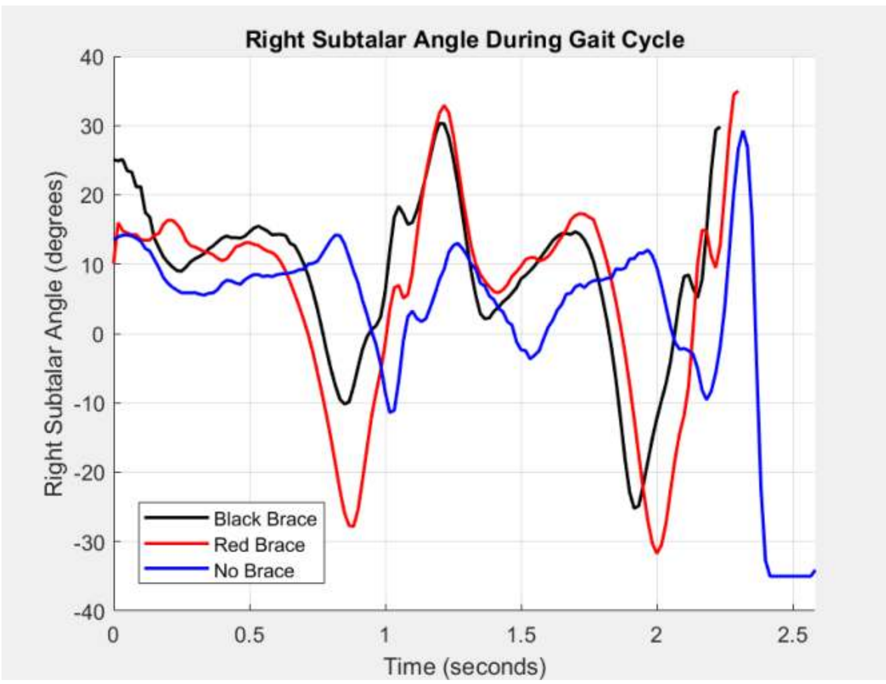
Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Document coding and data analysis of Open Cap Data

Content:

Plot:



MATLAB Code:

```
clc,clear;

%% Code for each

% BLACK BRACE:

data_anglesBB = readtable('BBSidewalk1mot.xlsx', MissingRule="omitrow");

data_anglesBB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu

% figure;

% plot(data_anglesBB.time, data_anglesBB.knee_angle_r, 'b-', 'LineWidth', 1.5);

% xlabel('Time (s)');

% ylabel('Knee Flexion Angle (degrees)');

% grid on;


% RED BRACE (shortest file - everything has to line up to this one)
```

```
data_anglesRB = readtable('RBSidewalk3.mot_EXCEL.xlsx', MissingRule="omitrow");

data_anglesRB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu

%figure;

% plot(data_anglesRB.time, data_anglesRB.knee_angle_r, 'b-', 'LineWidth', 1.5);

% xlabel('Time (s)');

% ylabel('Knee Flexion Angle (degrees)');

% grid on;


% NO BRACE

data_anglesNB = readtable('NBSidewalk1mot.xlsx', MissingRule="omitrow");

data_anglesNB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu

% figure;

% plot(data_anglesNB.time, data_anglesNB.knee_angle_r, 'b-', 'LineWidth', 1.5);

% xlabel('Time (s)');

% ylabel('Knee Flexion Angle (degrees)');

% grid on;


%% Offset - match up all 3 data sets to the same point

% Shortest: set offset to 1

% Others: (set offset to the length of its signal - shortest signal length) + 1

BBoffset = 127;

RBoffset = 1;   % set offset for shortest signal to 1, adjust the rest roughly by its signal length - the shortest signal length + 1

NBoffset = 187;

time = data_anglesNB.time; % taking the longest sample and temporarily storing time?

% Going from offset to the height (bottom of columns) & taking this for all columns:

data_anglesBB = data_anglesBB(BBoffset:height(data_anglesBB), :);

data_anglesRB = data_anglesRB(RBoffset:height(data_anglesRB), :);

data_anglesNB = data_anglesNB(NBoffset:height(data_anglesNB), :);


%% Plotting:

figure;

hold on;

% plot(time, knee angle data)

% dimensions need to match

% this won't run unless all the dimensions match

% need to see how long arrays are  and plot the time indicies from (1:number of rows)

plot(time(1:135), data_anglesBB.subtalar_angle_r, 'k-', 'LineWidth', 1.5);
```

```
plot(time(1:139), data_anglesRB.subtalar_angle_r, 'r-', 'LineWidth', 1.5);

plot(time(1:156), data_anglesNB.subtalar_angle_r, 'b-', 'LineWidth', 1.5);

xlabel('Time (seconds)');

ylabel('Right Subtalar Angle (degrees)');

title('Right Subtalar Angle During Gait Cycle');

xlim([0 2.5])

legend('Black Brace','Red Brace', 'No Brace')

grid on;

hold off;
```

Conclusions/action items: Unable to obtain clear data regarding ankle inversion from a healthy individual

4/21/2025 - Knee Flexion Gait Analysis

Title: OpenCap Hip Flexion Angle Analysis

Date: 4/21/2025

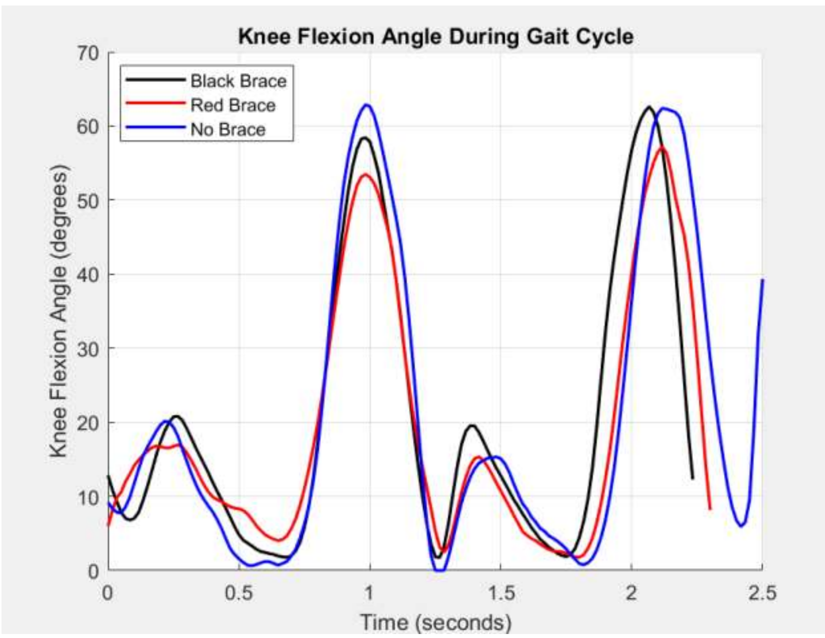
Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Document coding and data analysis of Open Cap Data

Content:

Plot:



MATLAB Code:

```
clc,clear;

%% Code for each

% BLACK BRACE:

data_anglesBB = readtable('BBSidewalk1mot.xlsx', MissingRule="omitrow");

data_anglesBB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu

% figure;

% plot(data_anglesBB.time, data_anglesBB.knee_angle_r, 'b-', 'LineWidth', 1.5);

% xlabel('Time (s)');

% ylabel('Knee Flexion Angle (degrees)');

% grid on;


% RED BRACE (shortest file - everything has to line up to this one)

data_anglesRB = readtable('RBSidewalk3.mot_EXCEL.xlsx', MissingRule="omitrow");
```

```
data_anglesRB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu

%figure;

% plot(data_anglesRB.time, data_anglesRB.knee_angle_r, 'b-', 'LineWidth', 1.5);

% xlabel('Time (s)');

% ylabel('Knee Flexion Angle (degrees)');

% grid on;


% NO BRACE

data_anglesNB = readtable('NBSidewalk1mot.xlsx', MissingRule="omitrow");

data_anglesNB.Properties.VariableNames = ["time", "pelvis_tilt", "pelvis_list", "pelvis_rotation", "pelvis_tx", "pelvis_ty", "pelvis_tz", "hip_flexion_r", "hip_addu

% figure;

% plot(data_anglesNB.time, data_anglesNB.knee_angle_r, 'b-', 'LineWidth', 1.5);

% xlabel('Time (s)');

% ylabel('Knee Flexion Angle (degrees)');

% grid on;


%% Offset - match up all 3 data sets to the same point

% Shortest: set offset to 1

% Others: (set offset to the length of its signal - shortest signal length) + 1

BBoffset = 127;

RBoffset = 1;   % set offset for shortest signal to 1, adjust the rest roughly by its signal length - the shortest signal length + 1

NBoffset = 187;

time = data_anglesNB.time; % taking the longest sample and temporarily storing time?

% Going from offset to the height (bottom of columns) & taking this for all columns:

data_anglesBB = data_anglesBB(BBoffset:height(data_anglesBB), :);

data_anglesRB = data_anglesRB(RBoffset:height(data_anglesRB), :);

data_anglesNB = data_anglesNB(NBoffset:height(data_anglesNB), :);


%% Plotting:

figure;

hold on;

% plot(time, knee angle data)

% dimensions need to match

% this won't run unless all the dimensions match

% need to see how long arrays are  and plot the time indicies from (1:number of rows)

plot(time(1:135), data_anglesBB.knee_angle_r, 'k-', 'LineWidth', 1.5);

plot(time(1:139), data_anglesRB.knee_angle_r, 'r-', 'LineWidth', 1.5);
```

```
plot(time(1:156), data_anglesNB.knee_angle_r, 'b-', 'LineWidth', 1.5);

xlabel('Time (seconds)');

ylabel('Knee Flexion Angle (degrees)');

title('Knee Flexion Angle During Gait Cycle');

xlim([0 2.5]);

legend('Black Brace','Red Brace', 'No Brace')

grid on;

hold off;
```

Conclusions/action items: Discuss Implications of Open Cap Testing and repeat analysis if client provides OpenCap testing

4/22/2025 - Open Cap Plots

SADIE ROWE - Apr 22, 2025, 6:52 PM CDT

Title: Open Cap Plots

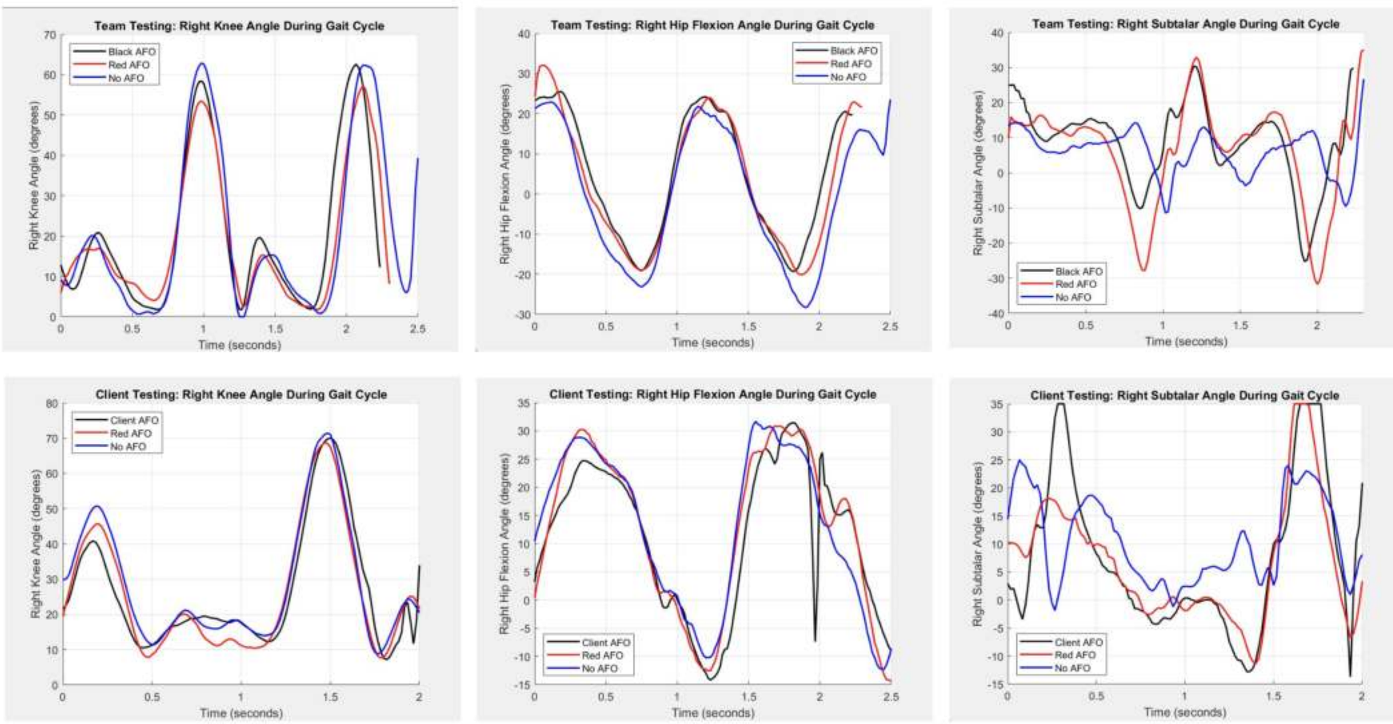
Date: 4/22/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Analyze plots from Team Open Cap testing and Client Open Cap testing

Content:



Conclusions/action items: Determine which plots to include in poster presentation and final report

4/22/2025 - Patient Comfortability Testing Results

SADIE ROWE - Apr 22, 2025, 7:49 PM CDT

Title: Patient Comfortability Testing Results

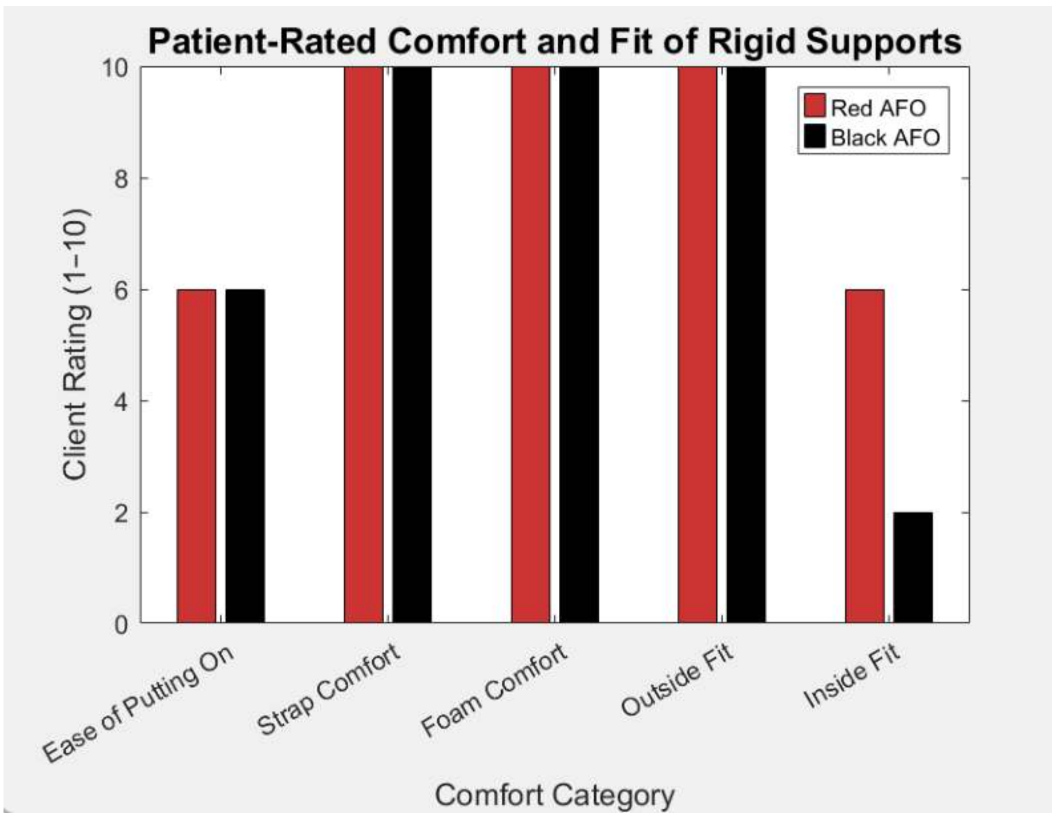
Date: 4/22/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Analyze comfort testing from patient

Content:



CODE:

```
categories = {'Ease of Putting On','Strap Comfort','Foam Comfort','Outside Fit','Inside Fit'};
red = [6, 10, 10, 10, 6];    % example values
black = [6, 10, 10, 10, 2];  % example values
data = [red; black]';
b = bar(data, 'grouped');
% Force MATLAB to update graphics before applying color
drawnow
% Set bar colors manually
b(1).FaceColor = [0.8 0.2 0.2];   % Red (RGB)
b(2).FaceColor = [0 0 0];   % Black (RGB)
```

```
set(gca, 'XTickLabel', categories, 'XTick', 1:numel(categories))
lgd = legend('Red AFO', 'Black AFO');
lgd.ItemTokenSize = [8, 8];  % [width, height] in points
ylabel('Client Rating (1–10)', 'FontSize', 12)
xlabel('Comfort Category', 'FontSize', 12)
title('Patient-Rated Comfort and Fit of Rigid Supports', 'FontSize', 14);
```

Conclusions/action items: Include testing analysis on final deliverables

4/22/2025 - Comparison of team and client testing via OpenCap

SADIE ROWE - Apr 29, 2025, 1:29 PM CDT

Title: Comparison of team and client testing via OpenCap

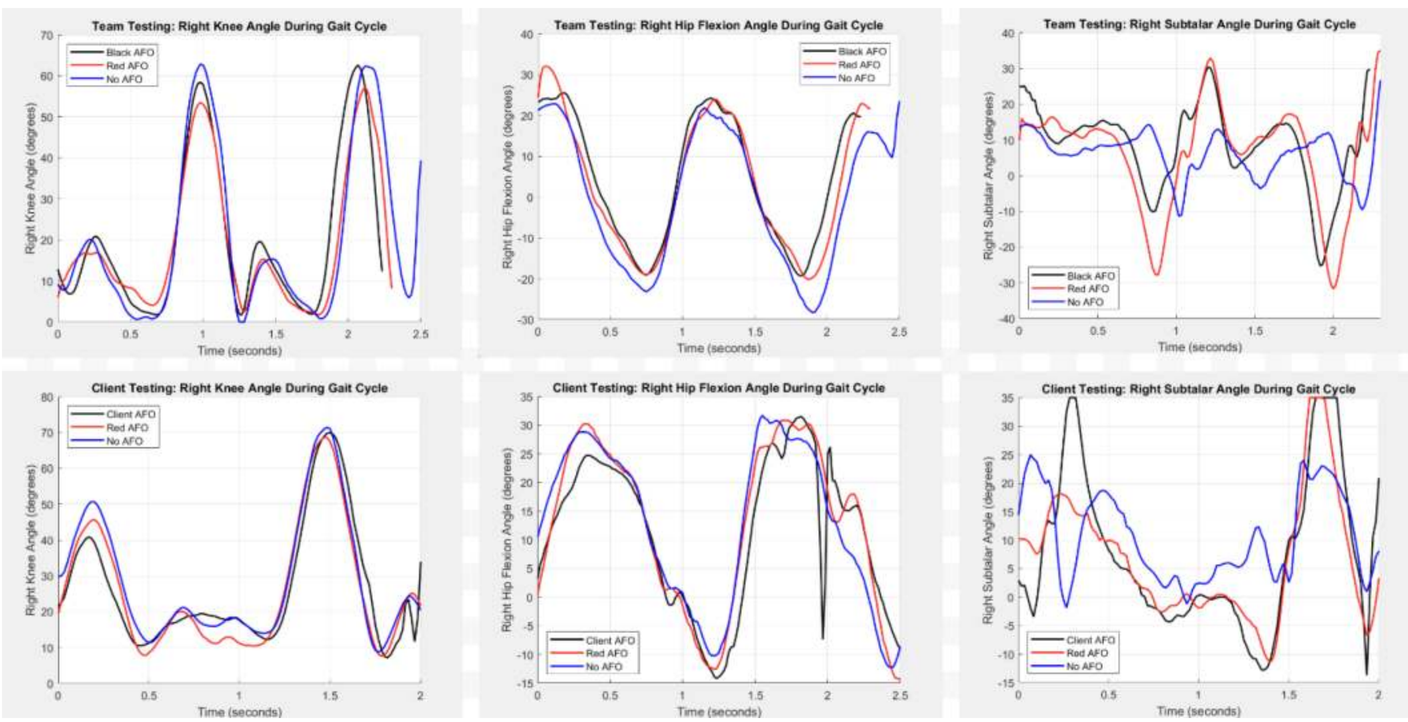
Date: 4/22/2025

Content by: Sadie Rowe

Present: Sadie Rowe

Goals: Compare angular fluctuations in gait between client and team testing

Content:



As shown in the top left and bottom left plots, the right knee flexion angle does not substantially differ between testing conditions in either the team or client testing. The similarity between plots, with the no AFO condition represented in blue, the red rigid supports in red, and either the black rigid supports (team testing) or the client's personal AFO (client testing) in black, supports the conclusion that the designed rigid supports and combined AFO structure do not adversely affect unintended knee joint motion during gait.

A similar relationship can be obtained from the middle figures, where hip flexion angles do not significantly differ between the testing conditions for either team or client testing. A noticeable dip in knee flexion angle is present in the client testing plot for the client's existing AFO condition (black line) around the two-second mark. This discrepancy is likely due to a processing error within OpenCap or a momentary occlusion of the body segment from the camera views, as the curve realigns to the expected pattern by approximately 2.3 seconds. This anomaly is not considered representative of true motion and was excluded from interpretation.

The fair right figures displays significant variation in the right subtalar angle between each of the three testing conditions. This angle represents ankle inversion and eversion, where eversion–tilting of the sole outward away from the midline–is indicated by a positive subtalar angle, and inversion–tilting inward toward the midline–is indicated by a negative subtalar angle.

In both the team and client testing plots, the no AFO condition demonstrated the least fluctuation in subtalar angles. In contrast, across both testing groups, the use of the client's existing AFO, the red prototype, or the black prototype was associated with increased inversion and eversion angles. This trend was unexpected, particularly for the client's existing AFO (black line, client testing), where improved gait performance was visually observed and subtalar angles would typically be expected to remain stable or decrease relative to the no AFO condition.

The unexpected increase in subtalar angle fluctuations may be attributed to displacement errors during motion capture. Specifically, the additional material from the compression sleeve of the orthotics may have been interpreted by the OpenCap software as part of the limb, artificially altering the calculated joint positions. This artifact could explain the consistent increase in inversion and eversion angles observed across all conditions involving an AFO. Due to the inaccuracies observed in the far right figures, inversion angle data obtained from motion capture testing are considered inconclusive. Further testing using non-optical analysis methods is required to draw more meaningful conclusions regarding the relationship between the designed rigid supports and their effectiveness in preventing ankle inversion. This adjustment is discussed further in the future work portion of the report.

Conclusions/action items: Include analysis in final report.

01/28/2025 - Current Therapeutic Approaches in FSHD

Madison Michels - Jan 28, 2025, 3:58 PM CST

Title: Current Therapeutic Approaches in FSHD

Date: January 28, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to learn about what FSHD is and the current techniques used in practice to combat this condition.

Content:

General Overview

- Facioscapulohumeral muscular dystrophy (FSHD)
- FSHD is the third most common muscular dystrophy
- Females typically present in their late twenties to early thirties
- Weakness of foot dorsiflexion and hip girdle muscles
- Hearing loss and retinal vascular disease occur in infantile-onset disease

Molecular Pathphysiology

- Expression of the DUX4 gene on chromosome 4q33 in skeletal muscle
- D4Z4 repeats are located at the telomeric end of chromosomes 4q and 10q with 11 to 150 copies
- In FSHD Type 1 (95% of patients), contraction of the D4Z4 repeats between 1-10 times
  - Associated with younger disease onset
  - Intensity of the disease increasese when the number of repeats goes down
- In FSHD Type 2, atleast one 4q33 D4Z4 with a contrcted array and mutation in a gene that plays a role in the epigenetic repression of the D4Z4 repeats

Therapeutic Approaches

- Open label trial of prednisone
- Randomized control trial of albuterol
- Intravenous myostatin inhibitor
- Oral antioxidants
- Intramuscularly-administered myostatin inhibitor (ACE-083)
- Effective blocking of DUX4 expression is ideal
- ALL FORMS OF TREATMENT WERE INEFFECTIVE

Citation:

L. H. Wang and R. Tawil, “Current therapeutic approaches in FSHD,” *Journal of Neuromuscular Diseases*, vol. 8, no. 3, pp. 441–451, Nov. 2020, doi: 10.3233/jnd-200554.

Conclusions/action items:

In conclusion, FSHD is a muscular condition in which a gene is not expressed in those with the condition. Most therpeutic approaches have been with drug use, so I plan to research more approaches using a physical brace.

Madison Michels - Jan 28, 2025, 10:42 AM CST


Review

Current Therapeutic Approaches in FSHD

disease mechanisms, potential therapeutic approaches as well as the state of trial readiness in the planning and execution of future clinical trials in FSHD.

Keywords: All neuromuscular diseases, muscle disease, facioscapulohumeral dystrophy (FSHD), outcome measures

INTRODUCTION

Facioscapulohumeral dystrophy (FSHD) is the third most common muscular dystrophy after Duchenne muscular dystrophy and myotonic dystrophy, with a prevalence of ~12–15 per 100,000 [1, 2]. Age of onset is variable with presentations at birth to late in life. On average, males tend to present earlier in their late teen years to mid-twenties whereas females present in their late twenties to early thirties. Classically, the disease presents with facial and proximal arm weakness with winged scapula followed by weakness of foot dorsiflexion and hip girdle muscles. Additionally, truncal muscles including the paraspinals and abdominal muscle are variably affected. Asymmetric involvement is frequent and often very prominent [3]. Bulbar, cardiac, and extraocular muscles are spared. Neuromuscular restrictive lung disease occurs in about 15% of individuals, with a minority needing non-invasive ventilatory support [4]. Symptomatic hearing loss and retinal vascular disease (Coats disease) are infrequent occurring exclusively in infantile-onset disease [4]. Nevertheless, FSHD can result in significant morbidity with 20% of the patients becoming wheelchair dependent after the age of 50 [5]. As the wide spectrum of age at disease onset suggests, the rate of disease progression is variable but generally slow [6, 7].

*Correspondence to: Leo H. Wang, Department of Neurology, University of Washington, 1959 NE Pacific Street Box 356465, Seattle, WA 98195, USA. Tel.: +1 206 598 7688; E-mail: [illegible]

MOLECULAR PATHOPHYSIOLOGY OF FSHD

Genetics of FSHD

Over the past decade, consensus was reached regarding the primary cause of FSHD, the inappropriate expression of the *DUX4* gene on chromosome 4q35 in skeletal muscle (see Figure 1). There are multiple tandem copies of the *DUX4* gene, each contained in a 3.3 kb repeat unit, known as a D4Z4 macrosatellite repeat [8]. Unlike microsatellite repeats that consist of a few base pairs, macrosatellite repeats are several kilobases in size. Tandem repeated DNA composes a significant portion (>50%) of the human genome and this type of copy number variation accounts for much of human phenotypic variation.

Download

therapeutic_approaches_in_FSHD.pdf (332 kB)

01/28/2025 - Gait Propulsion in patients with facioscapulohumeral muscular dystrophy and ankle plantarflexor weakness

Madison Michels - Jan 28, 2025, 4:20 PM CST

Title: Gait Propulsion in patients with facioscapulohumeral muscular dystrophy and ankle plantarflexor weakness

Date: January 28, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to find current technologies used in gait assistance for FSHD individuals. I am also aiming to learn more about the clientale of these treatments.

Content:

General

- 1:15,000 people suffer from FSHD
- It is characterized by fat infiltration of skeletal muscles
- Foot drop ccauses an increased risk of tripping. It is often compensated by exaggerated hip flexion and knee flexion.
- 56% of people with FSHD exhibit plantarflexor motion.
- Comfortable walking speed in FSHD in on average 20% slower than healthy controls.
    - 3.57 km/hr (29% lower in this study)
- Compensatory hip power is recruited to maintain a normal walking speed.
- **One way we could measure success of the brace would be to obtain a walking speed measurement.**

Citation:

N. H. M. Rijken, B. G. M. Van Engelen, J. W. J. De Rooy, V. Weerdesteyn, and A. C. H. Geurts, “Gait propulsion in patients with facioscapulohumeral muscular dystrophy and ankle plantarflexor weakness,” *Gait & Posture*, vol. 41, no. 2, pp. 476–481, Dec. 2014, doi: 10.1016/j.gaitpost.2014.11.013.

Conclusions/action items:

In conclusion, foot dropping is a very common issue in individuals with FSHD and can decrease the comfortable wakling speed for those individuals. Using this information, I think that testing the walking speed of an individual with FSHD while wearing the brace could be a good indicator of how successful our device is.

Madison Michels - Jan 28, 2025, 3:49 PM CST


Gait & Posture

Gait propulsion in patients with facioscapulohumeral muscular dystrophy and ankle plantarflexor weakness

N.H.M. Rijken, B.G.M. van Engelen, J.W.J. de Rooy, V. Weerdesteyn, A.C.H. Geurts

© 2014 Elsevier B.V. All rights reserved.

Download

Gait_propulsion_in_patients_with_FSHD.pdf (945 kB)

01/29/2025 - The Effect of Ankle Braces on the Prevention of Dynamic Forced Ankle Inversion

Madison Michels - Jan 29, 2025, 3:44 PM CST

Title: The Effect of Ankle Braces on the Prevention of Dynamic Forced Ankle Inversion

Date: January 29, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to determine what ankle braces are used to prevent ankle inversion. I hope to learn about what materials or types of rigid supports are used to prevent ankle inversion in current patients.

Content:

- The braces used in this study included Swede-O, Aircast, and Bledsoe.

Figure 1: Depiction of Ankle Braces that prevent inversion of the ankle. (A) Swede-O (B) Aircast (C) Bledsoe.

- Study was performed on healthy individuals to determien the efficacy of these braces in protecting ankle inversion when stimulated.
- Full foot inversion is characterized by a 24 degree rotation.
- All of the braces increased the subjects' success rates in resisting ankle inversion stimulus.
    - Bledsoe - 52%
    - Aircast - 46%
    - Swede-O -- 34%
- It was noted that the stiffer the brace and its interface with the foot, the greater the proportion of the external rotation moment the brace will resist and the less the peroneal muscles and lateral ligamentous tissues resist.
- Bledsoe and Aircast have higher stiffnesses than the Swede-O.
- One way to test our brace could be to mimic the angle of inversion upon walking. To do this, we could place markers on the tibia and heel to determine the angle of offset that occurs upon inversion.

Citation:

M. L. Ubell, J. P. Boylan, J. A. Ashton-Miller, and E. M. Wojtys, “The effect of ankle braces on the prevention of dynamic forced ankle inversion,” *The American Journal of Sports Medicine*, vol. 31, no. 6, pp. 935–940, Nov. 2003, doi: 10.1177/03635465030310063201.

Conclusions/action items:

In conclusion, ankle bracing in this format does help stabilize the ankle during athletics, which can be applied to FSHD as well. There was a drastic increase in the percent of successes while weearing the brace. I plan to research these braces and determine the material they used to fabricate them, as they are exactly the design we are looking to replicate.

Madison Michels - Jan 29, 2025, 3:44 PM CST

Download

ubell-et-al-2003-the-effect-of-ankle-braces-on-the-prevention-of-dynamic-forced-ankle-inversion.pdf (92.8 kB)

02/08/2025 - Evaluation of various design concepts in passive ankle-foot orthoses using finite element analysis

Madison Michels - Feb 08, 2025, 1:04 PM CST

Title: Evaluation of various design concepts in passive ankle-foot orthoses using finite element analysis

Date: February 8, 2025

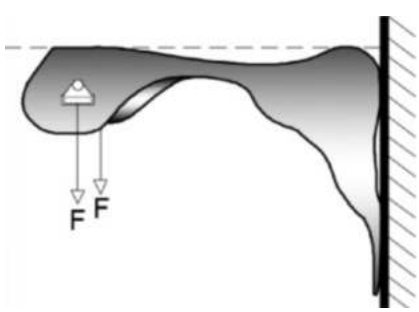
Content by: Maddie

Present: Maddie

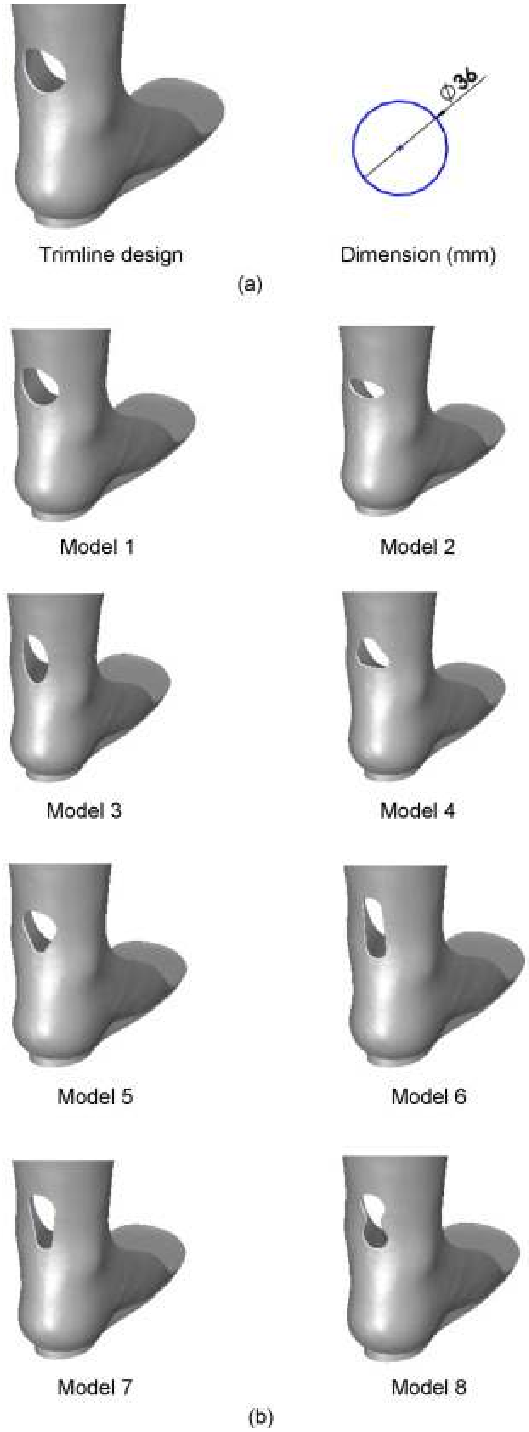
Goals: The goal of this research is to evaluate the success of different design concepts and apply them to our design ideas.

Content:

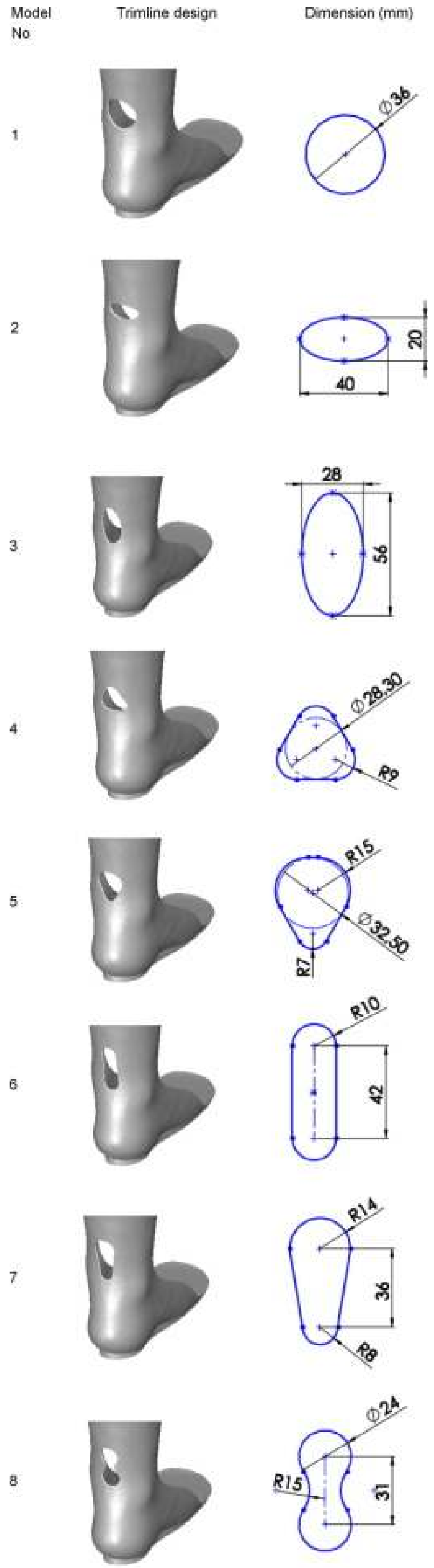
- Due to excessive and repetitive loading conditions, plastic material deformation is observed in many AFOs.
- AFOs are made from metal, leather, polypropelene (PP), polethylene (PE), acrylic, and nylon.
- Reduce excessive ankle plantar flexion.
- Depth of the trimline changes the strength of the AFO.
- Stresses in AFOs are concentrated in the lateral and medial parts of the ankle.
- A circular trimline was created to decrease the peak stress values by half.
    - Dorsal side
- Procedure
    - Child with spina bifida, age 12, 60kg, 161 cm
    - Vacuum molding technique
    - Thermal plastic sheet vacuumed onto a mold of the child's foot
    - SolidWorks Model
        - AFO was modeled by using 20 scans of the child and combining them to print into SolidWorks
    - Bending tests with fixed supports at plantar surface and lateral and medial loads in the anteroposterior direction
        - Minimum total force to cause large deformations was 34 N



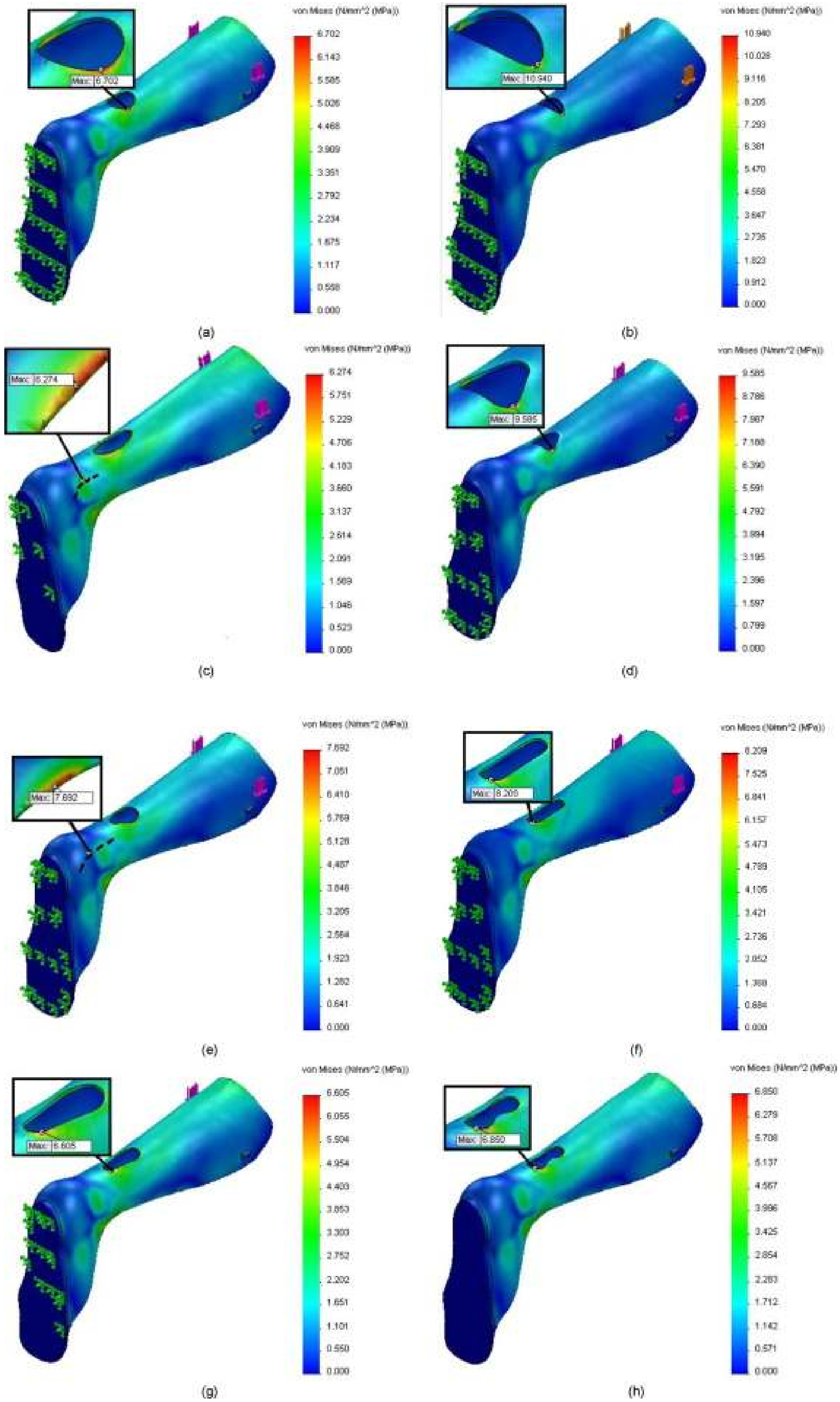
- Alternative dorsal trimlines were incorporated to determine the most stress reduction



- Model 1: Circle
- Model 2: Horizontal Ellipse
- Model 3: Vertical Ellipse
- Model 4: Rounded Triangle
- Model 5: Rounded Inverse Triangle
- Model 6: Slot
- Model 7: Slot Variations
- Model 8: Slot Variations
- Deep and Shap-edged trimlines cause high stresses
- Curvillinear trimlines and rounded angular geometries



- **Polypropylene copolymer:** Material type was defined as linear, isotropic, and elastic
    - Tensile yield strength: 27.6 MPa
    - Elongation at yield: 16%
    - Elastic modulus: 896 MPa
    - Tearing modulus: 315.8 MPa
    - Mass density: 890 kg/m^3
    - Poisson's ratio: 0.4103



- **Maximum Displacement:**
  - Model 1: 9.06
  - Model 2: 9.06
  - Model 3: 9.05
  - Model 4: 9.05
  - Model 5: 9.04
  - Model 6: 9.05
  - Model 7: 9.05

    - Model 8: 9.03
- **Maximum Strain:**
    - Model 1: 0.59
    - Model 2: 0.73
    - Model 3: 0.58
    - Model 4: 0.77
    - Model 5: 0.65
    - Model 6: 0.67
    - Model 7: 0.58
    - Model 8: 0.60
- **Maximum Stress:**
    - Model 1: 6.70
    - Model 2: 10.94
    - Model 3: 6.27
    - Model 4: 9.58
    - Model 5: 7.69
    - Model 6: 8.20
    - Model 7: 6.60
    - Model 8: 6.85
- Stresses are concentrated around the sides fo the brace while walking.
- Dorsal trimming leads to more homogenous stress distribution throughout the brace.
- The vertical elliptic trimline was the most effective in decreasing the magnitude of the peak stress value. The brace distributes stress along the edges of the ellipse.

Citation

H. K. Surmen and Y. Z. Arslan, "Evaluation of various design concepts in passive ankle-foot orthoses using finite element analysis," *Engineering Science and Technology, an International Journal*, vol. 24, no. 6, pp. 1301–1307, Dec. 2021, doi: 10.1016/j.jestch.2021.03.004.

Conclusions/action items:

Material destruction of the AFO can be prevented or delayed. The elongated ellipse (Model 3) was the most effective in reduced the maximum yield stress, which will help distribute the load and avoid microcracks in the brace.

Madison Michels - Feb 08, 2025, 11:01 AM CST


Engineering Science and Technology, an International Journal

Full Length Article

Evaluation of various design concepts in passive ankle-foot orthoses using finite element analysis

Hasan Kemal Surmen, Yunus Ziya Arslan

Download

Evaluation_of_various_designs.pdf (2.43 MB)

02/08/2025 - Design principles, manufacturing and evaluation techniques of custom dynamic ankle-foot orthoses: a review study

Madison Michels - Feb 12, 2025, 8:37 AM CST

Title: Design principles, manufacturing and evaluation techniques of custom dynamic ankle-foot orthoses: a review study

Date: February 8, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to evaluate the success of different design concepts for drop foot and apply them to our design ideas.

Content:

- Off-the-shelf AFOs have several limitations, namely in terms of comfort.
  - Sold in limited sizes
  - Do not match a patient's anatomy
  - Fixed mechanical properties that cannot address patient-specific concerns
  - Do not address other foot morphological alterations (pronated feet)
- Passive-dynamic AFOs (PD-AFOs) are ideal with lower severity symptoms.
- Solid braces are the most ideal for severe symtoms.
- PD-AFOs hav a flexible calf shell that can bend while walking and absord energy to help fuel the next steps.
- Literature Review
  - Literature review conducted on Google Scholar
  - Only papers on custom PD-AFOs were included
  - Study excluded:
    - Non-peer reviewed papers
    - Abstracts shorter than 3 pages
    - Lecture notes
    - Thesis dissertations
  - 75 papers total
    - 16 on scanning technologies
    - 14 on customization criteria
    - 19 production techinques
    - 16 on mechanical testing
    - 33 on functional testing
  - Keywords
    - dynamic; AFO; ankle foot orthosis; custom; patient-specific orthotic; mechanical testing; functional evaluation; gait analysis; drop-foot; customization; 3D printing; additive manufacturing; comfort; design and finite element analysis (FEA)

- AFOs are largely classified into 2 groups
  - Passive AFOs
    - Rigid or solid: characterized by stiff shelss which prevent ankle movement in 3 anatomical planes
  - Dynamic AFOs

        - Flexible in the saggital plane, allow for some dorsiflexion/plantarflexion movement
        - Flexibility provded by a deformable shell
        - Fixed-stiffness hinge joint
- Active AFOs
- Articulated and fitted with powered activators
- Flexion/extension movements at hte ankle joint are assisted with actuators

- Production Methods
    - Additive manufacturing
        - STL, OBJ files
        - SolidWorks, Blender
        - In case of wearing out or breakage, a new brace can be modeled using the same model as the old one
        - The cost and availability of 3D scanners limits the spreading of this technique
        - Allows for combination of different materials in the same AFO
    - Selective Laser Sintering (SLS)
        - More environmentally friendly solution for mass production
        - More time efficient (can make multiple models at once)
- Testing
    - FEA analysis helpful for unique shapes and finding stress points
        - Minimize production costs by assessing different designs and materials before manufacturing
    - Ease of donning
    - Walking confidence
    - Comfort
- There is no clear customization technique replicatable and available as of now.
- Scoring systems must be implemented to be able to compare AFO designs globally.

Citation

G. Rogati, P. Caravaggi, and A. Leardini, “Design principles, manufacturing and evaluation techniques of custom dynamic ankle-foot orthoses: a review study,” *Journal of Foot and Ankle Research*, vol. 15, no. 1, p. 38, May 2022, doi: 10.1186/s13047-022-00547-2.

Conclusions/action items:

In conclusion, many various types of AFO braces are created used different manufacturing techniques and do not specify their focus on biomechanical functimons or customizability. It is difficult to find a standard way to measure the efficacy of braces and evaluate their functionality.

New articles to look into from this source:

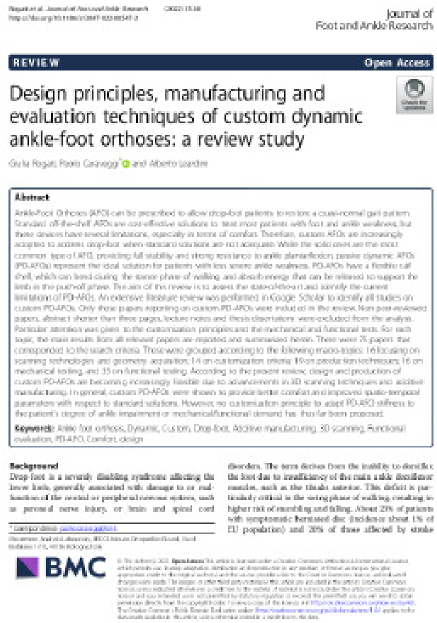
- Testing rotational stiffness: https://www.sciencedirect.com/science/article/abs/pii/S0957415821000623?via%3Dihub

- Fatigue failure of thermoplastic AFOs: https://www.sciencedirect.com/science/article/abs/pii/S135045331000072X?via%3Dihub

- Neutral ankle angle and MTP joints: https://www.sciencedirect.com/science/article/abs/pii/S0966636209001465?via%3Dihub

---

Madison Michels - Feb 08, 2025, 1:22 PM CST



Journal of Foot and Ankle Research

REVIEW — Open Access

Design principles, manufacturing and evaluation techniques of custom dynamic ankle-foot orthoses: a review study

Abstract

Background

Drop foot is a severely disabling syndrome affecting the lower limb, generally associated with damage to or malfunction of the central or peripheral nervous system, such as peroneal nerve injury, or brain and spinal cord disorders. The term derives from the inability to dorsiflex the foot due to insufficiency of the main ankle dorsiflexor muscles, such as the tibialis anterior. This deficit is particularly critical in the swing phase of walking, resulting in higher risk of stumbling and falling. About 25% of patients with symptomatic herniated disc (incidence about 1% of EU population) and 20% of those affected by stroke

BMC

Download

s13047-022-00547-2.pdf (737 kB)

01/30/2025 - Manufacturing Choices for Ankle-Foot Orthoses: A Multi-objective Optimization

Madison Michels - Jan 31, 2025, 11:40 AM CST

Title: Manufacturing Choices for Ankle-Foot Orthoses: A Multi-objective Optimization

Date: 01/30/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this reseaerch is to address the material choices and the manufacturing implications of those choices, most commonly used in ankle bracing.

Content:

- This is a study evaluating traditional plaster casting and two AM techniques
- Ankle-foot-arthrosis (AFO) is a custom-made medical device used to correct a patient's gait.
- Plaster Casting
  - The most traditional form of casting
  - Imperfect process with non-repeatable results
  - Dependent on skilled labor
  - Referal from a clinician, patient enters clinic, orthotist takes relevant mold by wrapping the foot in a plaster wrap, plastre is then poured into the negative mold to produce then mold of the leg.
  - Mold is covered in vacuum-sealed and heated with thermoplastic
  - **Polypropelyne (PP) and polyethylene (PE) are commonly used thermoplastics**
  - Carbon fiber reinforced polymer-based (CFRP) can be made with meticulous layering and laminating steps
  - Method procudes a lot of wasted materials, which are costly and environmentally inconsiderate.
- Additive Manufacturing
  - Foot scanning and computer-aided design (CAD)
  - Improve production times, lower waste, decrease costs, and improve AFO performance
  - Greater customization and enhanced repeatability
- PE was found to be *slightly* better than PP
- PP-PE composites are sometimes used as well
- The smaller the AFO, the thicker you need it

Citation:

D. Totah, I. Kovalenko, M. Saez, and K. Barton, “Manufacturing Choices for Ankle-Foot Orthoses: A Multi-objective Optimization,” *Procedia CIRP*, vol. 65, pp. 145–150, Jan. 2017, doi: 10.1016/j.procir.2017.04.014.

Conclusions/action items:

In conclusion, Polypropelyne (PP) and polyethylene (PE) are the two most common materials used. I plan to pursue researching these materials and exploring their ease of use and reproducability. We could also attempt a 3D printed AFO brace, but I expect there to be difficulties in scanning while doing CAD transferring.

Madison Michels - Jan 31, 2025, 11:25 AM CST

- Journals & Books
-

Help

- Search

My account
Sign in

- View PDF
- Download full issue

Search ScienceDirect

Procedia CIRP
Volume 65, 2017, Pages 145-150

Download

Manufacturing_Choices_for_Ankle-Foot_Arthrosis.htm (163 kB)

02/02/2025 - A Comparison of the Mechanical Properties of Fiberglass Cast Materials and Their Clinical Relevance

Madison Michels - Feb 02, 2025, 9:50 PM CST

Title: A Comparison of the Mechanical Properties of Fiberglass Cast Materials and Their Clinical Relevance

Date: February 2, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to evaluate the strength and applications of fiberglass tape and molding casts. I hope to utilize this research to determien the eligability of fiberglass tape as the rigid support of our design.

Content:

- Plaster of Paris (POP) materials used to be used for a ling time, but they have poor weight-bearing properties and messy applications. They also cannot be weight bearing for a long time.
- Fiberglass casting materials are lighter, stronger, and more radiolucent.
  - At least twice as strong as POP
  - Resistant to strength degredation by water
  - Short time until weight bearing
- The 6 brands studied were: Scotchcast Plus (SCP), KCast Tack Free (KCTF), KCast Improved (KCI), Deltalite "S" (DLS), Deltalite Conformable (DLC), and Specialist Plaster (SP).
  - All synthetic except plaster
  - Synthetic materials are knitted with fiberglass bandage inpregnated with water-activated polyeurethane resin
- Dip water temperatures of 70 +/- 2 degrees Farhenheit

TABLE 1. *Materials tested and the respective dip water temperatures, set times, and times to weight bearing*

Material type[a]	Dip water temperature (°F)	Set time (min)	Time to weight bearing
SCP	70–75	3–5	20 min
KCTF	60–80	5	30 min
KCI	60–80	5	30 min
DLS	70–80	4–5	20 min
DLC	70–80	4–5	20 min
SP	70–75	5–8	72 hr

[a] SCP, Scotchcast Plus; KCTF, KCast Tack Free; KCI, KCast Improved; DLS, Deltalite "S"; DLC, Deltalite Conformable; and SP, Specialist Plaster.

- Using beam deflection and the beam theory, the working strength was obtained.
- Scotchcast consistently yielded a smaller failure load.
- It would requires 10 layers of POP to withstand the same ultimate load as a 3 layer cast of synthetic materials.
- KCast Tack Free had the highest working load of 55 MPa.
- Deltalite "S" had a working load of 47 MPa.
- KCasy Improved - 37 MPa.

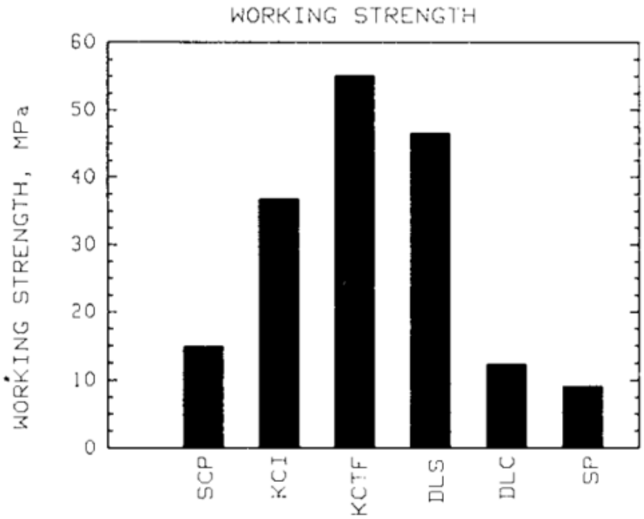


Figure 1: Working Strength of the Six Materials from the Beam Deflection Test.

- Two layers for most of the synthetics yielded a 50 N load, but a minimum of 3 layers should be applied to minimize delamination and strength reduction.
- POP materials fail in a brittle and catastrophic manner.
- Shells of the synthetic materials would return to their original shape upon deflection, unlike POP materials (plaster).

TABLE 5. *Thickness and required number of layers of material to sustain a 50 N load*

Material type[a]	Thickness per layer (mm)[b]	Thickness required for 50 N load (mm)	No. of layers required
SCP	0.72 (0.03)	2.44	4
KCTF	0.59 (0.02)	1.39	3
KCI	0.67 (0.03)	1.26	2
DLS	0.58 (0.02)	0.95	2
DLC	0.99 (0.07)	1.81	2
SP	0.40 (0.03)	3.99	10

- Failure load is proportional to the square of the thickness.

Citation:

A. T. Berman and B. G. Parks, “A Comparison of the Mechanical Properties of Fiberglass Cast Materials and Their Clinical Relevance,” *Journal of Orthopaedic Trauma*, vol. 4, no. 1, p. 85, Mar. 1990.

Conclusions/action items:

In conclusion, fiberglass polymer materials are significantly stronger and lighter than plaster molded POP materials. I plan to research the materials tested in this study and determine the best one for molding and the resin required to mold it.


A Comparison of the Mechanical Properties of Fiberglass Cast Materials and Their Clinical Relevance

Download

a_comparison_of_the_mechanical_properties_of.15.pdf (596 kB)

02/02/2025 - A Comparison of the Mechanical Properties of Fiberglass Cast Materials and Their Clinical Relevance (copy)

Madison Michels - Feb 19, 2025, 8:45 AM CST

Title: Purchasing Options for Fiberglass Molding Material

Date: February 12, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to locate the most applicable and price-concious location to purchase fiberglass casting tape.

Content:

McKesson Cast Tape Performance Casting

- https://mms.mckesson.com/product/831620/carolina-narrow-fabric-ct4wh?utm_campaign=mck+search+results&utm_source=mckesson.com&utm_medium=referral
- 4" x 12 feet
- White
- Set time: 3 to 5 minutes
- Manufacturer #: CT4WH
- Nonsterile

Cast Tape McKesson 3 inch x 12 foot Fiberglass

- https://mms.mckesson.com/product/733690/McKesson-Brand-115-3
- White
- One roll per package
- 3" x 4yds
- Set time: 3 to 4 minutes
- Manufacturer #: 115-3
- McKesson #: 733690
- Water-activated
- 10 rolls per box
- Size Options
  - 2in x 12 feet
  - 3in x 12 feet
  - 4in x 12 feet
  - 5in x 12 feet
- Color Options
  - Black
  - Blue
  - Green
  - Pink
  - Purple
  - Red
  - White

Medline Lightweight Fiberglass Casting Tape

- https://www.medline.com/product/Medline-Lightweight-Fiberglass-Casting-Tape/Z05-PF164910?question=fiberglass&
- Water activated
- 4 yards long
- 2 inches thick

Medline Scotchcast Plus Casting Tape

- https://www.medline.com/product/Scotchcast-Plus-Casting-Tape/Z05-PF41107?question=fiberglass&
- 20 minutes until weight bearing
- Lots of colors and sizes

Medline Delta-Lite Fiberglass Tape

- https://www.medline.com/product/DeltaLite-Plus-Fiberglass-Cast-Tapes/Z05-PF148713?question=fiberglass&
- 3 minute set time
- for primary or secondary casting

Medline CFN Medical Fiberglass Casting Tape

- https://www.medline.com/product/CFN-Medical-Fiberglass-Casting-Tape/Z05-PF140565?question=fiberglass&
- Water-activated
- set time of 5 minutes

Amazon - 3M Scotchcast Plus Cast Tape

- https://www.amazon.com/Scotchcast-Plus-Fiberglass-Black-82003A/dp/B07XYG1D8C/ref=sr_1_3?crid=3E0JA3JIX7RC7&dib=eyJ2IjoiMSJ9.1yME3nir3QmX_jrqBs-0D9p5-H_cy20-YieknR1KqgWBIkhSE2aj5dnxmbWrSf1p8s9yGiEHth7v-nPd7ww85XNfpu7JQ1jXh5qgzHONWO28UtMt0h-32-iSLZnr36F57Zrndpv2BW62EWuKfhJMRnDSlj3LycuxAtFUN8gXW9iIit9P1UXYkbwT7EEc-HvNx-vzaNuRa7sDP1_aJUqUNNJL3FozvyZJETy4AG61gmk.UwT_soI1BA8LEWsYEss0upZ1yGvRb41F0xCn_-fiXOk&dib_tag=se&keywords=fiberglass+casting+tape&qid=1739398686&sprefix=fiberglass+casting+tap%2Caps%2C167&sr=8-3
- $9.99 per roll
- 3in x 12ft
- Black
- Sold individually

Amazon - Scotchcast Cast Tape 2in x 12ft Fiberglass

- https://www.amazon.com/Scotchcast-Plus-Fiberglass-Bright-82002X/dp/B082VLH8YV/ref=sr_1_5?crid=3E0JA3JIX7RC7&dib=eyJ2IjoiMSJ9.1yME3nir3QmX_jrqBs-0D9p5-H_cy20-YieknR1KqgWBIkhSE2aj5dnxmbWrSf1p8s9yGiEHth7v-nPd7ww85XNfpu7JQ1jXh5qgzHONWO28UtMt0h-32-iSLZnr36F57Zrndpv2BW62EWuKfhJMRnDSlj3LycuxAtFUN8gXW9iIit9P1UXYkbwT7EEc-HvNx-vzaNuRa7sDP1_aJUqUNNJL3FozvyZJETy4AG61gmk.UwT_soI1BA8LEWsYEss0upZ1yGvRb41F0xCn_-fiXOk&dib_tag=se&keywords=fiberglass+casting+tape&qid=1739398686&sprefix=fiberglass+casting+tap%2Caps%2C167&sr=8-5
- Bright pink
- $7.99 per roll
- Sold individually

Amazon - TrelaCo 10 Pcs Cast Tape Fiberglass Casting Tape

- https://www.amazon.com/TrelaCo-Cast-Fiberglass-Casting-Black/dp/B0C7R1T5LN/ref=sr_1_6?crid=3E0JA3JIX7RC7&dib=eyJ2IjoiMSJ9.1yME3nir3QmX_jrqBs-0D9p5-H_cy20-YieknR1KqgWBIkhSE2aj5dnxmbWrSf1p8s9yGiEHth7v-nPd7ww85XNfpu7JQ1jXh5qgzHONWO28UtMt0h-32-iSLZnr36F57Zrndpv2BW62EWuKfhJMRnDSlj3LycuxAtFUN8gXW9iIit9P1UXYkbwT7EEc-HvNx-vzaNuRa7sDP1_aJUqUNNJL3FozvyZJETy4AG61gmk.UwT_soI1BA8LEWsYEss0upZ1yGvRb41F0xCn_-fiXOk&dib_tag=se&keywords=fiberglass+casting+tape&qid=1739398686&sprefix=fiberglass+casting+tap%2Caps%2C167&sr=8-6
- Pack of 10 for $33.99
- $0.28 per foot
- $3.40 per roll
- 2in x yds
- Does not use water
- Questionable??

Amazon - McKesson Cast Tape, Fiberglass, White

- https://www.amazon.com/McKesson-Fiberglass-White-Count-Packs/dp/B00ZJG23T6/ref=sr_1_16?crid=3E0JA3JIX7RC7&dib=eyJ2IjoiMSJ9.1yME3nir3QmX_jrqBs-0D9p5-H_cy20-YieknR1KqgWBIkhSE2aj5dnxmbWrSf1p8s9yGiEHth7v-nPd7ww85XNfpu7JQ1jXh5qgzHONWO28UtMt0h-32-iSLZnr36F57Zrndpv2BW62EWuKfhJMRnDSlj3LycuxAtFUN8gXW9iIit9P1UXYkbwT7EEc-HvNx-vzaNuRa7sDP1_aJUqUNNJL3FozvyZJETy4AG61gmk.UwT_soI1BA8LEWsYEss0upZ1yGvRb41F0xCn_-fiXOk&dib_tag=se&keywords=fiberglass+casting+tape&qid=1739398686&sprefix=fiberglass+casting+tap%2Caps%2C167&sr=8-16
- 2in x 4yds
- 10 per pack
- $34.07 per 10 rolls
- $3.41 per roll
- White

Conclusions/action items:

Overall, fiberglass casting tape is easily accesible in many places. It seems that the average price is about $9-$10 per roll whe purchased individually and $30-$40 when purchased in bulk. This would make the individual price per roll much lower, but we do not need 10 rolls. Additionally, finding a black roll would be ideal for our client. I plan to reach out to determine the bulk prices of the products on the UW site.

02/17/2025 - An Evaluation of Fiberglass Cast Application Techniques

Madison Michels - Feb 19, 2025, 8:46 AM CST

Title: An Evaluation of Fiberglass Cast Application Techniques

Date: 02/17/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this entry is to learnng. about application techniques for fiber glass casti

Content:

- Most application techniques involve spiraling the cast material up and down the limb with a 50% overlap.
- Most fail by bending on the compression side and by tearing on the tension side.
- Materials and Methods
    - Delta-Lie casting material was used for all trials
    - Water at room temperature
    - 5.5 cm outside diameter
    - Overlap by 50%
    - Eight thicknesses of the material
    - 2, 3, 4, 5 inch thicknesses tested 7 days after setting
    - Single longitudal splint and two longitudal splints used
- Results
    - All casts failed over the hinged section of the bending jig
    - Buckling on the compression side and tearing on the tension side
    - Five inch wide casting tape produced the stringest casts in bending

Table 1. Mean Load and Standard Deviation at Failure for Four Widths of Fiberglass Casting Material

Tape Width (inches)	Load at Failure (Newtons)	*SD* (Newtons)
2-inch	2303[b]	201
3-inch	2169[b,c]	398
4-inch	1805[c]	134
5-inch	3073[a]	495

** Not a linear, direct relationship

- Discussion
    - The ability of the cast to resist bending is related to the amount of material and the square of the distance of the material from the neutral axis
    - Splints applied to the dorsal and palmar surfaces provide the most support and resistance to bending
    - Plaster of Paris is stronger in compression, while fiberglass is stronger in tension
        - Add a splint to where compresion takes place to maximize cast strength
    - Should use the widest tape possible

Citation:

D. G. Wilson and R. V. Jr, “An Evaluation of Fiberglass Cast Application Techniques,” *Veterinary Surgery*, vol. 24, no. 2, pp. 118–121, 1995, doi: 10.1111/j.1532-950X.1995.tb01305.x.

Conclusions/action items:

In conclusion, fiberglass casting tape is strongest in tension. Therefore, to enhance the strength of fiberglass tape performance, splints should be added to the compression side of the cast. Additionally, the thickest material option should be selected to ensure the strongest support. Finally, the material should be layered 50% on top of the previous layer.

Madison Michels - Feb 17, 2025, 7:46 PM CST


ORIGINAL RESEARCH

An Evaluation of Fiberglass Cast Application Techniques

Download

Veterinary_Surgery_-_March_1995_-_WILSON_-_An_Evaluation_of_Fiberglass_Cast_Application_Techniques.pdf (442 kB)

02/17/2025 - Interface and performance of 3D printed continuous carbon fiber reinforced PLA composites

Madison Michels - Feb 17, 2025, 8:21 PM CST

Title: Interface and performance of 3D printed continuous carbon fiber reinforced PLA composites

Date: 02/17/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this reseaerch is to examine the fabrication and performance of carbon fiber reinforced PLA.

Content:

Introduction

- Continuous Fiber Reinforced Thermoplastic Composites (CFRTPCs) are replacing conventional thermosetting plastics and steel due to its mechanical performance, recycling, and light weight characteristics.
- Vacuum forming, filament winding, pultrusion, bladder-assisted molding, and compression are all faberication processes.
- Poly Lactic Acid is used for 3D printing (additive manufacturing techniques)
- For ABS (acrylonitrile-butadiene-styrene), the flexural strength was 127 MPa and 7.72 GPa when infused with carbon fiber.
    - 3 times higher than ABS' own flexural strength
- Goal: to determine the optimal temperature, layer thickness, feed rate of filament, hatch spacing, and transverse movement speed.

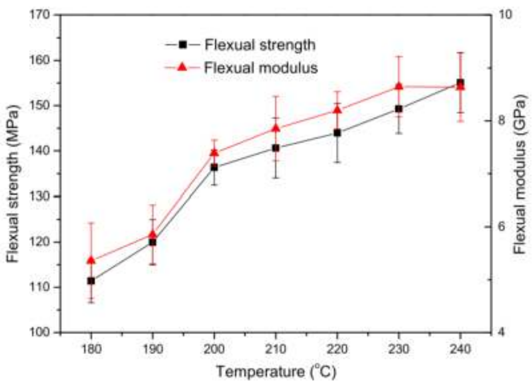
Experiment

- Polylactide (PLA)1.75mm from FLASHFORGE was used
- 2 mm diameter nozzle tip used
- Temperatures: 180-240 degrees Celsius used
- Layer thickmess: 0.3 to 0.8 mm
- Feed rate: 60 to 160 mm/min
- Hatch spacing: 0.4 to 1.8 mm
- Transverse movement speed: 100-600 mm/min
- Outcomes
    - Flexural strength in tensile machine
    - Density using Archimedes principle
    - Fracture surfaces observed using Hitachi S-3000N SEM
- 5 specimens of each experimental group

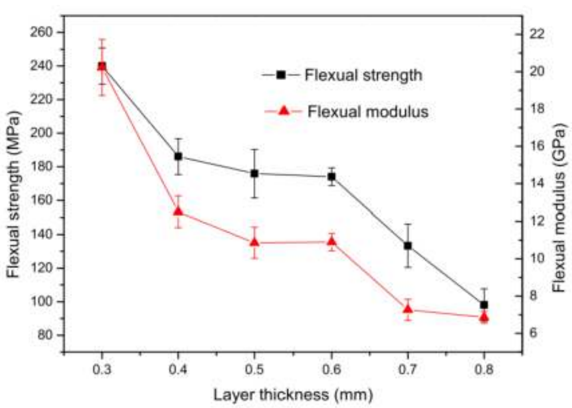
Results

- Temperature
    - Influences impregnation of matrix
    - Influences bonding strength
    - When the temp is lower than 180 degrees, it is difficult to extrude the melt plastic
    - When the temp is higher than 240 degrees, the PLA filament would melt into liquid and could flow naturally via gravity

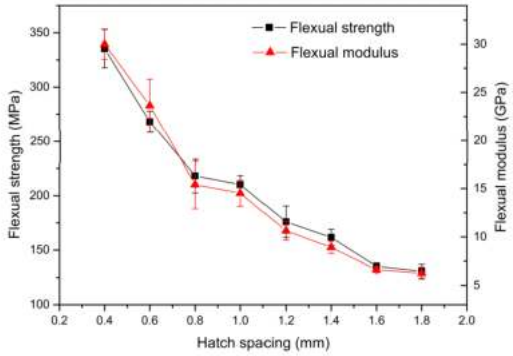
- Higher temperatures allow for more carbon fiber mixing and enhanced mechanical properties
- 200-230 degrees is suitable



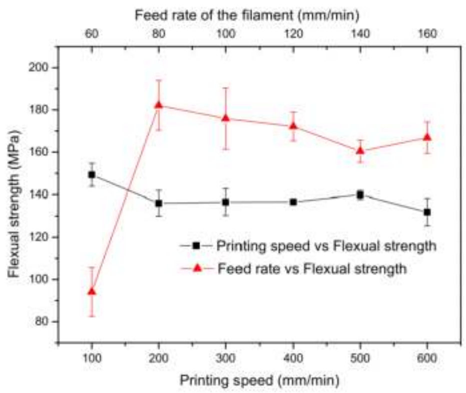
- Flexural strength
  - Positively related eto temperature until 240 degrees up to 8.6 GPa
  - At 240 degrees,the specimen lost surface integrity
  - Maximum printing temp is 230 degrees
    - At which the flexural strength is 145 MPa and 8.6 GPa
  - Table below shows flexural strength in terms of temperature change
- Layer thickness
  - Fabrication accuracy, efficiency, and mechanical properties
  - More layers integrates more carbon fiber into the printed specimen
  - Flexural strength is greatly decreased with too thick of material
  - 0.3mm thickness offered the greatest flexural strength of 240 MPa
  - Optimal manufacturing range: 0.4 - 0.6 mm to encorporate fabrication integrity and strength



- Hatch Spacing
  - The central distance betwwen 2 adjacent lines
  - Strength increased from 130 MPa to 335 MPa when decreasing the hatch space from 1.8 mm to 0.4 mm



- Feed Rate
  - 60 to 80 mm/min drastically increased strength
  - Inner pressure in liquefier and overlapping contact pressure between adjacent deposited lines due to large unit volume of extruded materials
  - Insignificant influence on flexural strength



- The average density of 3D printed CFR PLA composites was around 1.2 g/cm3
- Maximum strength of 335 MPa
- Maximum flexural modulus of 30 GPa
- CFR PLA fiber content of 27%

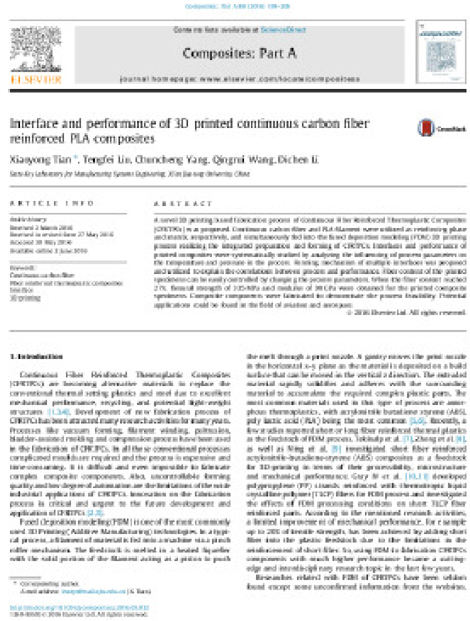
Citation:

X. Tian, T. Liu, C. Yang, Q. Wang, and D. Li, “Interface and performance of 3D printed continuous carbon fiber reinforced PLA composites,” *Composites Part A: Applied Science and Manufacturing*, vol. 88, pp. 198–205, Sep. 2016, doi: 10.1016/j.compositesa.2016.05.032.

Conclusions/action items:

In conclusion, with the optimal parameters of 200-230 degrees Celsius, layer thickness of 0.4mm to 0.6mm, and hatch spacing of 0.6mm, 27% fiber content will prodyce a flexural strength of 335 MPa. This is by far the strongest material we can apply to our rigid support while maintaning patient anatomy specifics.

Madison Michels - Feb 17, 2025, 7:50 PM CST



Download

1-s2.0-S1359835X16301695-main.pdf (2.64 MB)

02/23/2025 - Characterization of carbon fiber reinforced PLA composites manufactured by fused deposition modeling

Madison Michels - Feb 23, 2025, 1:42 PM CST

Title: Characterization of carbon fiber reinforced PLA composites manufactured by fused deposition modeling

Date: 02/23/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this reseaerch is to characterrize carbon fiber PLA composites in order to perform FEA testing in SolidWorks.

Content:

Purpose

- The main goal of the study is to investigate the mechanical properties of 3D printed thermoplastic parts reinforced with continuous carbon fibers (CCF) using Fused Deposition Modeling (FDM).
- It aims to enhance the mechanical performance (tensile and flexural properties) of FDM-generated thermoplastic parts, which are typically weak in terms of strength and stiffness, by incorporating continuous carbon fibers into the PLA (Poly-lactic acid) matrix.
- The study also aims to analyze the fracture behavior and the interfacial bond between carbon fibers and the thermoplastic matrix through optical microscopy.

Materials:

- PLA (Poly-Lactic Acid): Common thermoplastic used as the base matrix material.
- PLA-SCF (PLA with Short Carbon Fibers): PLA filament combined with short carbon fibers for enhanced properties.
- PLA-CCF (PLA with Continuous Carbon Fiber): PLA matrix reinforced with continuous carbon fibers.
- PLA-SCF-CCF: Combination of PLA with short carbon fibers and reinforced with continuous carbon fiber.
- Continuous Carbon Fiber Tow (T300B): Used as the reinforcement material, chosen for its high strength and stiffness.
- PLA 3D850**:** Used to impregnate the carbon fiber tow, providing necessary bonding between the fibers and PLA.

Fabrication and Processing:

1. Carbon Fiber Impregnation: PLA 3D850 was dissolved in dichloromethane, creating a solution for impregnating the carbon fiber tow. The impregnation process was carefully monitored to ensure proper bonding.
2. 3D Printing Process:Specimens were fabricated using two 3D printers:
   - MeCreator 2 Printer: Used for printing PLA-CCF and PLA-SCF-CCF samples.
   - Prusa i3 MK3S Printer: Used for printing pure PLA and PLA-SCF specimens.
   - Nozzle diameters and temperatures were adjusted for proper extrusion and impregnation of the continuous carbon fiber.
3. Printing Parameters: Various settings were optimized, such as nozzle diameters, extrusion multipliers, layer heights, and printing speed to ensure proper specimen formation.

Table 1. Parameters of 3D printing.

Parameters	3D Printers types			
	MeCreator 2		Prusa i3 MK3S	
	PLA-CCF	PLA-SCF-CCF	PLA	PLA-SCF
Nozzle Diameter	1.5 mm	1.5 mm	0.4 mm	0.4 mm
Extrusion Multiplier	0.5	0.5	1	1
Extrusion width	1.5 mm	1.5 mm	0.45 mm	0.45 mm
Layer height	0.5 mm	0.5 mm	0.2 mm	0.2 mm
Printing Speed	3.0 mm/s	3.0 mm/s	25 mm/s	25 mm/s
First layer speed	1.20 mm/s	1.20 mm/s	20 mm/s	20 mm/s
Extruder temperature	210 ^{O}C	250 ^{O}C	210 ^{O}C	250 ^{O}C
Bed temperature	90 ^{O}C	90 ^{O}C	60 ^{O}C	75 ^{O}C
Fan Speed	60%	60%	30%	30%
Internal/External fill pattern	Rectilinear	Rectilinear	Rectilinear	Rectilinear
Infill percentage	100%	100%	100%	100%

Specimen Dimensions and Testing:

- The specimens were designed for tensile and flexural testing, with exact dimensions provided.
- Tensile Testing: ASTM D3039 standards were followed for tensile testing using rectangular specimens.
- Flexural Testing: ASTM D790 standards were followed for three-point bending tests to assess flexural strength.
- Microscopic Analysis: After testing, specimens were analyzed under an optical microscope to observe fracture behavior, fiber-matrix bonding, and the failure modes of the printed parts.

Outcomes and Expected Results

Mechanical Properties:

- The study seeks to assess improvements in the tensile strength, flexural strength, and modulus of elasticity of PLA-based composites by reinforcing them with continuous carbon fibers.
- By comparing PLA, PLA-SCF, PLA-CCF, and PLA-SCF-CCF specimens, the study aims to quantify the improvements in mechanical performance provided by continuous carbon fibers.
- Results are expected to show that PLA-CCF and PLA-SCF-CCF have significantly higher strength and stiffness than pure PLA and PLA-SCF parts, especially in tensile and flexural tests.

Fracture and Interface Analysis:

- The fracture interface will be closely studied using optical microscopy to understand how the fibers interact with the matrix material.
- The goal is to observe the failure mechanisms, including fiber pull-out, matrix cracking, and fiber breakage, to evaluate the bonding strength between the carbon fibers and PLA matrix.
- The study will investigate how the continuous carbon fiber reinforcement affects the overall structural integrity and performance of the printed parts.

1. **Tensile Properties:**
   - **Tensile Strength**:
     - **PLA-CCF** exhibited the highest tensile strength (245.40 MPa), about 6 times higher than pure PLA (43.83 MPa).
     - **PLA-SCF-CCF** showed a tensile strength of 227.56 MPa, and **PLA-SCF** had the lowest (43.75 MPa).
   - **Young's Modulus**:
     - **PLA-SCF-CCF** showed the highest Young's modulus (27.93 GPa), followed by **PLA-CCF** (25.94 GPa).
     - Pure PLA had the lowest Young's modulus (3.09 GPa).
   - **Ductility**:
     - Pure PLA showed the highest ductility (7.87%).
     - **PLA-SCF** showed slightly lower ductility (7.39%).
     - **PLA-CCF** and **PLA-SCF-CCF** had lower ductility values (3.16% and 2.76%, respectively).
2. **Flexural Properties:**
   - **Flexural Stress**:
     - **PLA-CCF** exhibited the highest flexural stress (168.88 MPa), 121% higher than **PLA-SCF**, and 103% higher than pure PLA.
   - **Flexural Modulus**:
     - **PLA-SCF-CCF** had the highest flexural modulus (10.85 GPa), followed by **PLA-CCF** (10.63 GPa).
     - Pure PLA had the lowest flexural modulus (3.06 GPa).
3. **Fracture Interface Observations:**
   - **Tensile Test**:
     - Pure PLA and PLA-SCF showed poor interfacial bonding with separated layers and no adhesion at the interface.

- **PLA-CCF** demonstrated partial bonding between fibers and matrix, indicating load transfer during tension.
- **PLA-SCF-CCF** showed separation of fibers but still held together, suggesting poor adhesion.

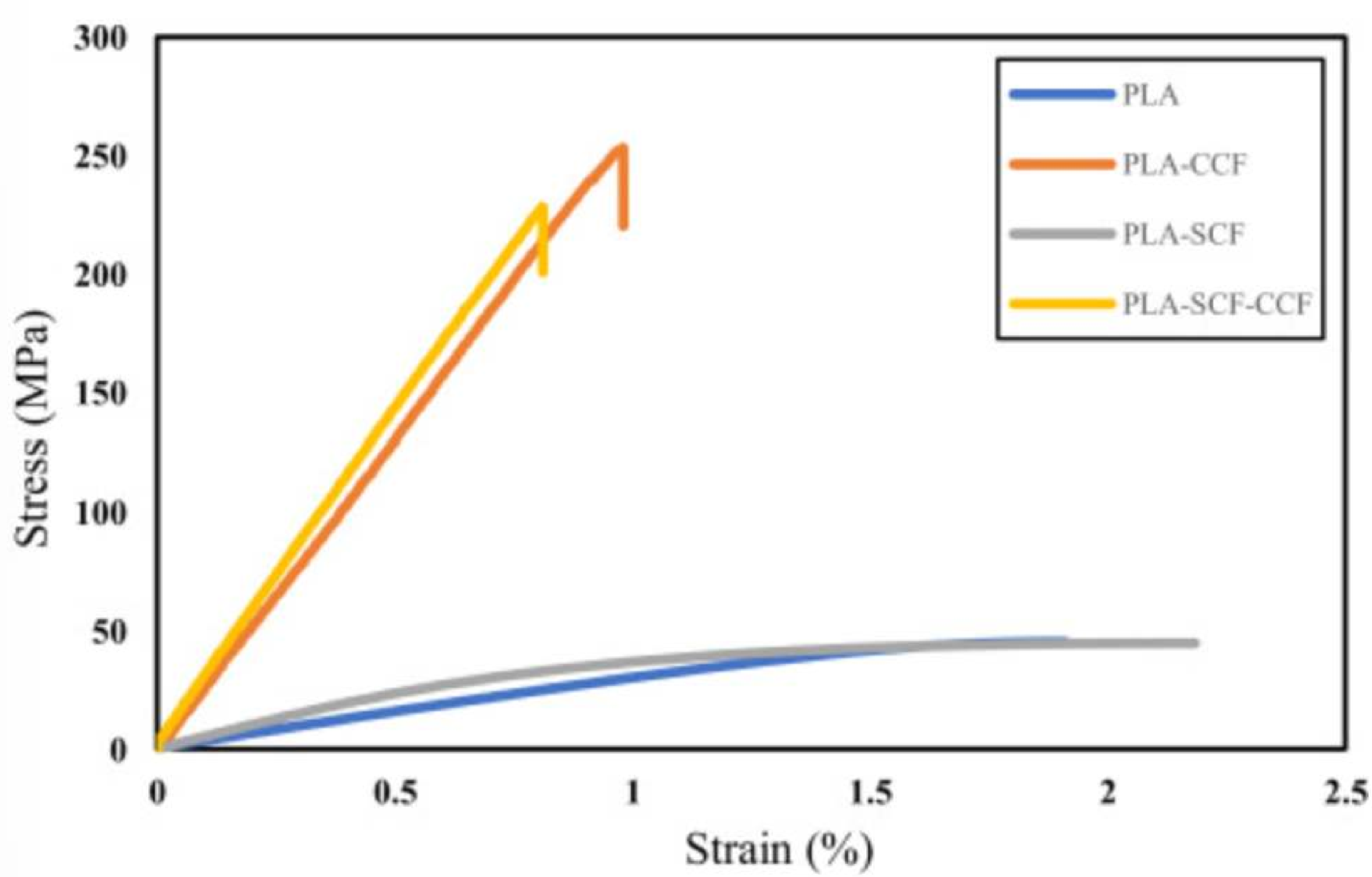


Table 3. Results of mechanical properties measured.

Specimens	Tensile Properties			Flexural Properties	
	Tensile strength (MPa)	Young's modulus (GPa)	Ductility (%)	Flexural stress (MPa)	Flexural modulus (GPa)
PLA	43.83±2.39	3.09±0.05	7.87±1.47	83.18±3.22	3.067±0.29
PLA-CCF	245.40±0.14	25.94±0.47	3.16±0.14	168.88±5.17	10.63±0.59
PLA-SCF	43.75±0.39	4.79±0.08	7.39±0.39	76.33±1.21	4.52±0.11
PLA-SCF-CCF	227.56±0.13	27.93±1.40	2.76±0.13	116.75±13.3	10.85±1.51

- **Flexural Test**:
  - **PLA-CCF** still held fibers together within the matrix, supporting load during bending.
  - **PLA-SCF-CCF** showed delamination during bending, indicating poor adhesion between the matrix and fiber.

Conclusion:

1. **PLA-CCF composite** demonstrated the highest tensile strength (245.40 MPa) and Young's modulus (27.93 GPa), with a significant increase in mechanical properties compared to pure PLA and PLA-SCF. This composite exhibited the best results for both strength and stiffness but lower ductility.

2. **Flexural stress** for **PLA-CCF** was 168.88 MPa, making it the strongest in bending, with a substantial increase in flexural properties compared to other groups. The **PLA-SCF-CCF** composite showed the highest flexural modulus (10.85 GPa), confirming that fiber reinforcement increases flexural stiffness.

3. **Fracture behavior** confirmed that PLA-CCF composites effectively transferred load during both tensile and flexural tests, showing better mechanical properties. The fracture interface showed improved fiber-matrix bonding in CCF-reinforced composites but delamination in the PLA-SCF-CCF samples during bending, indicating poor bonding between the fiber and matrix.

4. **Overall**, increasing fiber content (CCF) enhanced the mechanical properties of the composite, particularly in tensile and flexural tests, but reduced ductility. Poor interfacial bonding between fiber and matrix was a challenge, particularly with PLA-SCF-CCF.

Citation:

N. Maqsood and M. Rimašauskas, “Characterization of carbon fiber reinforced PLA composites manufactured by fused deposition modeling,” *Composites Part C: Open Access*, vol. 4, p. 100112, Mar. 2021, doi: 10.1016/j.jcomc.2021.100112.

Conclusions/action items:

In conclusion, I will compare this data to the Makerspace data to determine the the statistics of our carbon fiber PLA is in order to create my own material for CFR-PLA FEA testing.

Madison Michels - Feb 23, 2025, 1:41 PM CST


Composites Part C: Open Access

Characterization of carbon fiber reinforced PLA composites manufactured by fused deposition modeling

ARTICLE INFO

ABSTRACT

Download

1-s2.0-S2666682021000074-main.pdf (3.68 MB)

01/28/2025 - The socioeconomic burden of facioscapulohumeral muscular dystrophy

Madison Michels - Jan 28, 2025, 5:15 PM CST

Title: The socioeconomic burden of facioscapulohumeral muscular dystrophy

Date: January 28, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to determine what other, non health-related, issues arise from FSHD. This can help contextualize our project in the broader scheme of life.

Content:

- Those with FSHD have close to normal life expectancies.
- Current treatments include PT, pain reduction treatment, and monitoring of respiratory function.
- Cost implications of this condition include direct medical costs. These include hospital admissions, physician visits, visits to other healthcare professionals, medication, formal home care, and ventilation.
- For direct non-medical costs, house adaptation costs, aids and devices, informal care, and travel costs were considered.
- Indirect costs considered was loss of productivity in paid work.
- The table below exhibits the

Hospital clinical care	
Emergency ward admission(s)	7 (4)
Hospital admission(s)	5 (3)
Median duration hospital stay in days (IQR)	5 (2–7)
Hospital day admission(s)	9 (5)
Ambulance transport	2 (1)
Non-hospital institutional care (e.g. nursing home or rehabilitation center)	
Non-hospital clinical care	1 (1)
Non hospital day admissions	9 (5)
Visits to physicians	
General practitioner	81 (47)
Specialist physician	78 (45)
Rehabilitation doctor	45 (26)
Neurologist	33 (19)
Cardiologist	10 (6)
Internist	9 (5)
Company doctor	13 (8)
Visits to other health care professionals	
Physiotherapist	100 (58)
Occupational therapist	34 (20)
Speech-language therapist	9 (5)
Psychologist	17 (10)
Dietician	14 (8)
Social worker	8 (5)
Ventilatory support	
Non-invasive, < 24 h a day	6 (3)
Non-invasive, 24 h a day	0 (0)
Invasive, < 24 h a day	1 (1)
Invasive, 24 h a day	0 (0)
Home care	33 (19)
Informal care giving	72 (42)
Adaptations, aids and devices[3]	
Home adaptations	36 (21)
Aids and devices	62 (36)

Table 1: Utilization of medical resources by FSHD patients in the preceeding 3 months

- Of all patients considered, 42% had a paid job, 23% retired, and 24% was permanently disabled.
- 12% of paid workers reported abscences in the last 4 weeks due to FSHD.
- 67% had been absent for more than 4 weeks.
- 48% of paid workers said that their condition prevented them from being fully productive at work.

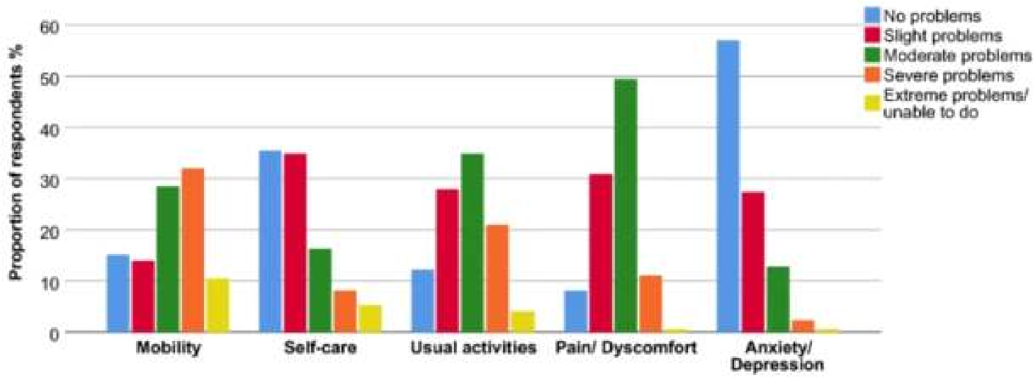


Figure 1: Quailty of life reporting by study participants

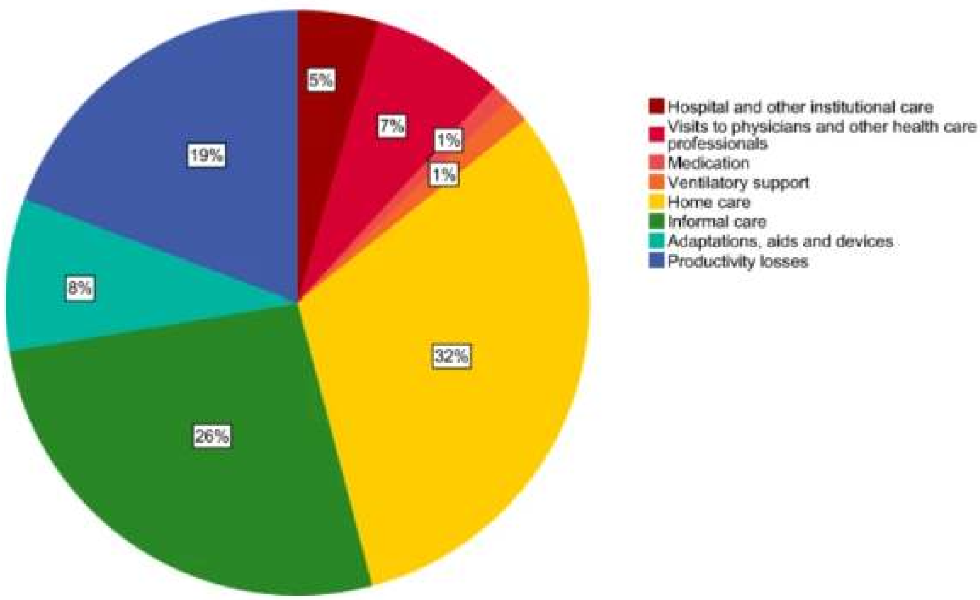


Figure 2: Per-Patient costs of FSHD in euros

- Total annual costs of illness added up to $27,452 per patient per year.
- When assigning monetary value to the loss in the patient's quality of life, the total cost would increase by $15,151.
- For patients with a walking mobility aid, their total costs would increase by $12,708.

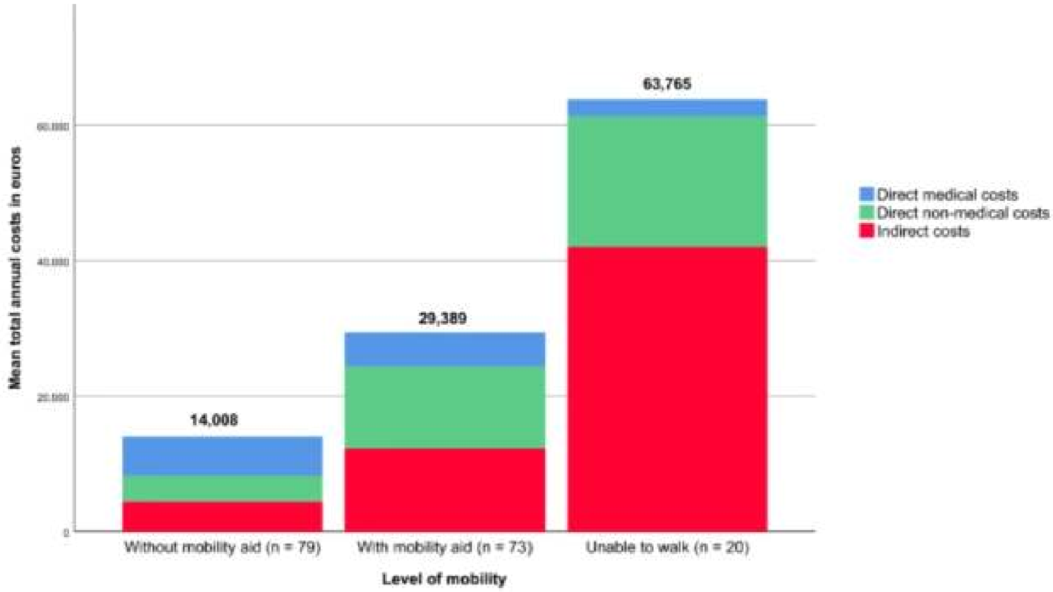


Figure 3: Mean per-patient annual costs of illness by level of mobility.

- The total socioeconmic burden of FSHD per patient per year is $42,604.

Citation:

A. M. Blokhuis, J. C. W. Deenen, N. C. Voermans, B. G. M. Van Engelen, W. Kievit, and J. T. Groothuis, “The socioeconomic burden of facioscapulohumeral muscular dystrophy,” *Journal of Neurology*, vol. 268, no. 12, pp. 4778–4788, May 2021, doi: 10.1007/s00415-021-10591-w.

Conclusions/action items:

In conclusion, FSHD results in significant economic expenses for society. Depending on the severity of the condition, costs of treatment and loss of productivity vary. This puts our project into perspective in terms of a greater contribution to society, not only healthcare.

02/05/2025 - The burden, epidemiology, costs and treatment for Duchenne muscular dystrophy: an evidence review

Madison Michels - Feb 05, 2025, 11:23 AM CST

Title: The burden, epidemiology, costs and treatment for Duchenne muscular dystrophy: an evidence review

Date: February 5, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to determine the economic implications for patients suffering from muscular dystrophy disorders, including treatment, direct healthcare costs, and indirect costs.

Content:

Outcomes of Literature Search:

- Point prevalence, birth prevalence, demographic characteristics, clinical characteristics of the disease, mortality, and progression of the disease.
- Impact of the disease on quality of life
- Cost of illness (patient and caregiver)
- Current treatment guidelines and treatment patterns

Economic Results:

- 110 titles were reviewed, written from 2005-2015
- Germany
  - Hospitalization: $2,080
  - Medication: $1,020
  - All medical: NR
  - All direct costs: $42,360
- Italy
  - Hospitalization: $1,420
  - Medication: $1,550
  - All medical: NR
  - All direct costs: $23,920
- UK
  - Hospitalization: $2,300
  - Medication: $930
  - All medical: NR
  - All direct costs: $54,160
- United States
  - Hospitalization: $10,012
  - Medication: $2,070
  - All medical: NR
  - All direct costs: $54,270
- Costs of home health aides were significantly higher in the UK.
- Out of Pocket Expenses per Year
  - Germany: $4,830
  - Italy: $4,250
  - UK: $3,180
  - US: $5,060
- Indirect costs (i.e. loss of productivity) are much higher than direct medical costs for early stage patients

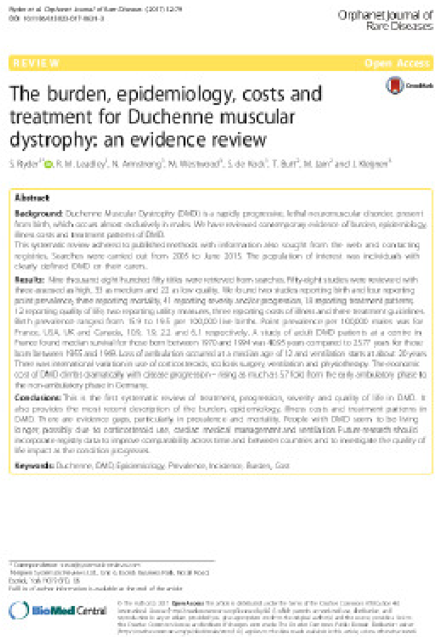
Citation:

Ryder, S., Leadley, R.M., Armstrong, N. *et al.* The burden, epidemiology, costs and treatment for Duchenne muscular dystrophy: an evidence review. *Orphanet J Rare Dis* 12, 79 (2017). https://doi.org/10.1186/s13023-017-0631-3

Conclusions/action items:

In conclusion, in the United States, patients pay about $5,060 out of their pockets. The total economic burden in the US for a muscular dystrophy disease is $54,060. With the use of AFOs with long durabilities, direct medical costs will greatly decrease.

Madison Michels - Feb 05, 2025, 11:05 AM CST


Orphanet Journal of Rare Diseases

REVIEW

Open Access

The burden, epidemiology, costs and treatment for Duchenne muscular dystrophy: an evidence review

Abstract

Keywords: Duchenne, DMD, Epidemiology, Prevalence, Incidence, Burden, Cost

Download

s13023-017-0631-3.pdf (1.28 MB)

02/05/2025 - Cost of illness for neuromuscular diseases in the United States

Madison Michels - Feb 05, 2025, 11:53 AM CST

Title: Cost of illness for neuromuscular diseases in the United States

Date: February 5, 2025

Content by: Maddie

Present: Maddie

Goals: The goal of this research is to determine the economic implications for patients suffering from muscular dystrophy disorders, including treatment, direct healthcare costs, and indirect costs.

Content:

- The annual per-patient costs in the United States for patients with muscular dystrophies is $50,952 with the total population cost being $787 million.
- Direct medical costs calculated using insurance plans and pharmacy claims
- <u>Subject Criteria:</u>
  - Diagnosed with a muscular dystrophy condition during the study year
  - Younger than 65 years old
  - Complete medical and pharmacy coverage
- <u>Cost of Illness Survey:</u>
  - Paper survey, mail-based
  - 55 questions
  - Survey was consent to enter the study
  - Household registered under the Muscular Dystrophy Association (MDA) received the survey
  - Response rate of 20% or above
- <u>Results:</u>
  - 83% of patients with ALS were covered by insurance
  - 51% of patients with DMD were covered by insurance
  - 70% of patients with DM were covered by insurance
  - Total per-patient medical costs (out-of-pocket and insurance covered)
    - ALS: $31,121
    - DMD: $22, 533
    - DM: $17,451

Table 1. Annual medical costs for neuromuscular disease patients.[a]

		Commercial plan			Medicare		
		ALS	DMD [e]	DM	ALS	DMD [e]	DM
N		945	1,966	378	583	199	137
Inpatient (acute)	Mean	$10,290	$9,393	$6,870	$9,411	$7,095	$4,939
	SE [d]	$1,374	$1,179	$1,885	$1,041	$1,582	$1,013
Inpatient (non-acute or long-term)	Mean	$617	$615	$328	$3,913	$1,445	$1,685
	SE	$132	$247	$167	$460	$476	$606
Outpatient	Mean	$17,555	$11,960	$9,450	$10,745	$6,362	$9,512
	SE	$1,710	$881	$759	$527	$866	$1,801
Durable medical equipment	Mean	$1,810	$1,108	$588	$5,158	$4,034	$1,079
	SE	$217	$91	$162	$413	$634	$177
Prescription medication [b]	Mean	$2,473	$2,154	$1,589	$2,539	$2,041	$1,643
	SE	$176	$158	$324	NA	NA	NA
Total annual cost [c]	Mean	$30,934	$24,122	$18,236	$31,766	$22,852	$18,858
	SE	$2,336	$1,667	$2,224	NA	NA	NA

- Calculation of Non-Medical Cost
    - Home costs, vehicle costs, paid professional daily care, food supplements, travel costs, training costs, etc.
    - Yearly
    - Highest for ALS - moving homes or modifying the existing home

Table 2. Annual nonmedical costs (self and other paid) by disease and type of expenses.*

Disease	Type of expenses	N	Mean	Standard error	95% CL for mean	
ALS	Moving or modifying home	109	$7,106	$2,096	$2,950	$11,261
	Purchase or modifying motor vehicle	107	$2,064	$385	$1,300	$2,827
	Professional caregiving	111	$4,570	$1,446	$1,704	$7,435
	Other nonmedical cost (e.g. food, travel, dietary supplements)	118	$5,908	$975	$3,977	$7,840
	Total nonmedical cost	**124**	**$17,889**	**$3,265**	**$11,426**	**$24,351**
DMD	Moving or modifying home	113	$3,050	$615	$1,832	$4,268
	Purchase or modifying motor vehicle	119	$1,680	$216	$1,252	$2,107
	Professional caregiving	113	$3,189	$1,315	$583	$5,794
	Other nonmedical cost (e.g. food, travel, dietary supplements)	123	$6,605	$1,837	$2,969	$10,240
	Total nonmedical cost	**131**	**$12,939**	**$2,465**	**$8,063**	**$17,816**
DM	Moving or modifying home	113	$990	$687	−$371	$2,350
	Purchase or modifying motor vehicle	116	$435	$356	−$269	$1,139
	Professional caregiving	109	$925	$712	−$487	$2,338
	Other nonmedical cost (e.g. food, travel, dietary supplements)	121	$3,067	$900	$1,285	$4,850
	Total nonmedical cost	**123**	**$5,157**	**$1,820**	**$1,554**	**$8,761**

- Calculation of Loss to Family Income
    - OLS Regression analysis
    - Age, race, gender, ethnicity, level of education of the primary caretaker, number of adults, disease duration, and Social Security income were considered.
    - Patients who required 16-24 hours of daily care earned $21,600 less than the care not needed group.
    - Patients who required 8-15 hours of daily care and 1-7 hours of daily care earned $7,325 and $4,172 less than the care not needed group per year.
    - Annual Loss of Income
        - DMD: $15,481
        - ALS: $14.682
        - DM: $9,628
- Total National Costs
    - Multiplied the total per-patient cost by the prevalence of each disease
    - 5.2/100,000 for ALS
    - 5.0/100,000 for DMD

  - 4.5/100,000 for DM
  - ALS national cost: $1,023 million
  - DMD national cost: $787 million
  - DM national cost: $448 million
- Significant Drivers of Cost
  - Ventilators and wheelchairs (ALS)
  - Cognitive impairment (DM)

Table 5. Aspects of disease progression that affect the cost of illness.

			Total family cost			
			N	Mean	Standard deviation	P-value †
ALS	Disease duration	Less than 10 years	65	$44,101	$61,747	
						0.174
		More than 10 years *	21	$23,753	$49,857	
	Ventilator use	On invasive ventilator/respirator	10	$84,789	$66,564	
						0.008
		On non-invasive ventilator	26	$50,478	$31,986	
						0.019
		Not on ventilator/respirator *	50	$24,102	$63,784	
	Cognitive Impairment	No	70	$34,842	$58,922	
						0.163
		Yes *	16	$57,903	$59,898	
	Wheelchair use	No	29	$9,932	$59,425	
						0.001
		Yes *	57	$53,989	$54,134	
DMD	Disease duration	Less than 10 years	46	$29,530	$46,750	
						0.522
		More than 10 years *	49	$36,282	$54,941	
	Ventilator use	On invasive ventilator/respirator	12	$51,733	$64,044	
						0.123
		On non-invasive ventilator	19	$37,624	$61,021	
						0.459
		Not on ventilator/respirator *	64	$28,133	$44,729	
	Cognitive Impairment	No	67	$30,975	$55,376	
						0.492
		Yes *	26	$37,887	$38,963	
	Wheelchair use	No	36	$26,439	$47,340	
						0.329
		Yes *	59	$37,023	$53,074	
					Total family cost	
			N	Mean	Standard deviation	P-value †
DM	Disease duration	Less than 10 years	11	$21,474	$30,330	
						0.623
		More than 10 years *	57	$15,659	$54,750	
	Ventilator use	On invasive ventilator/respirator	0	.	.	N/A
		On non-invasive ventilator	10	$24,823	$56,883	
						0.588
		Not on ventilator/respirator *	58	$15,182	$50,863	
	Cognitive Impairment	No	38	$2,307	$46,956	
						0.009
		Yes *	30	$34,704	$51,929	
	Wheelchair use	No	47	$9,056	$44,432	
						0.070
		Yes *	21	$33,484	$62,411	

Table 4. Overall annual cost of illness.*

	Direct Cost							
Disease	Medical Cost†	Nonmedical Cost‡	Indirect Cost ¶	Total Per-capita Cost	Prevalence Estimates (Orphanet)	Prevalence Estimates (Best U.S. Estimate)	Total National Cost (in millions) (Orphanet)	Total National Cost (in millions) (best U.S.)
ALS	$31,121	$17,889	$14,682	$63,693	16,055	4014–6792	$ 1,023	$256–$433
DMD	$22,533	$12,939	$15,481	$50,952	15,437	7101–9571	$ 787	$362-$488
DM	$17,451	$5,157	$9,628	$32,236	13,894		$ 448	$448
Total							$ 2,257	$1065-$1368

Combined Total Cost: $1.07 - $1.4 billion per year

Citation:

J. Larkindale *et al.*, “Cost of illness for neuromuscular diseases in the United States,” *Muscle & Nerve*, vol. 49, no. 3, pp. 431–438, 2014, doi: 10.1002/mus.23942.

Conclusions/action items:

In conclusion, in the United States, all patients with muscular dystrophies incur about $1.4 billion total every year. With the use of AFOs, hopefully the cost of the disease over time will result in less productivity loss.


COST OF ILLNESS FOR NEUROMUSCULAR DISEASES IN THE UNITED STATES

Download

Muscle_and_Nerve_-_2013_-_Larkindale_-_Cost_of_illness_for_neuromuscular_diseases_in_the_United_States.pdf (87.1 kB)

03/14/2025 - Motion Analysis

Madison Michels - Mar 14, 2025, 7:15 PM CDT

Title: Motion Analysis and Cortex

Date: 03/14/2025

Content by: Maddie

Present: N/A

Goals: The goal of this research is to explore the Badger Athletic Program's motion capture system and explore its use in out testing plan.

Content:

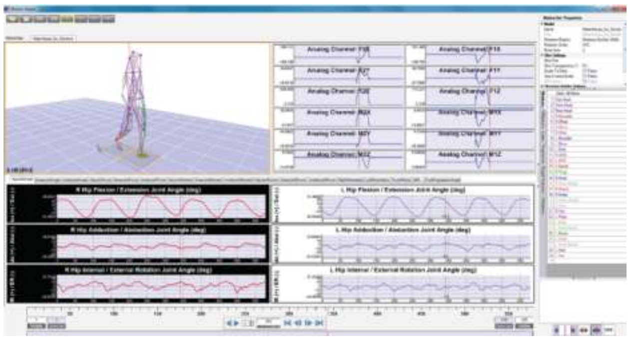
- Thunderbird
    - 5 cameras
    - Active and passive markers
    - 12 MP resolution
    - Output synchronization
- Kestrel Plus
    - Active and passive marker recognition
    - Available in 300, 1300, 2200, and 4200
        - Smaller the value, the smaller the space works best
- Active marker cameras
    - Compact
    - BaseCam is the entry-level model as a set of 12 cameras
    - Works with the MoCap software BaSix Go
    - Icefall (4.0 mpxl)
    - Lahtose (1.6 mpxl)
    - Can upgrade to Thunderbird 400 and 1600
    - Ideal for tracking rigid objects, like drones and robots

Camera		Active-only or hybrid	Pixels Mpxl	FPS full res	Upgradable?	Compatible with*
	Icefall	Active only	0.4	400	Yes, to Thunderbird 400	Icefall, Lhotse, Thunderbird
	Lhotse	Active only	1.6	160	Yes, to Thunderbird 1300	Icefall, Lhotse, Thunderbird
	Kestrel 300 Plus	Hybrid	0.3	810		Kestrel and Raptor
	Kestrel 1300 Plus	Hybrid	1.3	204		Kestrel and Raptor
	Kestrel 2200 Plus	Hybrid	2.2	332		Kestrel and Raptor
	Kestrel 4200 Plus	Hybrid	4.2	200		Kestrel and Raptor
	Thunderbird 400	Hybrid	0.4	400		Icefall, Lhotse, Thunderbird
	Thunderbird 1600	Hybrid	1.6	160		Icefall, Lhotse, Thunderbird
	Thunderbird 3200	Hybrid	3.2	190		Icefall, Lhotse, Thunderbird
	Thunderbird 5100	Hybrid	5.1	141		Icefall, Lhotse, Thunderbird
	Thunderbird 12M	Hybrid	12	63		Icefall, Lhotse, Thunderbird
						*and most legacy cameras

Cortex Programming:

- Cortex 10
- Integrated glove tracking - detailed finger tracking with Manus Meta gloves
- Marker templates
- Batch processing tools
- Editable system objects - enables easy cross-collaboration
- Trimming byb markerset
- Rainbow camera support - Rainbow HD video for high frame rate and color reference videos
- Biomechanics Features:
  - Calcium Solver - transferes captured marker data to a skeleton
  - SONIC Viewer - spread Calcium computations for a number of skeletons across different computers
  - KinTool RT - self-contained full-body kinetics and kinematics measurement package and custom model creation tool
    - Mass model editor
    - Output to ASCII file
    - Linear and rotational velocities
    - COM computations for segments and body
    - Overall force
    - Moment of intertia
    - https://motionanalysis.com/wp-content/uploads/2022/10/MAC_Kintools-RT-Rebranded.pdf
  - DV Reference - Simultaneous capture and playback of reference video data from stationary or moving camera

    - Skeleton Builder - Direct, simple, and fast calculations of bones that are defined and calculated from one joint center to another
        - Cortex 3D workspace allows for editing of skeletons
        - Calculations done in real-time with immediate feedback
        - DOF specifiable
        - https://motionanalysis.com/wp-content/uploads/2022/10/MAC_Skeleton-Builder-Rebranded.pdf
    - CamTrak - system that can track people and objects in a studio
    - Motion Composer - Gathering and integration of interactive motion captured data
        - Presentable data analysis and associated features
        - https://motionanalysis.com/wp-content/uploads/2022/10/MAC_Motion-Composer-Rebranded.pdf



- Continuous Calibration - self-diagnosing, self-correcting calibration tool. Eliminates wand calibration.

Papers that used this system:

- https://journals.lww.com/acsm-msse/fulltext/2021/05000/lower_extremity_kinematic_and_kinetic_asymmetries.8.aspx

- https://journals.lww.com/acsm-msse/fulltext/2019/10000/foot_angle_and_loading_rate_during_running.11.aspx

Citation:

“Cortex - Our Most Powerful Motion Capture Software Yet,” Motion Analysis. Accessed: Mar. 14, 2025. [Online]. Available: https://www.motionanalysis.com/software/cortex-software/

Conclusions/action items:

In conclusion, we plan to use this system to conduct IMU gait analysis on our client. We will conduct practice testing runs an create testing protocols to match this system.

3/18/2025 - Assessment of Scientific Tools for Kinematic Analysis in Sports Performance

Madison Michels - Mar 18, 2025, 12:36 PM CDT

Title: Assessment of Scientific Tools for Kinematic Analysis in Sports Performance

Date: 03/18/2025

Content by: Maddie

Present: N/A

Goals: The goal of this research is to explore the differences and similarities among 15 different motion capture systems, including Motion Analysis and Kinovea.

Content:

- Methods and Softwares
  - Data collected from onoline database (scientific)
  - Siliconcoach: video capture, slow-motion playback, angle measurement, and comparison of multiple video clips
  - **Kinovea**: Open source, user-friendly, frame-by-frame video analysis, angle measurement, distance and speed tracking, and overlays.
  - Templo: multi-camera support, real-time feedback, comprehensive reporting, integration with other measurement devices
  - **Gaiton**: specialized for gait analysis, gait cycle analysis, spatiotemporal parameters, customizable reports.
  - Helix 3D: running mechanics, 3D visualization, real-time feedback, data analytics
  - Dartfish: tagging and annotation, slow-motion analysis, cloud-based sharing
  - Coach's Eye (Mobile): mobile app, video capture, slow-motion playback, annotation tools
  - Vicon: high precision, real-time data capture, extensive integration options
  - **Motion Analysis Corporation**: High accuracy, multi-camera setups, real-time analysis, customizable software packages
  - Noraxon: integrates EMG and kinematic data
  - Qualisys: 3D motion capture, real-time feedback, and robust software support
  - Pro-trainer: Detailed kinematic and kinetic analysis, customizable workflows, and comprehensive reporting
  - Xsens: wearable motion capture systems, Inertial sensor technology, real-time response, and compatibility with other systems
  - SIMI Motion: Multi-camera support, real-time processing, and detailed reporting
  - Shutter precision: High frame rate capture, precise measurement tools, and customizable analysis options

Table 2. Comparison between software feature.

Software	Video Capture	3D Analysis	Real-time Feedback	Integration	Customizable Reports
SiliconCoach	Yes	No	No	Yes	Yes
Kinovea	Yes	No	No	No	Yes
Templo by Contemplas	Yes	Yes	Yes	Yes	Yes
GaitON	Yes	No	No	Yes	Yes
Helix 3D by RunDNA	Yes	Yes	Yes	No	Yes
Dartfish	Yes	No	Yes	Yes	Yes
Coach's Eye	Yes	No	No	No	Yes
Vicon	Yes	Yes	Yes	Yes	Yes
Motion Analysis Corporation	Yes	Yes	Yes	Yes	Yes
Noraxon myoResearch	Yes	No	Yes	Yes	Yes
Qualisys	Yes	Yes	Yes	Yes	Yes
Pro-Trainer	Yes	Yes	Yes	Yes	Yes
Xsens	Yes	Yes	Yes	Yes	Yes
SIMI Motion	Yes	Yes	Yes	Yes	Yes
Shutter Precision	Yes	No	No	No	Yes

- Accessibility
  - Gaiton: 30 day free trial, or $20 per month
  - Kinovea: Free and open source
  - Motion Analysis Corp.: N/A - must contact
  - Coach's eye: free, mobile
- Kinovea and SiliconCoach are ideal for educational purposes and small-scale studies due to their simplicity and accessibility
- Motion Analysis Corporation and Vicon are best for high-stakes, large-scale research and professional applications
- Performance Analysis:
  - SiliconCoach: Known for its moderate processing speed, it is suitable for real-time analysis but is not as fast as high-end systems. It provides good data accuracy for general sports applications and has moderate hardware requirements, making it accessible to a wider range of users
  - **Kinovea**: This open-source software offers efficient video analysis with good accuracy for basic kinematic analysis. It requires low to moderate hardware resources, making it a highly accessible tool for both amateur and professional use
  - Templo by Contemplas: Templo offers high processing speed suitable for complex analyses, with very high data accuracy that meets professional standards. It requires high-end hardware, which can be a limitation for some users but is justified by its advanced capabilities
  - **GaitON:** It is designed for real-time gait analysis, providing high processing speed and accuracy. It has moderate hardware requirements and is user-friendly, making it suitable for both clinical and sports settings
  - Helix 3D by RunDNA: This software excels in real-time running analysis, offering high processing speed and precision. It requires moderate to high hardware resources and is designed for ease of use with detailed tutorials
  - Dartfish: Known for its efficient video analysis, Dartfish provides good accuracy for general sports analysis with low to moderate hardware requirements. Its customizable interface enhances usability for both novice and advanced users.
  - Coach's Eye (Mobile): This mobile-based tool offers fast processing for video analysis, suitable for general coaching purposes. It requires only a smartphone or tablet, making it highly accessible but less precise for detailed research.
  - Vicon: Renowned for very high processing speed and exceptional sub-millimetre accuracy, Vicon systems are ideal for detailed biomechanical studies. They require high-end hardware and extensive training, which can be a barrier for smaller organizations
  - **Motion Analysis Corporation:** This advanced tool offers high processing speed and precision, suitable for complex motion analysis. It requires high-end hardware and professional training, making it best suited for highend research and professional use
  - Noraxon myoResearch: Providing high processing speed and precision with advanced sensors, Noraxon myoResearch is reliable for both clinical and research applications. It requires specialized hardware and training, positioning it as a premium option

- Qualisys: Offering real-time motion capture with exceptional accuracy, Qualisys systems demand highperformance hardware and professional training. They are highly reliable and suitable for professional and research settings
- ProTrainer: With moderate processing speed and good accuracy for general training analysis, Pro-Trainer has moderate hardware requirements and is designed for easy use by coaches and trainers

Citation:

“(PDF) Assessment of Scientific Tools for Kinematic Analysis in Sports Performance,” *ResearchGate*, Feb. 2025, doi: 10.58723/inasport.v3i1.266.

Conclusions/action items:

In conclusion, the most accessible applications for us to use would be Kinovea and Coach'sEye mobile. We may, however, have access to Motion Analysis Corp. through the Badger Athletic Performance Lab (BAP). I also plan to look more into the GaitON software and attempt to use Coach'sEye mobile.

Madison Michels - Mar 18, 2025, 12:36 PM CDT


ResearchGate

Assessment of Scientific Tools for Kinematic Analysis in Sports Performance

Download

Inasport266Publish.pdf (579 kB)

02/05/2025 - Team AFO Final Report Briefing

Madison Michels - Feb 05, 2025, 3:40 PM CST

Title: Team AFO Final Report Briefing

Date: 02/05/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this entry is to update myself on last semester's work and their future directions for this semester.

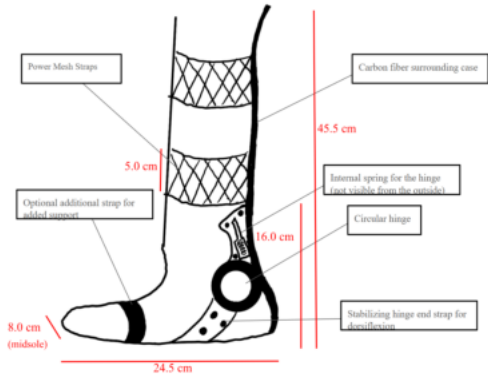
Content:

Background and Client Requirements:

- FSHD leads to progressive muscle weakness
- AFOs prevent the drop-foot symptom of the disease (difficulty with dorsiflexion)
- A rigid piece along the ankle is needed to prevent ankle inversion
- Discrete, lightweight
- Bungee cord used to create tension that helps raise the foot
- Styled to look like an athletic brace
- Flexible AFOs
  - Good mediolateral stability
  - Flexible
  - Patient struggles with medial instability
- Jointed AFO
  - Chunky
  - Great support of ankle
  - Allows for dorsiflexion
  - Only works for individuals with elementary foot drop
- Support dorsiflexion, avoid ankle inversion, thickness of 3.175 mm, follows the dimensions and anatomy of the patient

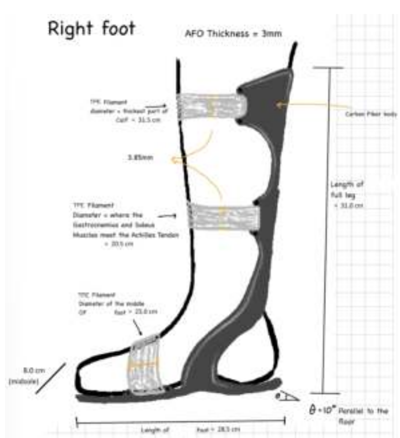
Designs

- Hinge Design
  - Strap around the foot
  - Looks large and hard to fit into a shoe
  - Not a lot of medial support
  - Hinge allows for a full range of motion
  - Circular hinge is compact
  - Carbon fiber piece runs up the back of the leg



- Bungee Brace
  - Rotating dial to increase and decrease tension in the foot
  - Adjustable velcro straps
  - Needs a better rigid support method to prevent inversion
  - Can use fiber casting material
  - Can 3D print a scan of the patient's provided foot model
  - Appears like an athletic brace

- Strap Brace Design
  - Straps made from thermoplastic elastomer filament
  - Carbon fiber backing
  - Not a lot of medial support
  - Extremely tall



<u>Materials and Fabrication:</u>

- Absorptive materials: Nylon, polyester, and latex for the sleeve
    - Nylon has low elongation, strength, high-temperature resistance, and is lightweight.
    - Polyester is strong and durable, retains its strength and resists wrinkles, shrinking, environmental elements, and outdoor conditions.
    - Latex is flexible, durable, and liquid-resistant.
- Carbon fiber for the rigid support
    - lightweight
    - 3D printed PLA for the prototype
        - Difficulty modeling patient anatomy in SolidWorks
    - Extremely expensive
- Bungee cord for tension
    - less bulky, 100 lb. tensile strength, recoil
- 3D printed the rigid PLA piece and printed on Bambu printer
- Bungee cord cut and modified for application to the brace
- Locklace was 3D printed on the Ultimaker printer and designed in SolidWorks
    - Easy to adjust
- Gel-padded compression sock sewn into the brace
    - Behind calf
    - Around the ankle bone
    - Around the ball of the foot
    - Along strap supports
- Carbon fiber component sewn into the side of the brace underneath the straps

<u>Testing</u>

- Two types of bungee cords tested: thick (176 lbs.) and thin (100 lbs.)
    - Cord displacement measured to achieve a tension angle of 10 degrees
    - Repeated four times
    - Thicker bungee cord required a greater displacement to achieve the 10 degree angle
    - Cord placement should be adjusted based on individual patient needs
    - Thinner bungee cord was chosen
- SimulationXPress Analysis Wizard
    - PLA carbon fiber piece testing
    - Identify potential failure points
    - 200N load applied from the ankle inversion direction
    - Showed little likelihood of failure under this load
- Runeasi
    - Brace effects on a healthy individual
    - Dynamic Instability
    - Ground time contact (ms)
    - Impact magnitude
    - Cadence
    - 3 minute intervals for each condition
    - Little variation in gait patterns
- The cord slipped 8 degrees during testing

<u>Future Work</u>

- Runeasi testing will be conducted in Madison with the patient
- Order a new ankle brace to replace the straps and compression sleeve
- Material testing on the carbon fiber backbone

Conclusions/action items:

In conclusion, last semester's prototype worked very well. The testing done with the brace was significant and thorough. It seems that the initial step for this semester is to add a rigid support piece that matches the anatomy of the patient.

02/12/2025 - Design Ideas

Madison Michels - Feb 12, 2025, 9:38 AM CST

Title: Preliminary Design Ideas

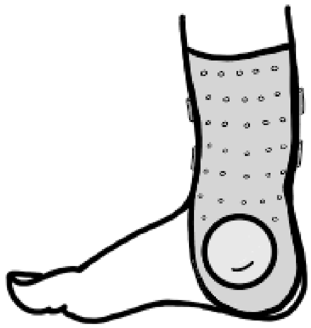
Date: 02/12/2025

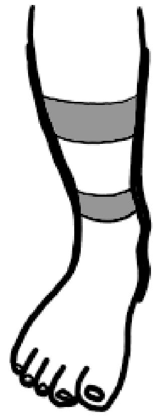
Content by: Maddie

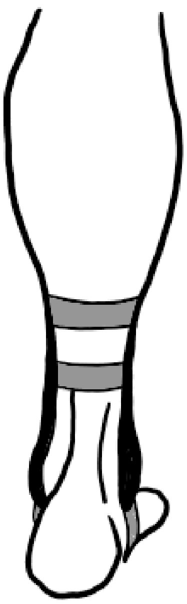
Present: Maddie

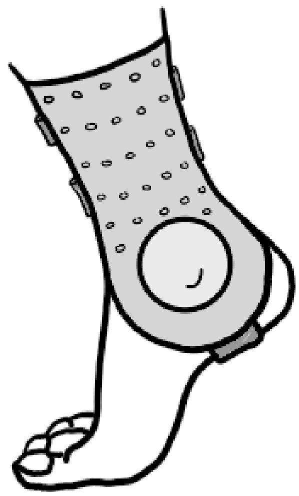
Goals: The goal of these designs are to outline the current design initiative and create a display of what we intend to fabricate.

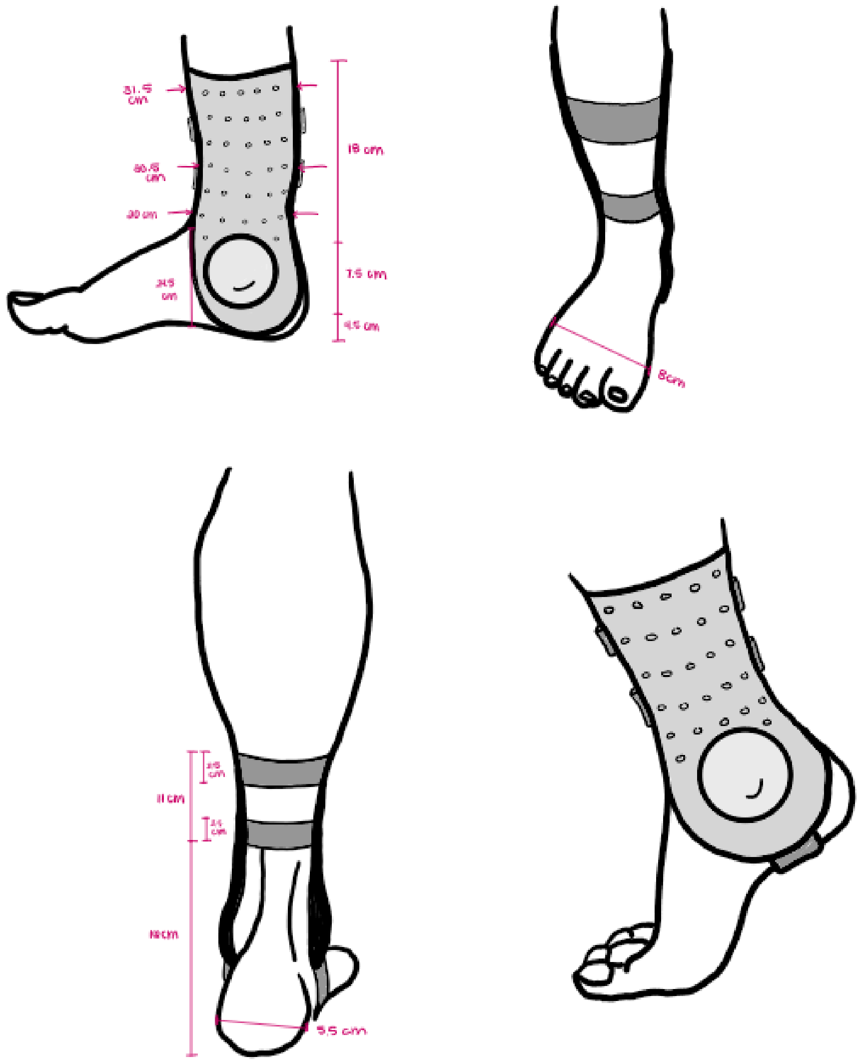
Content:











This concept outlines the rigid support aspect of our brace. In consists of two rigid porous plates that are modeled/AutoCADed to the patients foot and ankle anatomy. We will combine these aspects using elastic bands or a BOA system. Each plate has a gel pad over the ankle to avoid rubbing on the ankle joint. A bottom strap will be attached that wraps underneath the heel of the foot to join the two pieces together.

Conclusions/action items:

In conclusion, we can use these drawings in the design matrix and attempt to fabricate this design in conjuntion with the bunjee design.

02/17/2025 - OpenSim AFO Simulation

Madison Michels - Feb 17, 2025, 9:23 AM CST

Title: OpenSim AFO SImulation

Date: 02/17/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this simulation is to replicate the conditions of ankle inversion while wearing an AFO with varying stiffnesses.

Content:

Procedure:

No AFO

1. Download ToyDropLanding
2. In OpenSim, click on Open File and select ToyDropLanding
3. Select the coordinates panel and ensure
    1. platform_rx = 20 degrees
    2. platform_ry = 0 degrees
    3. platform_rz = 0 degrees
4. Lock these settings if they alreayd are not
5. Press the green arrow next to the simulate button and select End Time..
6. Change the end time to 0.4 seconds
7. Click the Simulate button and allow the simulation to run
8. Click on the navigator panel and find the motions list
9. Right click on Results and Rename it to the desired file name ("Unassisted Results")
10. To save the results, right click the name and select Save as..
11. Open a new plot by selecting Tools --> Plot
12. Click on Y Quantity button and Load file
13. Select your "Unassisted" file
14. Use the filter by pattern option to find and click on subtalar_angle_r/subtalar_angle_r/value and click OK.
15. Select X-Quantity and choose time as the independent variable
16. Click Add to display the curve on the graph
17. Rename the curve and the title of the graph by right clicking on their labels.

Soft AFO

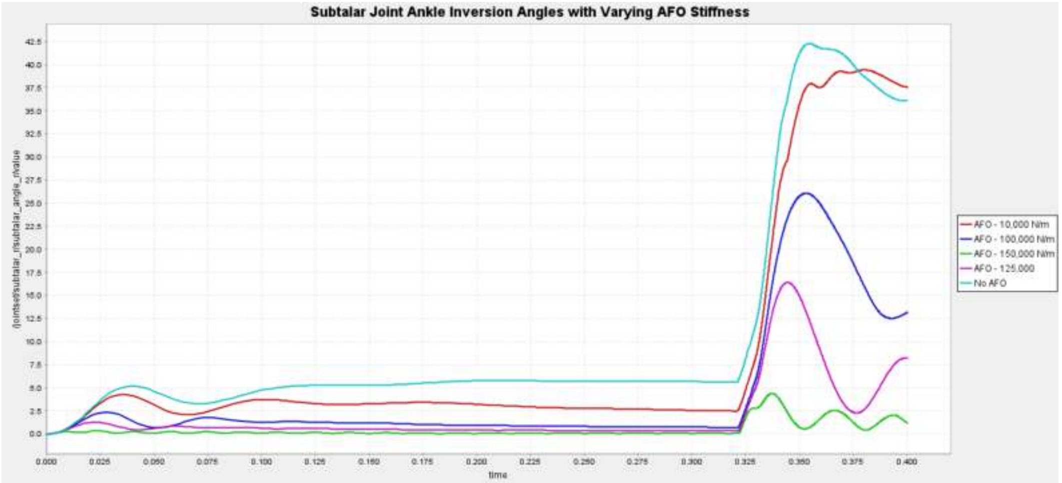
1. Download and open the ToyLandingModel_AFO.osim
2. Repeat the same steps from no AFO to analyze the soft AFO.

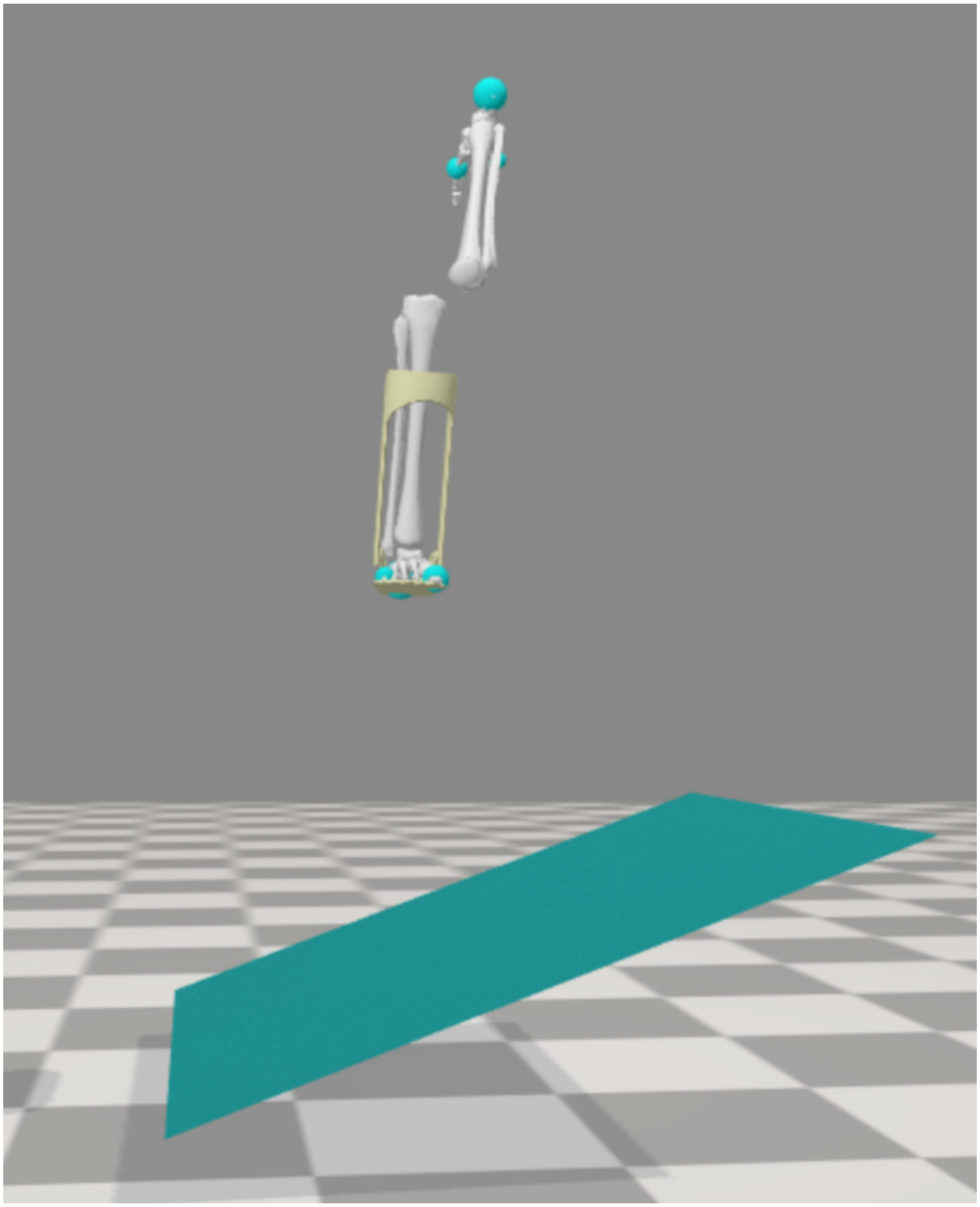
Varying AFO Stiffness

1. In the navigator panel, go to Forces --> Other Forces to locate AFO_med_bushing
2. Highlight the AFO_med_bushing by clicking on it.
3. Find the translational stiffness property and change it to your desired value
4. Repeat steps 1-3 for AFO_lat_bushing.

5. Finally, repeat the steps from no AFO to analyze the brace under simulation.
6. Change the brace stiffness to examine more stiffnesses.

Results





The video attached shows the simulation undergoing the applied load of the platform.

Source:

https://opensimconfluence.atlassian.net/wiki/spaces/OpenSim/pages/53088618/Simulation-Based+Design+to+Prevent+Ankle+Injuries#Simulation-BasedDesigntoPreventAnkleInjuries-V.Analyzetheeffectsofmuscleco-activation

Conclusions/action items:

In conclusion, to avoid ankle inversion of over 25 degrees and a slope of 20 degrees, our AFO should have a tranverse stiffness of atleast 100,000 Nm. We can use literature to determine what materials would provide us with this stiffness.

Madison Michels - Feb 17, 2025, 9:21 AM CST

Download

Ankle_Inversion_Simulation.mp4 (149 kB)

02/23/2025 - SolidWorks Preliminary Design Model

Madison Michels - Feb 23, 2025, 1:27 PM CST

Title: SolidWorks Preliminary Design Model

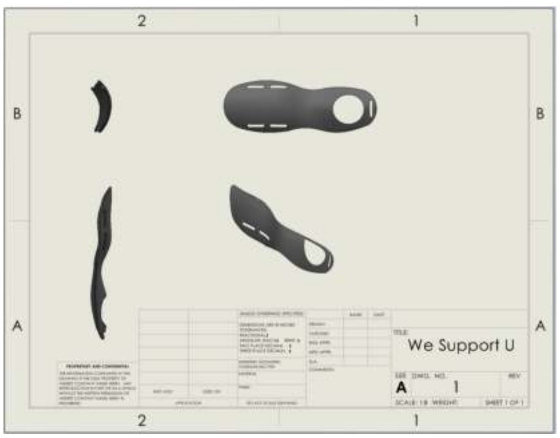
Date: 02/23/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this design is to learn how to loft in SolidWorks and to depict our rigid support design.

Content:



We Support U is the final design, as it resembles a "U" shape along the ankle and offers support while walking. The design consists of two rigid plates placed medially and laterally along the side of the shin to the subtalar joint. The plates may incorporate perforations to allow for breathability and airflow. There are two adjustable elastic straps along the front and back of the calf to allow for customizability and adjustability for the patient.These straps will travel through slots along the side of the brace and wrap back onto themselves. A gel pad is inserted into a cavity on the lateral sides of the brace to ensure the ankle does not rub on the rigid support. Lastly, another elastic band dives under the posterior arch of the foot to fasten the bottoms of the slabs together.

This design balances appearance with functionality, as the client will likely grow in her condition, needing more support over time than the other two braces can offer. The carbon fiber reinforced PLA supports will prevent ankle inversion and eversion at the subtalar joint. The gel pad will reduce discomfort and rubbing on the ankle joint, and the elastic straps will allow for adjustability and customizability for the patient. Strap attachment methods are being considered, but will likely be composed of slots travelling along the exterior edge of the brace and one under the gel pad for the underfoot strap.

Conclusions/action items:

In conclusion, this is our preliminary final design model. It is subject to change upon testing and new measurements.

03/18/2025 - Fabric/Foam Attachment Ideas

Madison Michels - Mar 09, 2025, 1:58 PM CDT

Title: Fabric/Foam Attachment Ideas

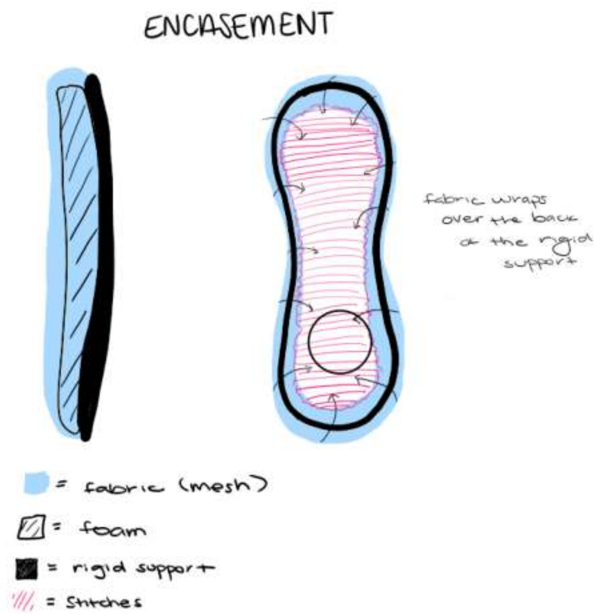
Date: 03/09/2025

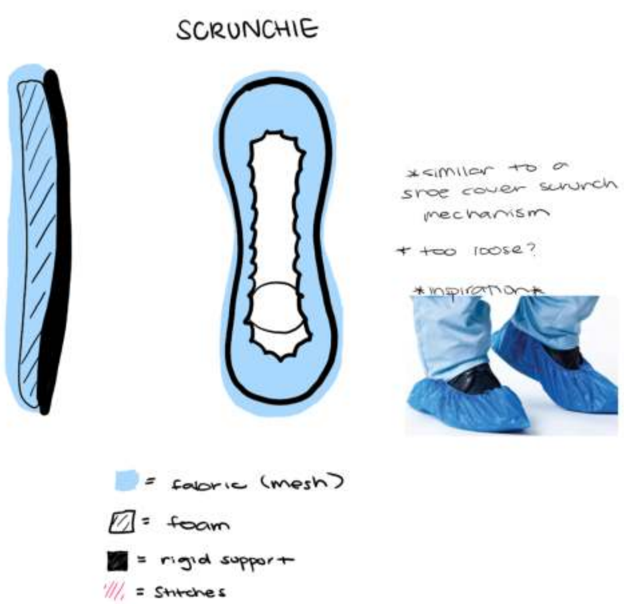
Content by: Maddie

Present: Maddie

Goals: The goal of this design is to determine

Content:





Conclusions/action items:

The attachment of the foam to the brace is a challenging task because the foam will not adhere to fabric adhesives and will rip. Additionally, plastic inhihbits the ability to sew the foam and fabric on. We want a fabric casing to reduce the ripping of the foam and it will behave as a pillowcase.

01/29/2025 - Library Session 1

Madison Michels - Jan 29, 2025, 2:04 PM CST

Title: Library Session 1: Article searching, source evaluation and citation management

Date: 01/29/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this lecture today is to learn about proper searching techniques and citation format in literature.

Content:

- The following sources are ones I found using Google Scholar. I used the keywords "FSHD", "AFO", "Muscular Dystrophy", "Gait", and "dorsiflexion".
    - L. H. Wang and R. Tawil, “Current therapeutic approaches in FSHD,” *Journal of Neuromuscular Diseases*, vol. 8, no. 3, pp. 441–451, Nov. 2020, doi: 10.3233/jnd-200554.
    - N. H. M. Rijken, B. G. M. Van Engelen, J. W. J. De Rooy, V. Weerdesteyn, and A. C. H. Geurts, “Gait propulsion in patients with facioscapulohumeral muscular dystrophy and ankle plantarflexor weakness,” *Gait & Posture*, vol. 41, no. 2, pp. 476–481, Dec. 2014, doi: 10.1016/j.gaitpost.2014.11.013.
    - A. M. Blokhuis, J. C. W. Deenen, N. C. Voermans, B. G. M. Van Engelen, W. Kievit, and J. T. Groothuis, “The socioeconomic burden of facioscapulohumeral muscular dystrophy,” *Journal of Neurology*, vol. 268, no. 12, pp. 4778–4788, May 2021, doi: 10.1007/s00415-021-10591-w.
- My group used mostly search engines and the PubMed database. This allowed us to customize the date range we wanted and control the key words we used to find articles. One thing we disliked was the generality and number of sites that come from one search. Additionally, almost all of the articles go extremely in depth on their subjects instead of providing a surface level introduction. This may be beneficial in a very specific search, but not when initially diving into the topic.
- Online search engines - bring stuff in based on their algorithms (crawlers)
    - Google, Bing
- Databases - Directly include index or information sources, all of the stuff is bedded
    - Scopus, PubMed, IEEE Explore
- LLM Chatbots - Produce text based on your imput,
    - ChatGPT, CoPilot
- To search, go to library.wisc.edu -- click on databases, sort by topic and click on a topic (most likely engineering)
- Do not get primary and review articles confused
- You can get the full text by clicking "full text options", use FindIt.UW to determine which databases we have that provide the article.
- PubMed includes the pdf.
- Evaluating you sources
    - Relevance
    - Authority
    - Quality
    - Currency
    - Read laterally!! - make sure to open things up about the source, find out about the company
- Technical Reports
    - publish the results of scientific or technical research

    - Using federal funds
    - DTIC, NTRL, OSTI databases
    - Not as ideal as commercial databases and search engines, but have wonderful papers
    - Go into a lot of detail
- Presenter: Dave Bloom
- AskSEL@library.wisc.edu

Conclusions/action items:

In conclusion, I plan to apply these concepts to my project research and technical writing this semester. I plan to implement Zotero as I continue to research my project and its impacts on society and the environment.

0//26/2025 - Diversity Design Considerations

Madison Michels - Feb 26, 2025, 2:12 PM CST

Title: Designing for Diversity

Date: 02/26/2025

Content by: Maddie

Present: N/A

Goals: The define diverse and universal designs for engineering initiatives.

Content:

Diversity in Engineering

- Ethnicity
- Socioeconomic status
- Culture
- Experiences
- Skill sets

Universal Design

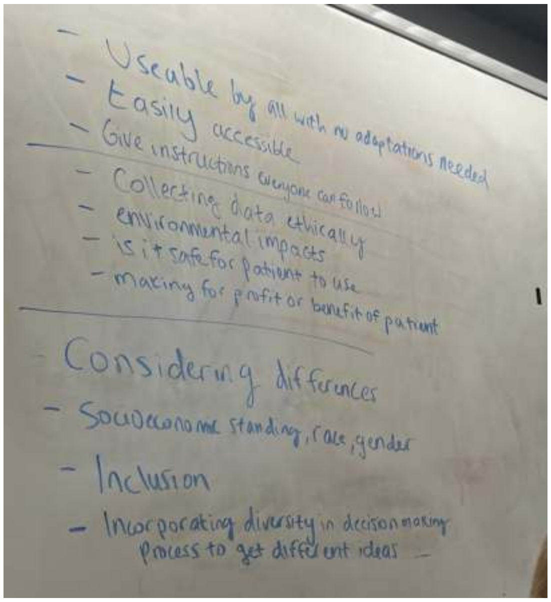
- Useable by all people without the need ofr adaptiations
- Not designed for the average user, but the greatest portion of users

7 Principles of Universal Design:

1. Equitable use
2. Flexibility in use
3. Simple an intuitive use
4. Perceptable information
5. Tolerance for error
6. Low physical effort
7. Size and space for approach and use

Relation to Ethics:

- Data collection - ethical collection?
- Environmental impacts
- Safe for the patient to use
    - Injury risk
- Creating it for a profit?



Our design:

What components of the design could be improved:

- Flexibility of Use: straps allow for the patient to customize effectiveness and comfort of the design
- Provide the patient with an assembly guide
- Patient-specific modeling
- Improve the ease of application. The current compression sleeves require significant strength to place over the ankle

Which of the 7 principles are you addressing:

- Flexibility of Use
- Low physical effort
- Tolerance for errors: address velcro wearing down

How can we make these improvements:

- Quick release straps
- Magnetic closures for the strapping mechanism
- Instruction videos
- Choose a elastic material for the straps
- Create a fixture to help assemble the brace and apply the compression sock
- Make the rigid support adaptable to any foot scan

Conclusions/action items:

In conclusion, we can implement these ideas into our designa, especially as we enter the fabrication phase. Ethics are critical to consider to protect patient health and integrity.

03/12/2025 - Library Session 2

Madison Michels - Mar 12, 2025, 2:09 PM CDT

Title: Library Session 2

Date: 03/12/2025

Content by: Maddie

Present: N/A

Goals: Learn about patent seaerching and applications.

Content:

- ASTM Standards
- ASABE standards
- IEEE
- Historical print collection
- Check TechStreet Enterprise for titles
- Business Databases:
  - Data Axle Reference Solutions
  - IBISWorld Industry Reports
  - ProQuest One Business
- US and foreign patents and patent applications
- Use classifications for patent searching
- Dependent claims
  - Must refer to a previus claim
  - Must further limit the claim
  - Includes all limitations it refers to
- Independent claims
  - contain al limitations
  - standalone
- Squirrel patent observations:
  - Second patent (10010051) is more specific
  - US 6474260 is much more detailed in its appearance
  - You could still market your device using different appearances or verbiage describing your device's functionality.
  - Similar language, change in depth of description
  - Aesthetic difference ina design patent
  - Second patent specifically mentions squirrels as the type of wildlife it is aimed towards
  - Verbage is how they worked around
  - The first patent is expired and the second one is inactive, so you would be able to market your own device

Conclusions/action items:

In conclusion, we can utilize these searching mechanisms to ensure that our design does not violate any patents that currently exist.

03/19/2025 - Elevator Pitches, Executive Summaries, and Abstracts

Madison Michels - Mar 19, 2025, 1:39 PM CDT

Title: Elevator Pitch & Executive Summaries & Abstracts

Date: 03/19/2025

Content by: Maddie

Present: N/A

Goals: To write and outline an effective elevator speech.

Content:

Elevator Pitch:

1. Attention grabber: start with a hook to gather attention
2. Introduction: project title and members
3. Value proposition: why does your project matter, target customer, don't waste time on unecesary background
4. Benefits: advantages of your design idea
5. Call to action: ask for their help

- Opportunity to apply for Tong Award and BME Design Excellence Award
    - Patent files, monetary value
- Dos
    - Concise
    - Tailor it to different audiences
    - Exude confidence
- Donts
    - Don't sound rehearsed
    - overwhelm with details

Executive Summaries:

- one-page document
- Design report in a concise way
- Brevity: about saying more with less
- Introduction
- Problem statement
- Solution
- Benefits
- Future work
- Executive summary draft due 4/4
- NO CITATIONS

- Tong judges: industry prfoessionals
- Design excellence: UW professionals, TAs, etc.

Abstracts:

- 150-300 words
- clear, conscise, specfici summary of report
- helps reader decide if they want to read the report
- background
- objectives
- methods
- results and analysis
- discussion/conclusion
- NO CITATIONS

Conclusions/action items:

In conclusion, we will use these outlines to summarize our project and compete for design awards in the future.

4/02/2025 - Ethics Lecture

Madison Michels - Apr 02, 2025, 1:56 PM CDT

Title: Ethics

Date: 4/02/2025

Content by: Maddie

Present: N/A

Goals: To learn about personal and professional ethics.

Content:

How do we define ethics?

- Moral principles that guide decision making and outline what is "right" and "wrong" based on honesty, respect, fairness, and integrity

Personal: morals, family values, social aspects

Professional: professionally integrated ethics codes, how your personal beliefs play a role in work environments

Where do ethics come from?

- Upbringing
- Culture
- Personal past experiences
- FDA
- Family, friends, professors

Ethical problem solving is similar to the design process

- Establish a need: questioning if it is an ethical action
- Understand the problem

Ethical Decision-Making Process:

- Awareness
- Stakeholders
- Options
- Analysis of options

Ethical tests

- Harm test: fewest negative consequences (both short and long term)
- Publicity test: Would you want your decision published online, or in the news?
- Reversibility test: how would you feel if someone you loved were affected adversely?
- Universality Test: if everyone were to use this solution, would that produce a just society?
- Respect for persons test: best response to the rights and dignity of others?
- Utilitarian tests
- Social justice test: does this option impact one population negatively

Ethics Case Study:

Consider the different perspectives on this case listed below, and discuss these questions in detail. Type your responses as a team.

1. **The Guidant VPs**: Most of the VP's at Guidant are very much against reporting the data to the FDA. (a) How might they continue to justify their case? (b) What would be the moral foundations of their perspective?
    a. The FDA's policies are "updated" to include less detailed disclosure of complications. It's better for the company to make money.
    b. If it helps some, it is worth leaving on the market
    c. Saves more lives than it takes (⅔)

    d. Don't want to destroy company reputation

2. **Patients and doctors**: Think about the position of those directly impacted: primarily patients who might be candidates for this surgery, and the doctors who use the device: (a) what arguments would those people want to ensure are considered by both the VPs and the design engineers about whether to report or not report the complications data? (b) What might be the ethical foundations of their perspective?
    a. Informed consent: the patient's life is at risk, and they are not willing to risk it if there is such a significant rate of complications and death. The doctors recommending the device to patients do not want to inflict harm on their patients. Also, unsuccessful surgeries and death would taint their image and prestige, and patients would stop coming to their practice.
    b. The doctors' personal morals of not wanting to put patients at risk and the fact they want to be successful doctors. The patients don't want to take risks with their health if they have family at home to take care of.

3. **The design engineers**: (a) What else can they say or do? (b) What arguments can they try to make, and to whom?
    a. The design engineers can contact the FDA directly or send an anonymous tip.
    b. They can argue that if one device is mistrusted on the market, any new devices they invent will have a negative reputation with the medical device industry and practitioners.
4. **The design engineers**: What options do they have? Generate a list of possible options (a minimum of 3 from the perspective of the design engineers), describe how each stakeholder is affected, then analyze them using the BME Code of Ethics (https://www.bmes.org/bmes2023-policies) and a couple of tests from the ethical decision-making system. Explain in detail the best option you would consider trying to act on.
    a. Write a protocol on what type of patients they can prescribe this treatment to and make the patients aware of the risk. They can outline a smaller subset of patients that are viable for the device.
    b. Quit - no more engineers = no more products
    c. Contact the FDA
    d. Start a new company with the "good" VP and use their new and current ideas in new products that are appropriately approved by the FDA.

Design project assignment

- In your design teams, identify components (at least 2) of your design that could face ethical dilemmas or have an ethical dimension (for example, safety is often a trade-off).
    1. Testing ethically - cannot induce ankle inversion pain upon testing
    2. Reduced quality of life due to over dependence on brace?

Conclusions/action items:

In conclusion, we can draw a line between personal and prfoessional ethics. Codes of ethics guide the healthcare system and, therefore, BME design as a whole.

02/23/2025 - SolidWorks FEA Testing

Madison Michels - Mar 14, 2025, 7:36 PM CDT

Title: SolidWorks FEA Testing

Date: 02/23/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this testing is to determine the displacement and stress that our rigid support will undergo under a maximum load of 266 Newtons.

Protocol:

Materials:

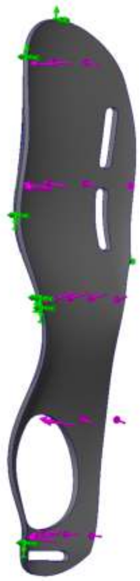
- SolidWorks on computer

Protocol:

1. Open SolidWorks
2. Under “Open File”, choose to open your rigid support part
3. If not done already, enable the FEA add-in
    a. Click Tools → Add-Ins
    b. In the add-ins window, enable the SOLIDWORKS Simulation by clicking on the left checkbox
4. Select the Simulation Xpress
5. Set the default units to meters and specify the folder you’d like to save the results to
6. Click the “Next” button
7. Select “Add/Edit Fixture” on the right tab
8. Select the surface (s) of your part you would like to fix
    a. To represent ankle inversion, fix the top and bottom of the rigid support
9. Select “Next”
10. Select “Add/Edit Forces”
11. Add a force of 266 N pointing towards the concave side of the brace:

Using the data sheet on CF-PLA from the Makerspace and external research, the settings to create a CF-PLA composite in SolidWorks are shown above.

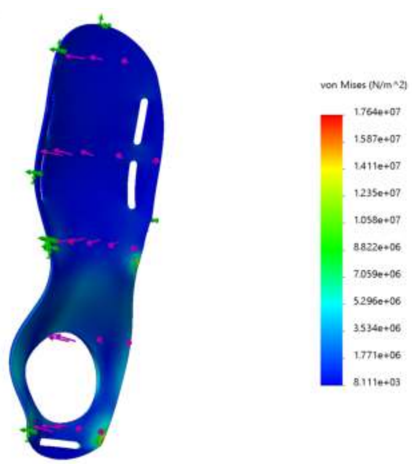
Force and Fixtures:



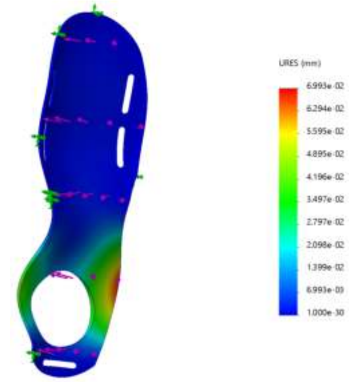
- Force of 266 N applied along the inside of the rigid support
- Brace fixed around the edges apart from near the ankle
- Allows movement near the circle gel pad (subtalar joint)

Inside:

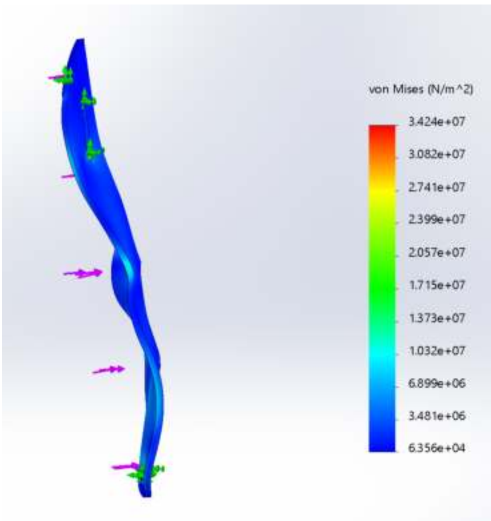
Von Mises Stress:

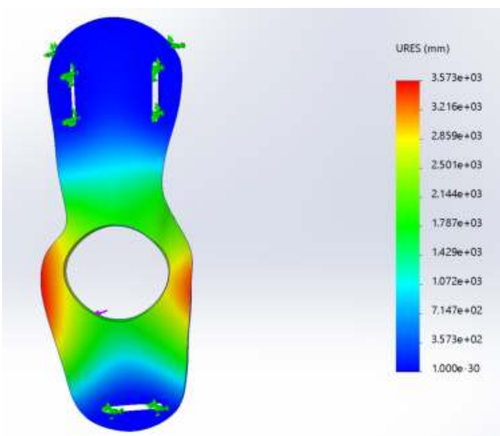


Displacement:



Outside:





Conclusions/action items:

In conclusion, the maximum stress experienced by the rigid support was about 1.587e07 N/m^2. The maximum displacement was 6.993e-02 mm on the outside of the gel pad edge. Both of these occured under a maximum transverse load of 266 N.

03/09/2025 - Informal Inversion/Eversion Testing

Madison Michels - Mar 09, 2025, 1:05 PM CDT

Title: Informal Inversion/Eversion Testing

Date: 03/09/2025

Content by: Maddie

Present: N/A

Goals: The goal of this testing to to determine the rigid support's efficacy in preventing ankle inversion/eversion. We also wanted to determine the comfort of the padding in a shoe.

Content:

My ankle was greatly inhibited from rolling when the brace was placed in a shoe. Outside of a shoe, however, the rigid supports did not help as much. I placed equal amounts of force on both of my ankles to invert and evert them. With shoes on, I was not able to roll my ankle in either direction.

Eversion:

Inversion:

Conclusions/action items:

In conclusion, the fluffier white foam was much more comfortable than the cheap, purple, sticky foam. We decided to order a mesh foam to attach the comfort to the brace and plan to assemble that upson its arrival. We also need to brainstorm ways to attach the foam.

03/19/2025 - MTS Testing Protocol and Results

Madison Michels - Mar 19, 2025, 9:28 AM CDT

Title: MTS Testing Protocol and Results

Date: 03/19/2025

Content by: Maddie

Present: Sadie, Presley, Kate, Maddie

Goals: The goal of thihs entry is to outline our 3 point bending test for three different CF-PLA printing infills.

Content:

Protocol:

1. Obtain three 3D printed rigid supports with infills of 15%, 35%, and 50%
2. Record the mass of the sample with scale and dimensions of the samples. Examine the sample for defects that could potentially lead to failure or errors.
3. Know the maximum possible load for the sample. Choose a proper load cell and fixture that are correct for the sample.
4. Insert the three point bending attachment pieces on to the MTS Criterion Model 43 Machine
5. Attached steel bars via rubber bands to the two end pieces
6. Open Test suite on the adjacent computer
7. Set values for testing rate 0.05 mm/mm, 10 hz, and 191 mm gauge length
8. Set the Safety Stops.
9. Lock the machine.
10. Place the sample into the fixture.
11. Rotate the emergency switch to the right, and it should pop outwards.
12. Double click the lock button, and the light should turn green.
13. Zero the load by right-clicking on the load cell on the software and hitting “zero signal”.
14. Use the wheel to scroll down until the top clamp is barely touching the sample. Carefully watch the load values and wait for a small spike in load as the fixture makes contact with the sample.
15. Record the test rate.
16. Lock the MTS machine by pressing the lock button on the hand controls.
17. Zero the crosshead and the load using the same process as before (Step 13).
18. Press the play button on the computer screen to start the test trial.
19. Enter the sample’s measured diameter.
20. Allow the MTS machine to run until sample failure, the curve on the graph flattens, or until the load almost (but does not) reach load cell capacity or fixture capacity.
21. Press Stop. Kill the switch or press the stop button if something goes wrong.
22. Repeat testing trails using the same steps above for each rigid support with a different infill.
23. Export the data by right-clicking on the trial and selecting the proper file location.
24. Power off the machine, return components, and clean up the sample and surrounding area.

Code:

```
%% RS Dimensions

L = 191; % mm

length = 12.557; % mm

width = 2.7; % mm

surface_A = 9200.346; % mm

x_sectional_A = 33.38; % mm


%% Data Imports

[if_50, if_50_path] = uigetfile('*','TestRun3_50infill');

if_50 = importdata([if_50_path,filesep,if_50]);

[if_35, if_35_path] = uigetfile('*','TestRun2_35infill');

if_35 = importdata([if_35_path,filesep,if_35]);

[if_15, if_15_path] = uigetfile('*','TestRun4_15infill');

if_15 = importdata([if_15_path,filesep,if_15]);


%% Variable Assignment
```

```
disp_if_50=if_50.data(:,1); % mm

force_if_50=if_50.data(:,2); % N

time_if_50=if_50.data(:,3); % sec


disp_if_35=if_35.data(:,1); % mm

force_if_35=if_35.data(:,2); % N

time_if_35=if_35.data(:,3); % sec


disp_if_15=if_15.data(:,1); % mm

force_if_15=if_15.data(:,2); % N

time_if_15=if_15.data(:,3); % sec


%% Force Plot

figure(1);

hold on;

title("15%, 35%, 50% Infill Rigid Support Forces");

plot(force_if_50, 'r');

plot(force_if_35, 'b');

plot(force_if_15, 'g');

xlabel("Time (ms)");

ylabel("Force (N)");

grid on;

hold off;


%% Max Displacements

max_disp_50 = max(disp_if_50);

max_disp_35 = max(disp_if_35);

max_disp_15 = max(disp_if_15);
```

```
%% Load vs. Deflection Plots

figure(2);

hold on;

title("15%, 35%, 50% Infill Rigid Support Load vs. Displacement")

plot(disp_if_50,force_if_50, 'r');

plot(disp_if_35,force_if_35, 'b');

plot(disp_if_15,force_if_15, 'g');

grid on;

xlabel("Displacement (mm)");

ylabel("Force (N)");

hold off;


%% Peak Load

if_50_pl = max(force_if_50); % N

if_35_pl = max(force_if_35); % N

if_15_pl = max(force_if_15); % N


%% Stress Data

if_50_stress = force_if_50/x_sectional_A;

if_35_stress = force_if_35/x_sectional_A;

if_15_stress = force_if_15/x_sectional_A;


%% Strain Data

if_50_strain = disp_if_50/L;

if_35_strain = disp_if_35/L;

if_15_strain = disp_if_15/L;


%% Stress vs Strain Plot

figure(3);
```

```
hold on;

title("15%, 35%, 50% Infill Rigid Support Stress vs. Strain")

plot(if_50_strain,if_50_stress, 'r');

plot(if_35_strain,if_35_stress, 'g');

plot(if_15_strain,if_15_stress, 'b');

grid on;

xlabel("Strain");

ylabel("Stress (MPa)");

hold off;


%% Max Stress From Data

if_50_maxstress2 = max(if_50_stress); %MPa

if_35_maxstress2 = max(if_35_stress); %MPa

if_15_maxstress2 = max(if_15_stress); %MPa
```

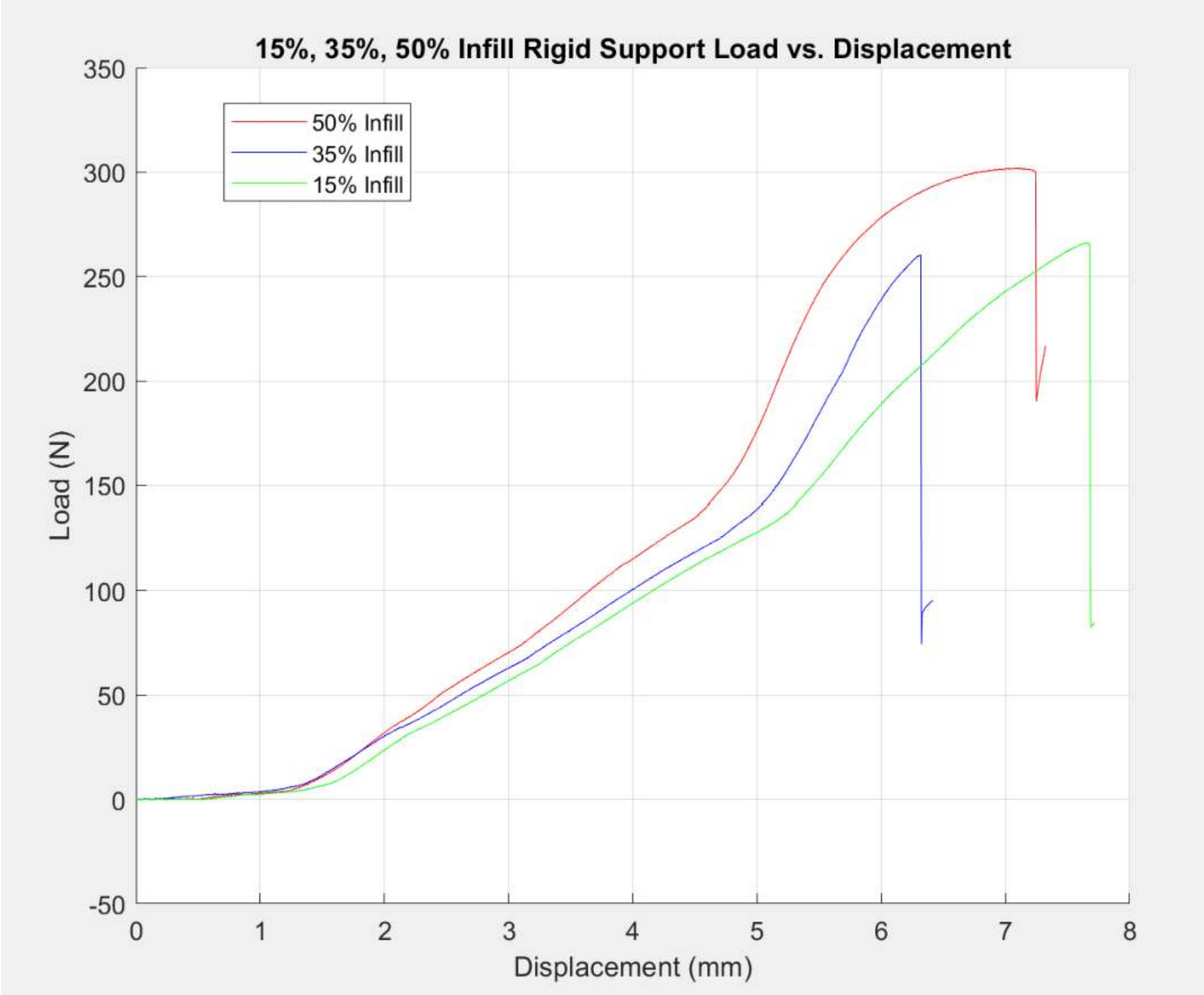
Results:

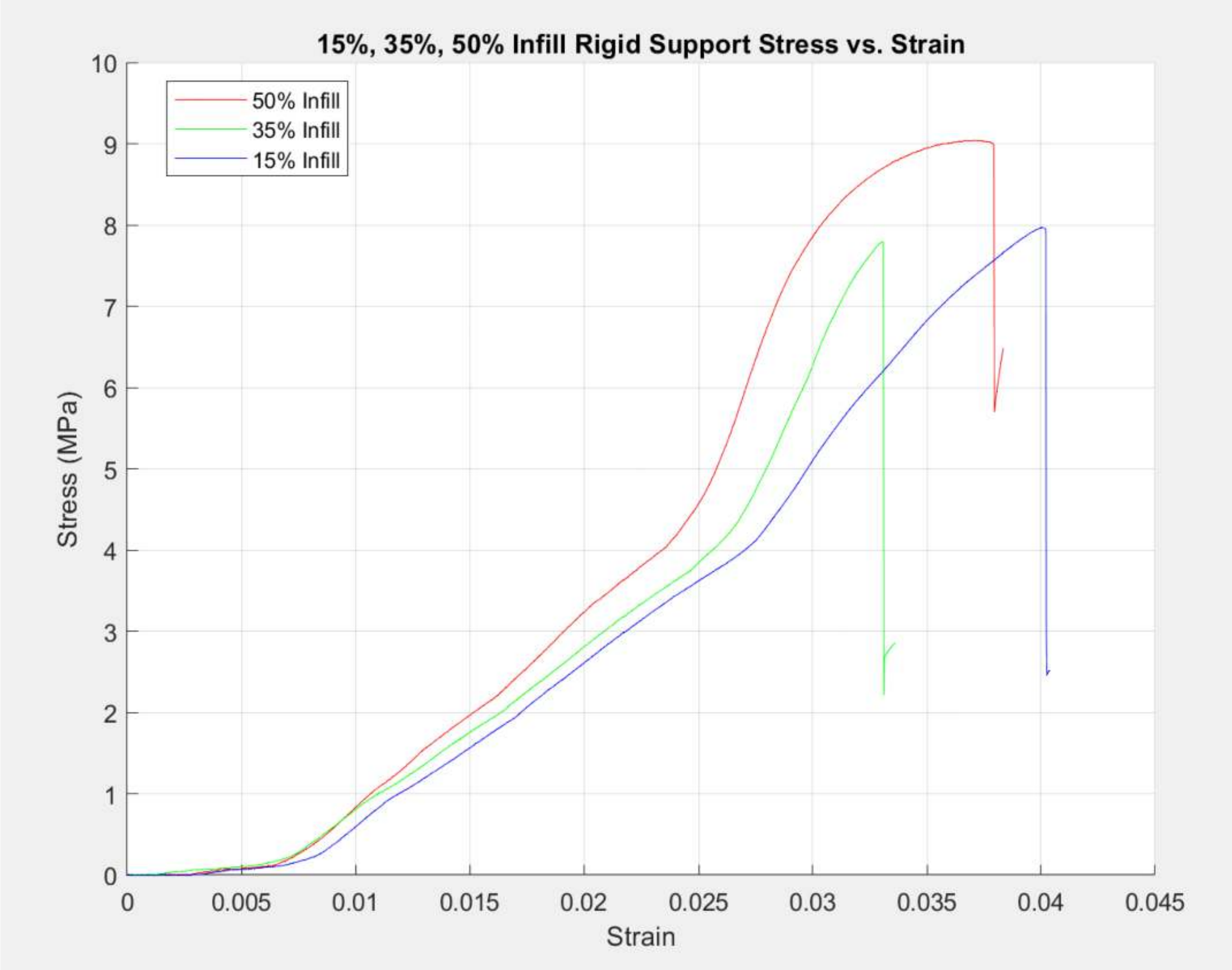

35% Fill : PRE


35% Fill: POST


15% Fill: PRE


15% Fill: POST


15%, 35%, 50% Infill Rigid Support Load vs. Displacement
50% Infill
35% Infill
15% Infill
Load (N)
Displacement (mm)
350
300
250
200
150
100
50
0
-50
0
1
2
3
4
5
6
7
8



Maximum Displacement:

- 15% infill: 7.7151 mm
- 35% infill: 6.4202 mm
- 50% infill: 7.3250 mm

Maximum Loads:

- 15% infill: 266.0517 N
- 35% infill: 260.1523 N
- 50% infill: 301.7794 N

Maximum Stress:

- 15% infill: 595.4 N/mm^2
- 35% infill: 582.2 N/mm^2
- 50% infill: 675.3 N/mm^2

Conclusions/action items:

In conclusion, 15% and 50% infill provided us with the maximum amount of strength we need when resisting anklle inversion. 35% infill was the least string, but deflected the least of the three. 15% infill deflected the most at about 7.7151 mm. We have also concluded that infill does not cause drastic changes in rigid support performance, as we were told by the Makerspace staff.

04/12/2025 - Force Plate Testing Protocol and Results

Madison Michels - Apr 27, 2025, 1:51 PM CDT

Title: Force Plate Testing Protocol and Results

Date: 4/12/2025

Content by: Maddie

Present: Sadie, Lucy, Kate, Maddie

Goals: The goal of this entry is to determine the stability impacts of our brace designs compare to one another and without a brace.

Protocol:

Recording Data with the Force Plates:

a. Pre-Test Measurements

i. Measure the subject's foot length in centimeters.

b. Power on the amplifier boxes for each force plate you intend to use (**Figure 1a**)

	maddie	lucy	sadie	kate	presley	Average of 3	SD	n	significance (T Test against no brace)
'OFECBLACK'	4.242959191	3.851636	70.42489	0.380435	166.1276	2.82501003	1.735943	3	0.053647626
'OFECNB'	5.475463094	4.188148	4.337895	8.526237	4.768138	5.459176329	1.597338	5	0
'OFECRED'	4.301522993	4.301523	4.756908	0.512364	225.6308	3.468084352	1.718572	4	0.07847905
'OFEOBLACK'	3.484627593	3.484626	38.68166	0.317016	58.94291	2.428757108	1.493226	3	0.155026368
'OFEONB'	3.615200386	3.6152	0	3.918209	2.769632	3.479560308	0.428138	4	0
'OFEORED'	3.321785641	3.321786	3.687635	0.294463	20.49683	2.656417362	1.37183	4	0.179729952
'WEDGEBLACK'	3.748656618	3.591146	3.586631	3.695003	2.810226	3.506332403	0.304402	5	0.175236329
'WEDGEEONB'	4.254704198	3.857448	3.699386	0	3.21793	3.757367173	0.428841	4	0
'WEDGERED'	4.015117116	3.413368	3.814916	3.748092	2.932285	3.564755628	0.379462	5	0.282540934

4.242959191	3.851636	0.380435		
5.475463094	4.188148	4.337895	8.526237	4.768138
4.301522993	4.301523	4.756908	0.512364	
3.484627593	3.484626	0.317016		
3.615200386	3.6152	3.918209	2.769632	
3.321785641	3.321786	3.687635	0.294463	
3.748656618	3.591146	3.586631	3.695003	2.810226
4.254704198	3.857448	3.699386	3.21793	
4.015117116	3.413368	3.814916	3.748092	2.932285

group	Red Brace	Black Brace	No Brace
Wedge	3.565	3.506	3.757
Eyes Open	2.650	2.429	3.48
Eyes Closed	3.468	2.825	5.459

- Based on the data above, our two braces provided a decrease in COP variability and total distance traveled. This means that, when compared to no brace, either of our brace designs provides greater stability around that ankle. Additionally, in all of our trials, the black brace had the shortest average path length.

Stabilograms: all stabilogras are included in the link below. While these stabilograms do not provide great quantitative insight into the effectiveness of our braces, they do depict general trends in our success. We can see that, generally, the larger scribble occurs in the No Brace category. Additionally, it is interesting to note that in the wedge trials, the trails with the braces provided greater anterior-posterior support, beacuse the scribble became narrower vertically.

https://drive.google.com/drive/u/1/folders/17eeNg325hIchZELKLMKr8vpZXsWHsrGU

Conclusions/action items:

We can conclude that the black brace showed the greated support of the ankle and the greatest reduction in path length, meaning it was the most functional brace.

04/12/2025 - OpenCap At-Home Testing

Title: OpenCap At-Home Testing

Date: 4/12/2025

Content by: Maddie

Present: Sadie, Lucy, Kate, Maddie, Presley

Goals: The goal of this entry is to determine the gait impacts of our brace on the client.

Protocol:

OpenCap is a smartphone application and a web application that enables cloud computing. To collect data, users open an application on two or more iOS devices and pair them with the enables users to record videos simultaneously on the iOS devices and to visualize the resulting 3-dimensional (3D) kinematics. In the cloud, 2D keypoints are extracted from multi-view v time synchronized using cross-correlations of keypoint velocities, and 3D keypoints are computed by triangulating these synchronized 2D keypoints. These 3D keypoints are converted in neural network (LSTM) trained on a large motion capture dataset. 3D kinematics are then computed from marker trajectories using inverse kinematics and a musculoskeletal model with using muscle-driven dynamic simulations that track 3D kinematics.

Equipment:

- Computer
- 2 Apple IOS devices (iPad and/or iPhone)
- 2 Tripods (or chairs to set up the cameras)
- Printed checkerboard calibration target

I. Data Acquisition

For recommended best practices, additional tips, and set up videos please visit this link

Tips for smooth data collection:

1. Have a stable internet connection.
2. All devices should be connected to the same WIFI network.
3. Do not move the two cameras once the calibration is completed and the reference frame is set.
4. Note that the checkerboard calibration target is only used for calibrating the cameras. The checkerboard can remain on the wall of

II. Equipment set up

a. Take the checkerboard calibration target and hang it in the area where you expect to do the focused data collection.

Figure 1. Set up recommended for the positioning of the cameras relative to the area of data collection (rectangle containing the checkered calibration squ

III. Data Collection

a. Log in to OpenCap on your computer. It should provide a QR code that needs to be scanned by both of your data collection devices (in the C follow the instructions to lead you to the point of data collection.

i. NOTE: A red error message will appear if the devices are not properly connected or the checkered calibration sheet is not in f adjust camera angles. Both devices should be pointed in the same direction. If the issue persists, attempt using a different IO

ii. Do not touch devices once calibrated.

b. After calibration, you will see this screen below. You'll need to enter a new subject, including weight in kg and height in meters.

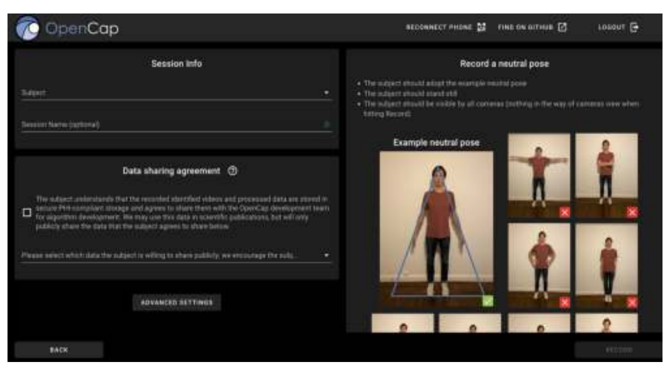
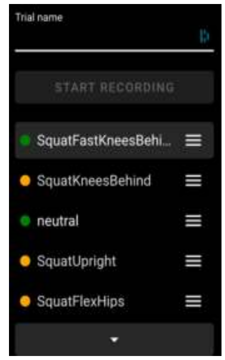


Figure 2. Initial screen prompting user for subject information and providing prompts for the data calibration.

c. After entering subject information, read and check the box under Data Sharing Agreement. Then select in the dropdown below it (circled) "S descriptive- include your subject's name, for example "Maggie_No_AFO" Once all of the fields are filled out on this page, you can move on t



bottom right corner- **RECORD** (this actually will not start the recording yet).

d. On the next screen, name the file before starting to record (File Names Listed Below). You will record one file for each movement.
e. Press record.
f. Wait 5 seconds before walking.
g. Walk 5 steps.
h. Stop recording.
    i. NOTE: Keep the videos as short as possible- they can take quite a while to process.
    ii. Processing time: approximately 2 minutes
i. Your recording will show up under the START RECORDING button. A green dot means it has been processed and is ready to download for an Red means it has failed and the video should be re-taken.
    i. Once green, click on the title of the trial and ensure the skeleton model resembles recorded movement.
j. Repeat action for all conditions listed in the table below. There should be **8 total tests**.
k. Download your data once all movement files show a green dot (this can sometimes take several minutes). Click on **DOWNLOAD DATA** and f computer.
    i. Do not unzip files
    ii. Drag and drop all files into the Data folder within the OpenCap folder in the Google Drive

Table 1: Test Motion, Conditions, and corresponding file names

Test Motion	Condition	File Name
Walk 5 steps toward cameras	No AFO, With Shoes	No_AFO_Toward
Walk 5 steps along wall	No AFO, With Shoes	No_AFO_Along
Walk 5 steps toward cameras	Maggie's AFO, With Shoes	Maggie_AFO_Toward
Walk 5 steps along wall	Maggie's AFO, With Shoes	Maggie_AFO_Along
Walk 5 steps toward cameras	Black Prototype, With Shoes	Black_AFO_Toward
Walk 5 steps along wall	Black Prototype, With Shoes	Black_AFP_Along
Walk 5 steps toward cameras	Red Prototype, With Shoes	Red_AFO_Toward
Walk 5 steps along wall	Red Prototype, With Shoes	Red_AFO_Along

Conclusions/action items:

We have sent a video to the client to be followed along with this protocol. They will perform the testing at home and send the data back. This

04/12/2025 - Comfort Evaluation Form

Madison Michels - Apr 12, 2025, 6:23 PM CDT

Title: Comfort Evaluation Form

Date: 4/12/2025

Content by: Maddie

Present: Maddie

Goals: The goal of this entry is to create a form for our client to fill out while wearing our braces to determine pain points and overall comfort levels.

Content:

The form is under the attachments.

Conclusions/action items:

Maggie will fill this form out during/before testing to indicate her dislikes and likes about our designs.

Madison Michels - Apr 12, 2025, 6:24 PM CDT

Short Outside and Long Inside (Red Brace)

Ease of Putting On:

1 2 3 4 5 6 7 8 9 10

Notes:

Strap Comfort:

1 2 3 4 5 6 7 8 9 10

Notes:

Foam Comfort:

1 2 3 4 5 6 7 8 9 10

Notes:

Outside Support Fit:

1 2 3 4 5 6 7 8 9 10

Notes:

Inside Support Fit:

1 2 3 4 5 6 7 8 9 10

Notes:

Download

Comfort_Evaluation.pdf (146 kB)

03/03/2025 - CAD Modeling of Braces

Lucia Hockerman - Apr 30, 2025, 2:46 PM CDT

Title: CAD Modeling of Braces

Date: 03/03/2025

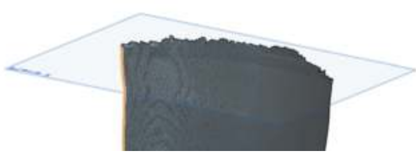
Content by: Maddie

Present: Maddie

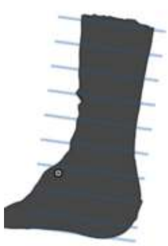
Goals: The goal of this entry is to document the pocedure for modeling the rigid support using the 3D imported mesh.

Content:

1. Open OnShape
2. Import stl or obj file by clicking "create" --> "import files"
3. If prompted, import the part in mm
4. Click on the document that displays your part.
5. Using the plane tool, create a 3 point plane that intersects the top of the cast.



1. Using the plane feature again, creat offset planes every 1 inch down the cast until you reach the bottom.

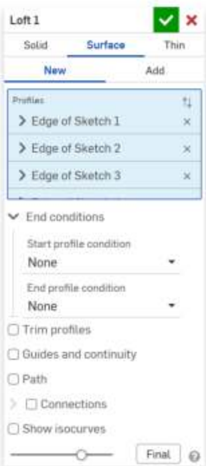


1. Create another plane using 3 point selection that splits the cast to create a smooth edge along the backside.
2. Using the split tool, select the cast mesh as the surface and the plane you created in step 7. Unselect "keep both sdies" and ensure the deleted side is the back half of the cast to produce the part shown below.

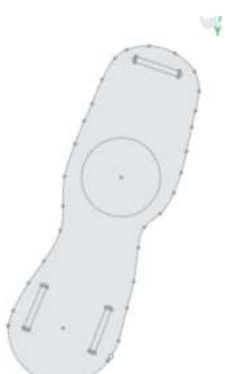
1. On the face of the plane created in step 5, create a sketch.
2. Use the spline tool to draw a curved line that matches the curvature of the cast at that intersection.
3. Use the line tool to connect the ends of the spline.

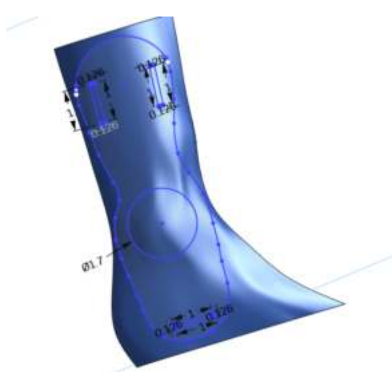
1. Repeat steps 9-11 on every plane down the cast mesh.

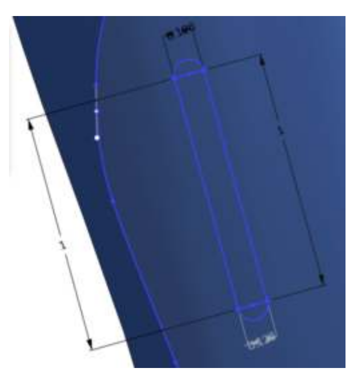
1. Using the "loft" tool, connect the sketches in thr order they appear on the cast.



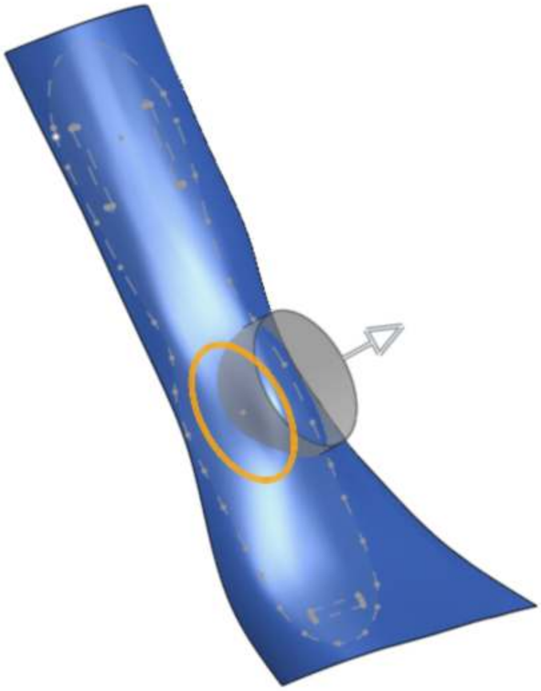
1. On the resulting suface, create a sketch that includes 3 one inch rounded slots and a 1.7 inch diameter circle using the plane created in step 6 and 7.







1. Click ont he extrude tool
2. Select the lofted surface
3. Select the circle in sketch created in step 14
4. Extrude the circle fully through the part



1. Repeat steps 15 - 18 for every line/component in the same sketch.
2. Using the cut tool, select the surface to cut and select the extruded pieces to cut with
3. Uncheck keep both sides and ensure the holes are removed, not the surface itself.
4. Use the thicken tool to thickent the final design to 0.105 inches.

Conclusions/action items:

In conclusion, these were the steps I took to create the rigid support on the brace, following the 3D mesh of the cast as a guide.

03/03/2025 - 3D Scanning of the Cast

Madison Michels - Mar 03, 2025, 11:12 AM CST

Title: 3D Scanning of the Cast

Date: 03/03/2025

Content by: Maddie

Present: Maddie, Kate, Sadie

Goals: The goal of this entry is to outline the steps taken to 3D scan the two halves of the cast and create an importable file from the resulting scans.

Content:

1. Enter the Creality software on the Makerspace computer.
2. Select "New Design"
3. Place your part on the rotating disc
4. Set up dotted blocks around your part to allow for spatial awareness
5. Click the green arrow to begin scanning your part.
6. Hold the wand about one foot away from your part, carefully watching the light ont he handle.
    1. Green = acceptable distance from the part
    2. Orange = too close to the part
    3. Red = Extrememly close tot he part
    4. Light blue = too far away from the part
    5. Dark blue = Extremely far away from the part
7. Continue scanning the part until the part is fully defined and green on the screen
8. Once done scanning (about 15 minutes), click the all in one edit tool to smooth, refine, minimalize your mesh.
9. Delete the components of the mesh that do not include your design/part.
10. Select "export" and select "obj" file.


Conclusions/action items:

In conclusion, this mesh allows us to use the features and dimensions in the cast as a model for our rigid support design.

03/03/2025 - Measurement of Foot Dimensions

Madison Michels - Mar 03, 2025, 4:39 PM CST

Title: Measurement of Foot Dimensions

Date: 03/03/2025

Content by: Maddie

Present: Maddie

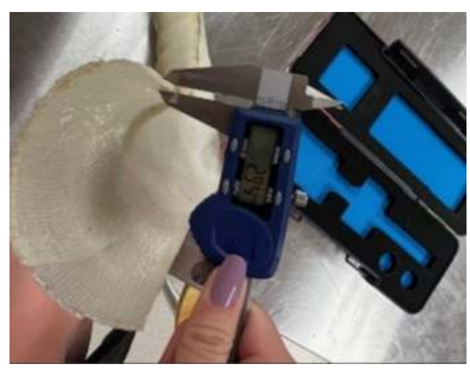
Goals: The goal of this entry is to document the different dimensions and discrepencies found in the client's foot dimensions.

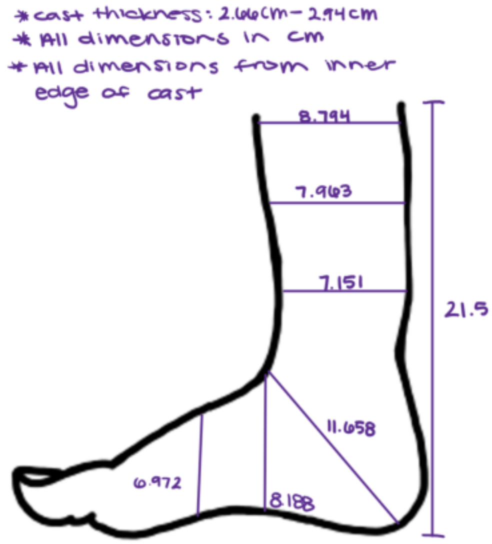
Content:

Procedure: Using calipers, I dimensionsed the plaster cast procided to us by the client. I noticed discrepencies between the cast dimensions and the client's provided dimensions from last semester.







Conclusions/action items:

In conclusion, these are the most accurate dimensions based on the cast design. We have changed our models to match these dimensions.

04/12/2025 - Strap and Foam Attachment

Madison Michels - Apr 12, 2025, 4:47 PM CDT

Title: Strap and Padding Attachment

Date: 04/12/2025

Content by: Maddie

Present: Kate, Maddie, Lucy, and Sadie

Goals: The goal of this entry is to outline the process that the team took to assemble the rigid support component of the device.

Content:

Padding:

1. Cut two pieces of the mesh off of the sheet
    1. Ensure they are big enough to cover the full rigid support dimensions
2. Trace one outline of a rigid support onto the smooth side of the mesh padding sheet, including the slits for the straps
3. Lay a second mesh sheet on top of the first, ensuring the smooth side you traced onto is visible on one side and the other has mesh
4. Sew the two pieces together along the traced lines, excluding the strap slits.
5. Trim the pieces down to about 1 mm outside of the sewn lines
6. Place the piece of mesh onto the rigid support (smooth side facing the support) and ensure the shapes are consistent with one another
7. Using the Weld-On 4 (shown below), apply the liquid to the concave side of the rigid support until fully covered
    1. 

8. Quickly place the smooth foam side onto the adhesive and press until firmly adhered
9. Let the full part sit for about 15 minutes before moving
10. Check the edges for loose pieces of foam and apply more adhesive if needed
11. Using scissors, cut the slits for the straps out of the mesh padding
12. Leave the circle over the rigid support hole intact!

Straps:

1. Cut 1 foot-long strips of robust black material about one inch thick (cut 4)
2. Cut four more straps, one inch thick, to the patient's specfici foot dimensions
3. Cut 4 velcro squares of the adhesive velcro about one inch wide

4. Peel the paper off of the back of these squares and adhere to the outside of the 3D printed rigid support component
    1.  You can see the velcro piece adhered to the outside of the brace just above the strap slit
    2. Repeat for all four braces
5. Sew four velcro strips (length can be modified for patient dimensions) to one end of the smaller underfoot straps
    1. Do for all four braces
6. Loop the other end of the underfoot strap through the bottom of the brace ad sew it to itself
    1. Ensure the underfoot strap is an appropriate length for your client with minimal adjustments required
    2. Repeat for all four braces
    3. Note: the underfoot strap lengths may change based on support lengths
7. Cut four pieces of non-adhesive velcro and sew them into the longer, one foot long straps
8. Sew one velcro piece onto each end and on opposite sides of the strip
    1. Repeat for all four straps
9. Loop the straps through the foam slits and into the holes int he rigid support to secure

** FAILED ATTEMPT USING CARPET TAPE **

Conclusions/action items:

In conclusion, the four braces are completed and we have shipped two of them off to Michigan for client testing.

2025/01/28 - Quantifying alignment bias for AFOs

Presley Hansen - Feb 04, 2025, 11:56 PM CST

Title: Quantifying alignment bias for AFOs

Date: 2025/01/28

Content by: Presley Hansen

Present: N/A

Goals: to learn about quantifying alignment bias during the fabrication and fitting of AFOs

Literary Search Base: PubMed

Search Term: (AFO OR "ankle-foot orthosis") AND mold*

Link: https://www.sciencedirect.com/science/article/abs/pii/S0966636222001308?via%3Dihub

Citation:

A. J. Ries, J. Klein, T. F. Novacheck, K. Walt, and M. H. Schwartz, "Quantifying alignment bias during the fabrication and fitting of ankle-foot orthoses: A single center study," *Gait & posture*, vol. 96, pp. 29–34, Jul. 2022, doi: https://doi.org/10.1016/j.gaitpost.2022.05.007.

Content:

- The sagittal plane alignment of ankle-foot orthoses (AFO) and AFO footwear combinations (AFO-FC) has been shown to influence gait outcomes

- How does the alignment of an AFO change during the fabrication and fitting process with respect to the intended, benchmark sagittal plane alignment identified by the consulting orthotist?

- Sagittal plane alignment of AFOs refers to the positioning of an ankle-foot orthosis (AFO) in the sagittal plane, which means how much the foot is angled up (dorsiflexion) or down (plantarflexion) relative to the leg

- The assessment of AFO alignment was performed using 125 custom molded AFOs from 68 individuals (57 bilateral AFOs, 11 unilateral AFOs).

- A bilateral AFO means there is an AFO on each foot

- The alignment of each AFO was measured at 5 distinct steps during the fabrication and fitting process

- Repeated measures ANOVA showed that AFO alignment changed between all fabrication and fitting steps

- AFO alignment changed between all fabrication and fitting steps

- AFO alignment was consistently 2-5 degrees more dorsiflexed than the benchmark alignment

- Prior to fitting shoes, 55% of fabricated AFOs measured more than 2 degrees from the benchmark alignment.

- After fitting shoes, nearly 87% of AFO-FCs were more than 2 degrees from the benchmark alignment.

Conclusions/action items: The finding of systematic dorsiflexion bias and changes in AFO alignment throughout the fabrication and fitting process indicates the need to improve AFO fabrication precision. When creating our AFO, it is important to create an AFO that is precise to our client's measurements and account for this systematic dorsiflexion bias, otherwise there could be differences in the intended and actual dorsiflexion angle.

2025/01/27 - Multiplanar Stiffness of AFOs

Presley Hansen - Feb 05, 2025, 12:34 AM CST

Title: Multiplanar Stiffness of AFOs

Date: 2025/01/27

Content by: Presley Hansen

Present: N/A

Literary Search Base: PubMed

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC8420787/

Citation:

B. R. Shuman and E. Russell Esposito, “Multiplanar Stiffness of Commercial Carbon Composite Ankle-Foot Orthoses,” *Journal of Biomechanical Engineering*, Jul. 2021, doi: https://doi.org/10.1115/1.4051845.

Goals: Learn about multiplanar stiffness of commercial carbon composite AFOs

Content:

- the purpose of the study was to quantify the rotational stiffness of thirteen commercial, nonarticulated (no moveable joint at ankle), carbon composite ankle-foot orthoses.

- A custom, instrumented test fixture deflected an AFO through 20 deg of plantar/dorsiflexion motion about a specified, but adjustable, ankle axis.

- Sagittal, frontal, and transverse plane rotational stiffness were calculated, and reliability was assessed between cycles, sessions, and testers.

- The test fixture demonstrated good-to-excellent reliability between testers, sessions, and cycles

- Sagittal plane AFO stiffness ranged from 0.58 N·m/deg to 3.66 N·m/deg.

- AFOs with a lateral strut (lateral piece for ankle stability) demonstrated frontal plane stiffnesses up to 0.71 N·m/deg of eversion while those with a medial strut demonstrated frontal plane stiffnesses up to 0.53 N·m/deg of inversion.

- Transverse plane stiffnesses were less than 0.30 N·m/deg of internal or external rotation.

- These results directly compare AFOs of different models and from different manufacturers using consistent methodology

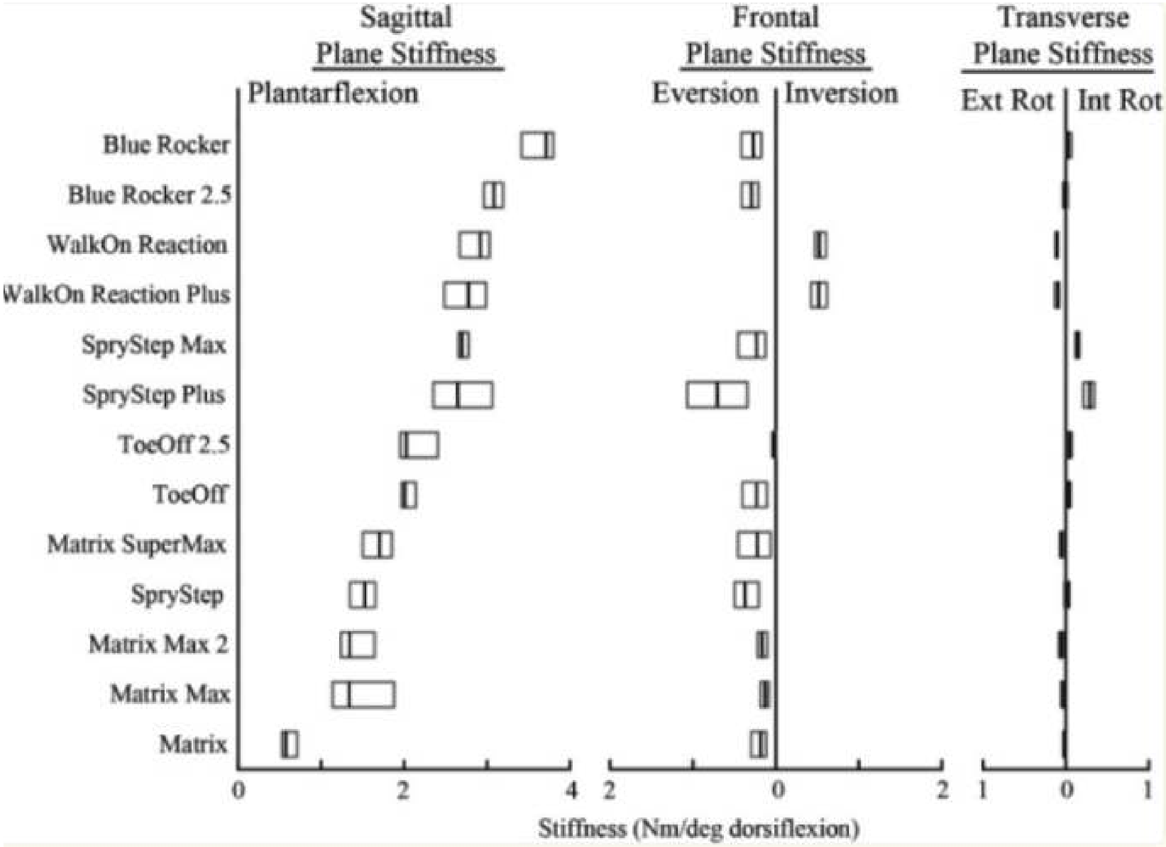


Figure 1: Measured AFO Stiffness for Various AFO Types

Figure 2: Trulife Matrix AFO

https://trulife.com/products/matrix

-

Conclusions/action items: AFO stiffnesses across 13 commercially available carbon composite AFOs were compared.The Trulife Matrix AFO is made of carbon composite. This AFO has the lowest sagittal plane stiffness of all the AFO's tested in this study. Our patient would like a more flexible AFO, so this material and design is something to consider.

2025/02/02 - Economical Impact of AFOs

Presley Hansen - Feb 05, 2025, 12:34 AM CST

Title: Economical Impact of AFOs

Date: 2025/02/02

Content by: Presley Hansen

Present: N/A

Goals: To learn about the economical impact of AFOs

Literary Database: PubMed

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC4811757/#R11

Citation:

K. Bjornson, C. Zhou, S. Fatone, M. Orendurff, R. Stevenson, and S. Rashid, “The Effect of Ankle-Foot Orthoses on Community-Based Walking in Cerebral Palsy,” *Pediatric Physical Therapy*, vol. 28, no. 2, pp. 179–186, 2016, doi: https://doi.org/10.1097/pep.0000000000000242.

Content:

- Orthotic intervention has large economic implications for children with Cerebral Palsy and their families and insurers. Given that approximately 53,000 AFOs are fabricated each year in the United States at an average Medicare reimbursement of $417, more than $2.2 million per year are spent on them

- These costs may make AFOs inaccessible to low-income families.

Conclusions/action items: more than $2.2 million per year are spent on AFOs in the US. These costs may make AFOs inaccessible to low-income families.

2025/02/11 - The effects of a PAFO on healthy and impaired individuals

Presley Hansen - Feb 11, 2025, 2:41 PM CST

Title: The effects of an AFO on healthy and impaired individuals

Date: 2025/02/11

Content by: Presley Hansen

Present: N/A

Goals: To learn about the effects of an AFO on healthy and impaired users while walking

Literary Database: PubMed

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC6167899/

Citation:

M. Moltedo, T. Baček, T. Verstraten, C. Rodriguez-Guerrero, B. Vanderborght, and D. Lefeber, "Powered ankle-foot orthoses: the effects of the assistance on healthy and impaired users while walking," *Journal of NeuroEngineering and Rehabilitation*, vol. 15, no. 1, Oct. 2018, doi: https://doi.org/10.1186/s12984-018-0424-5.

Content:

- It has been shown that the effect of powered ankle-foot orthoses (PAFOs) on healthy users is altered by some factors of the testing protocol.

- The paper I looked at provides an overview of the effect of powered walking on healthy and weakened users.

The performance of PAFOs in reducing the biological effort of users depends on several factors:

- the adaptation of the user to powered assistance → it takes a certain amount of time for each user to learn how to take advantage of the PAFO and optimize their walking pattern in the powered condition
- the timing of the actuation profile → The effectiveness of the assistance provided at the ankle highly depends on the synchronization between the actuation of the PAFO and the user's motion. An inaccurate timing impedes the user in his/her movements and interferes with the action of the biological muscles.
- the assistance magnitude → defined as the average power provided by the PAFO per stride
- the type of controller → the proportional myoelectric controller (PMc) vs the phase-based controller (P-Bc)

- the subjects reached a steady state increasingly faster over different sessions. This result shows that the subjects could retain the walking pattern used in previous powered trials.
- the PMc and the P-Bc are the main types of controllers used in PAFOs.

-The PMc has the advantage of being better synchronized with the user, resulting in a more physiological controller because the user has direct control over the timing and amplitude of the actuation
- The P-Bc has lower complexity and it does not need sensors on the user's limbs, since they can, in general, all be placed on the device.

- an assistive PAFO can be used to prevent the occurrence of drop foot, while not hindering the ankle joint in plantarflexion

Conclusions/action items: As seen in healthy subjects, the metabolic cost of walking of these patients tended to decrease with multiple sessions, although the differences were not statistically significant. From the comparison of the outcomes of different studies, it can be seen that the effects of a PAFO on weakened subjects cannot be extrapolated from the ones obtained on healthy ones.

2025/02/11 - How does an AFO improve gait?

Presley Hansen - Feb 12, 2025, 9:19 AM CST

Title: How does an AFO improve gait?

Date: 2025/02/11

Content by: Presley Hansen

Present: N/A

Literary Database: Google Scholar

Link: https://www.tandfonline.com/doi/full/10.1080/1463922X.2019.1616332

Citation:

R. Taiar *et al.*, "Can a new ergonomical ankle–foot orthosis (AFO) device improve patients' daily life? A preliminary study," *Theoretical Issues in Ergonomics Science*, vol. 20, no. 6, pp. 763–772, May 2019, doi: https://doi.org/10.1080/1463922x.2019.1616332.

Goals: Can a new ergonomical ankle–foot orthosis (AFO) device improve patients' daily life?

Content:

- The objective of this study was to quantify the impact of the AFO on patients having a deficit of dorsi-flexion during gait in the aim to improve their daily lives.

- The pressure force plate used in this experimentation aimed to measure the patients' behaviors with and without an AFO.

- The results showed a significant impact of using an AFO in terms of spatio-temporal analysis ($p < 0.05$)

- Spatio-temporal analysis is the study of data that has both spatial (physical position space) and temporal (order of events in time) dimensions. It's used to describe and predict how things change over time and space.

- In posturography (a test that measures a person's balance and posture), the results showed that patients increased their balance by using an AFO ($p < 0.05$)

- The results showed the positive impact of the AFO on the spatiotemporal parameters during gait.

- AFOs have an effect in raising the gait speed for adults suffering from calf muscle weakness.

- Wearing the orthosis by the patients increased step length and step velocity significantly. A higher velocity means more fluidity in the body movement and less energy spent by the patient.

- The AFO also gives a better stability balance during gait. The orthosis makes the movement easier, faster and less exhausting for the patients.

Conclusions/action items: This AFO increased step length and step velocity of the patients which resulted in more fluid body movement and less energy excursion. The AFO provides more stability during gait.

2025/02/17 - FSHD

Presley Hansen - Feb 18, 2025, 10:14 PM CST

Title: FSHD

Date: 2025/02/17

Content by: Presley Hansen

Present: N/A

Goals: To learn how a person gets FSHD

Reference:

Facioscapulohumeral muscular dystrophy (Fshd). (n.d.). Muscular Dystrophy UK. Retrieved October 3, 2024, from https://www.musculardystrophyuk.org/conditions/a-z/facioscapulohumeral-muscular-dystrophy-fshd/

Content:

- Facioscapulohumeral muscular dystrophy (FSHD) is a muscle wasting condition caused by a genetic mutation, which switches on a gene that shouldn't normally be switched on.

- The name describes the areas where FSHD usually causes weakened muscles. ('facio' = facial, 'scapulo' = shoulder blade, 'humeral' = upper arm)

- FSHD is one of the most common forms of muscular dystrophy. Experts estimate that between three and five people out of every 100,000 have FSHD.

- The earlier in life the weakness appears, the more severe it will eventually be.

- One fairly common feature of FSHD is an asymmetry of weakness

- About 10 to 20 percent of people with FSHD eventually require a wheelchair

- Generally speaking, life-expectancy is not affected

- FSHD is caused by a genetic mutation that removes some of the DNA on chromosome 4. This chromosome contains lots of repeated pieces of DNA called D4Z4 repeat units. In someone with FSHD, the number of D4Z4 repeat units is reduced. This causes a gene called DUX4 to be unnecessarily switched on and produce DUX4 protein.

- DUX4 protein is thought to contribute to muscle wasting, inflammation and damage inside the muscle cells of someone with FSHD.

- On average, men with FSHD tend to show more weakness and from a slightly earlier age than women.

- There are no cures for FSHD or specific drug treatments. Regular exercise helps to keep people moving and manage pain. Orthoses or surgery can also help.

Conclusions/action items: Learned about the specific genetic mutation that causes FSHD

2025/02/17 - Client Research

Presley Hansen - Feb 18, 2025, 10:28 PM CST

Title: Client/Patient Research

Date: 2025/02/17

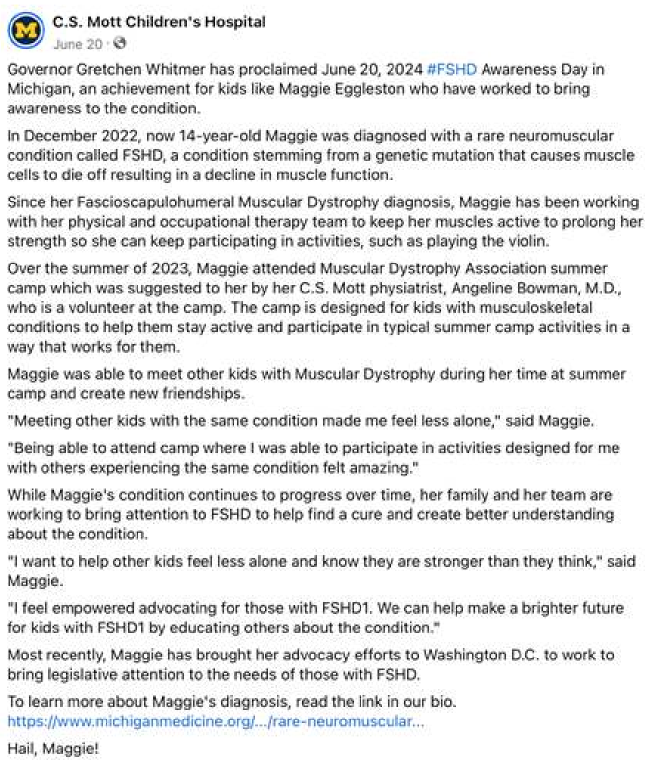
Content by: Presley Hansen

Present: N/A

Link: https://www.michiganmedicine.org/health-lab/rare-neuromuscular-disorder-diagnosis-brings-long-awaited-answers-teen?fbclid=IwY2xjawFQFClleHRuA2FlbQIxMAABHbepSfgRU1mUvuzXfEAfEfMp3jDJaHZz95zrVOZoMSc5Lqg6t9Wmyk1mTA_aem_nBlnR8M-FhYVAfuMckrCIA

Goals: To get more background information on our client and patient

Content:



C.S. Mott Children's Hospital
June 20 ·

Governor Gretchen Whitmer has proclaimed June 20, 2024 #FSHD Awareness Day in Michigan, an achievement for kids like Maggie Eggleston who have worked to bring awareness to the condition.

In December 2022, now 14-year-old Maggie was diagnosed with a rare neuromuscular condition called FSHD, a condition stemming from a genetic mutation that causes muscle cells to die off resulting in a decline in muscle function.

Since her Fascioscapulohumeral Muscular Dystrophy diagnosis, Maggie has been working with her physical and occupational therapy team to keep her muscles active to prolong her strength so she can keep participating in activities, such as playing the violin.

Over the summer of 2023, Maggie attended Muscular Dystrophy Association summer camp which was suggested to her by her C.S. Mott physiatrist, Angeline Bowman, M.D., who is a volunteer at the camp. The camp is designed for kids with musculoskeletal conditions to help them stay active and participate in typical summer camp activities in a way that works for them.

Maggie was able to meet other kids with Muscular Dystrophy during her time at summer camp and create new friendships.

"Meeting other kids with the same condition made me feel less alone," said Maggie.

"Being able to attend camp where I was able to participate in activities designed for me with others experiencing the same condition felt amazing."

While Maggie's condition continues to progress over time, her family and her team are working to bring attention to FSHD to help find a cure and create better understanding about the condition.

"I want to help other kids feel less alone and know they are stronger than they think," said Maggie.

"I feel empowered advocating for those with FSHD1. We can help make a brighter future for kids with FSHD1 by educating others about the condition."

Most recently, Maggie has brought her advocacy efforts to Washington D.C. to work to bring legislative attention to the needs of those with FSHD.

To learn more about Maggie's diagnosis, read the link in our bio.
https://www.michiganmedicine.org/.../rare-neuromuscular...

Hail, Maggie!

- Patient: Maggie Eggleston - is now 16 years old (sophomore in high school)

- Maggie was diagnosed with FSHD1 in December 2022 (about 2 years ago when she was 14)

- Started noticing symptoms after age 10

- Maggie's condition is progressing over time

- The trials that are being done are geared towards adults, so it will be a while before the research moves down to pediatrics

- Client: Debbie Eggleston - physical therapist and activist

- Debbie has joined many Facebook groups and organizations to help bring awareness to the need for research on FSHD1 in the pediatric population.

Conclusions/action items: Refreshed my memory on important information like when our patient was diagnosed, how old she currently is, etc.

2025/01/26 - AFO with resistance-adjustable joints

Presley Hansen - Feb 05, 2025, 12:33 AM CST

Title: AFO with resistance-adjustable joints

Date: 2025/01/26

Content by: Presley Hansen

Present: N/A

Goals: to learn about the effects of an AFO with resistance-adjustable joints on lower limb joint kinematics and kinetics during gait

Literary Search Base: PubMed

Search Term: (AFO OR "ankle-foot orthosis") AND "gait"

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC6234099/

Citation:

T. Kobayashi *et al.*, “The effects of an articulated ankle-foot orthosis with resistance-adjustable joints on lower limb joint kinematics and kinetics during gait in individuals post-stroke,” *Clinical Biomechanics*, vol. 59, pp. 47–55, Nov. 2018, doi: https://doi.org/10.1016/j.clinbiomech.2018.08.003.

Content:

- Resistance is a key mechanical property of an ankle-foot orthosis that affects gait in individuals

-Triple Action® joints allow independent adjustment of plantarflexion resistance and dorsiflexion resistance of an ankle-foot orthosis

- aim of this study was to investigate the effects of incremental changes in dorsiflexion and plantarflexion resistance of an articulated ankle-foot orthosis with the Triple Action joints on lower limb joint kinematics and kinetics in individuals post-stroke during gait.

- Gait analysis was performed on 10 individuals who were post-stroke under eight resistance settings using the AFO shown in Figure 1 below

- adjustment of plantarflexion resistance had significant main effects on the ankle and knee angles at initial contact, while dorsiflexion resistance had significant main effects on the peak dorsiflexion angle in stance

- Restricting foot-drop in the swing stage of gait requires an AFO that is rigid enough to resist the plantarflexion force of the ankle

- There are many ankle joint options available for AFOs, and choosing an adjustable ankle component is one approach to individually tune resistance in orthotic design.

- These articulated AFOs may permit more anatomical movement of the ankle joint with proper resistance while walking compared to non-articulated AFOs.

- They also allow simple and convenient adjustment of AFO resistance --> our client's disease is progressive so this would be helpful to have an easy adjustment

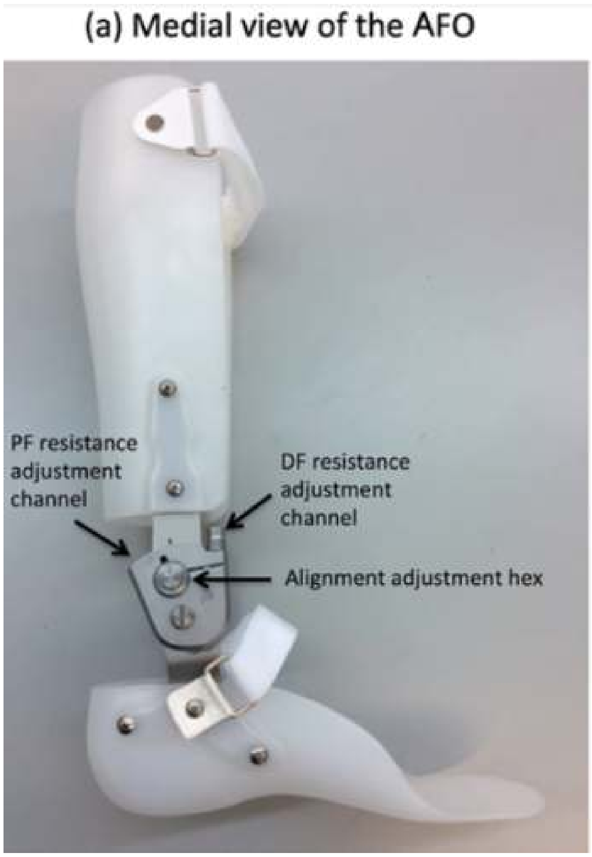


Figure 1: Medial view of an articulated AFO with Becker Triple Action® ankle joints

Conclusions/action items: This study demonstrated that the adjustments of resistance in the ankle-foot orthosis with the Triple Action joints influenced ankle and knee kinematics in individuals post-stroke. A joint could be a good addition to the design of an AFO. It may not be possible to make the AFO inconspicuous or fit inside a shoe, however.

2025/01/28 - Hybrid ankle foot orthosis

Presley Hansen - Feb 05, 2025, 12:33 AM CST

Title: Hybrid ankle foot orthosis

Date: 2025/01/28

Content by: Presley Hansen

Present: N/A

Goals: To learn what this hybrid AFO consists of and if it helpful with improving gait

Literary Search Platform: PubMed

Search Term: (AFO OR "ankle-foot orthosis") AND mold*

Link: https://pubmed.ncbi.nlm.nih.gov/24088782/

Citation:

K. H. Do *et al.*, “Effect of a hybrid ankle foot orthosis made of polypropylene and fabric in chronic hemiparetic stroke patients,” *American journal of physical medicine & rehabilitation*, vol. 93, no. 2, pp. 130–7, 2014, doi: https://doi.org/10.1097/PHM.0b013e3182a92f85.

Content:

- investigate the effect of a hybrid AFO made with polypropylene and fabric in comparison with a conventional plastic AFO in terms of convenience and effect in patients with chronic hemiparetic stroke.

- hybrid AFO made with polypropylene and fabric compared to a conventional plastic AFO

- these two were individually molded and fitted to the seventeen patients with chronic hemiparetic stroke recruited for the study

- satisfaction was greater for the hybrid AFO; it was also lighter than the plastic AFO

- In gait analysis, faster walking speed, larger mean and peak ankle dorsiflexion angles, and ankle dorsiflexion angles at heel strike and toe off were observed for the hybrid and plastic AFOs compared with barefoot --> both AFOs were helpful with improving gait

- No significant difference was observed between the two orthoses, except for ankle dorsiflexion angle at heel strike, in which the plastic AFO showed higher ankle dorsiflexion angle than did the hybrid AFO

Conclusions/action items: Although the hybrid AFO was more comfortable for users than the traditional plastic, the traditional plastic AFO showed higher ankle dorsiflexion angles. Although we are trying to design an AFO that is comfortable and discreet for our client, functionality is becoming more important as their disease progresses. A hybrid AFO does not seem to be as functional as the traditional plastic AFO in regards to ankle dorsiflexion angles. We are designing an AFO to prevent foot drop, so larger ankle dorsiflexion angles are most important.

2025/03/07 - Foam Research

Presley Hansen - Mar 11, 2025, 10:41 PM CDT

Title: Types of Foam Research

Date: 2025/03/07

Content by: Presley Hansen

Present: N/A

Goals: To find possible types of foam that can be easily attached to the inside of the rigid support

Content:

- EVA (Ethylene Vinyl Acetate) foam is lightweight, flexible, durable, and water resistant, but it has limited grip on slippery surfaces and potential environmental
concerns. --> unsure if this would provide enough comfort for the patient

Figure 1: Roll of EVA Foam

- Gel Pads can aid in pressure relief, distribute weight, and provide comfort, but can also be heavy, and trap heat. --> Also unsure how it would stay attached to the rigid support piece; not a viable option

Figure 2: Ankle Splint with Gel Pad for Comfort

- Memory Foam is the most comfortable option. It helps distribute pressure and absorbs shock, but it can retain heat which could lead to sweaty feet. --> Most viable option of the three but should look into materials that can provide more air flow.

Figure 3: Memory Foam Shoe Inserts

References:

EVA: https://kanefootwear.com/blogs/kane-blog/what-is-eva-foam#:~:text=While%20EVA%20foam%20offers%20advantages,grip%2C%20especially%20on%20wet%20surfaces.

Gel: https://airhawk.net/2018/07/15/your-motorcycle-seat-cushion-buying-guide-foam-gel-airhawk-or-ist/#:~:text=Gel%20motorcycle%20seat%20pads%20contain,cushioning%20for%20the%20money%20invested.

Memory Foam: https://www.upstep.com/a/answers/orthotics/what-are-the-pros-and-cons-of-using-memory-foam-orthotics

Conclusions/action items: Memory Foam seems to be the most viable option of the three, but materials that can provide more air flow should be looked into.

2025/03/07 - Foam Attachment Methods

Presley Hansen - Mar 11, 2025, 11:20 PM CDT

Title: Foam Attachment Methods

Date: 2025/03/07

Content by: Presley Hansen

Present: N/A

Goals: Brainstorm Methods to attach foam to the inside of the rigid support

Content:

- adhesive tape (Scotch extreme mounting tape or Gorilla mounting tape for example) --> Using adhesive tape to attach foam is easy, quick, and messy-free, but is not as strong as liquid adhesives and will require a flatter surface.

- foam-specific glue (loctite foam adhesive, etc.) --> creates strong bonds and fairly easy to use, but needs proper bracing during curing and is messier. Might leak through a specific type of foam or not be strong enough?

-foam adhesive spray (3M, Gorilla, etc.) --> strong bond and easy to apply, but messy, can overspray, possibly cause irritation, and not compatible with all types of foam. Spray adhesives can degrade over time.

- low-temperature glue sticks (Gorilla, Stanley, etc.) --> need to make sure the temperature is low enough so the foam does not melt, but still high enough where the foam can bond to the rigid support. Make sure the glue doesn't seep through the foam.

- adhesive glue points --> I brought some of these from home and we tested them with the foam we currently have, but it was not strong enough to hold the foam firmly in place.

- sewing --> will take more time and will need to 3D print a new rigid support with a few extra holes so we can weave thread through somewhere. This might be a viable option because the foam will be well secured to the rigid support and there will not be glue that can lose stickiness over time. Need to make sure that we have the right type of foam that will not rip when the string pulls the foam from the side.

Conclusions/action items: Overall, sewing might be the most viable option for securing the foam to the rigid support. This will take more time, but will ensure that the foam will be well secured to the rigid support.

2025/02/26 - Universal Design

Presley Hansen - Feb 26, 2025, 2:06 PM CST

Title: Universal Design

Date: 20245/02/26

Content by: Presley Hansen

Present: Presley Hansen

Goals: To think about diversity, universal design, and ethics

Content:

- Useable by all with no adaptations needed
- Easily accessible
- Give instructions everyone can follow

- Collecting data ethically
- environmental impacts
- is it safe for patient to use
- making for profit or benefit of patient

Considering differences

- Socioeconomic standing, race, gender
- Inclusion
- Incorporating diversity in decision making process to get different ideas

Rise and Stride: Ethics Discussion

What components of the design could be improved:

- Flexibility of Use: straps allow for the patient to customize effectiveness and comfort of the design
- Provide the patient with an assembly guide
- Patient-specific modeling
- Improve the ease of application. The current compression sleeves require significant strength to place over the ankle

Which of the 7 principles are you addressing:

- Flexibility of Use
- Low physical effort
- Tolerance for errors: address velcro wearing down

How can we make these improvements:

- Quick release straps
- Magnetic closures for the strapping mechanism
- Instruction videos
- Choose a elastic material for the straps
- Create a fixture to help assemble the brace and apply the compression sock
- Make the rigid support adaptable to any foot scan

Conclusions/action items: Considered ways to make our design more universally inclusive

2025/03/11 - OptiTrack

Presley Hansen - Mar 11, 2025, 11:53 PM CDT

Title: OptiTrack Motion Capture

Date: 2025/03/11

Content by: Presley Hansen

Present: N/A

Goals: Learn about the Optitrack motion capture system

Content:

- 3D motion capture software in the teaching lab is an OptiTrack Motion capture system.

- This system is a passive (retroreflective markers), optical (using markers and cameras) , motion capture system

- This method of motion capture is valid and reliable for tracking human movement and is known as the gold standard

- in-ground force plates used to track walking

- you will need a TA or instructor to assist you with data collection

- Raw coordinate and ground reaction force data is collected through OptiTrack and exported as a text file. This data is imported to OpenSim, fit to a musculoskeletal model, and kinematic data is exported (.mot file) with joint angles and position coordinates for each body segment.

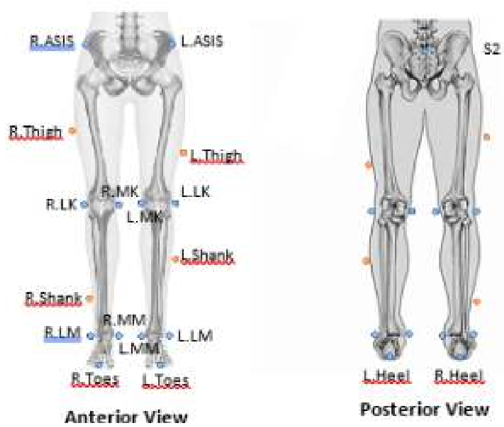


Figure 1: Marker placement locations

Marker Label	Related Segment	Description
R.ASIS L.ASIS	Pelvis	Anterior superior iliac spine
R.Thigh L.Thigh	Upper Leg	Place near the midline of the thigh. Used only for a tracking purpose of distinguishing left and right side. For best result, offset the height of the marker between left and right side.
R.Knee L.Knee	Upper Leg	Most lateral prominence of the lateral femoral epicondyle. Together with LM markers, it determines the location of knee joint axis.
R.Shank L.Shank	Lower Leg	Place near the midline of the shin. Used only for a tracking purpose of distinguishing left and right side. For best result, offset the height of the marker between left and right side.
R.LM L.LM	Lower Leg	Distal apex of the lateral malleolus.
R.MM L.MM	Foot	Distal apex of the medial malleolus.
R.Toes L.Toes	Foot	These markers are added on the distal phalanx only for the toe segment tracking purpose, and they are not included in the biomechanical analysis.
R.Heel L.Heel	Foot	Upper ridge of the calcaneus posterior surface. The aspect of the Achilles tendon insertion on the calcaneus.
S2	Pelvis	2nd Sacral vertebrae

Figure 5. Helen Hays Lower Body Markerset with visual representation of marker placement and associated description of placements and labels used.

Figure 2: Marker placement location descriptions

Conclusions/action items: Solidify dates for when the client is available to come for testing. Either reserve the motion capture machine/lab, or at least arrange a time with a instructor or TA to assist with data collection.

2025/03/18 - MTS Data Analysis

Presley Hansen - Mar 18, 2025, 4:20 PM CDT

Title: MTS Data Analysis

Date: 2025/03/18

Content by: Presley

Present: N/A

Goals: Put the MTS data into Matlab and make graphs of Stress vs Strain for the 3 different rigid supports

Content:

Figure 1: MTS Test Setup

Figure 2: 50% Fill Rigid Support After Failure

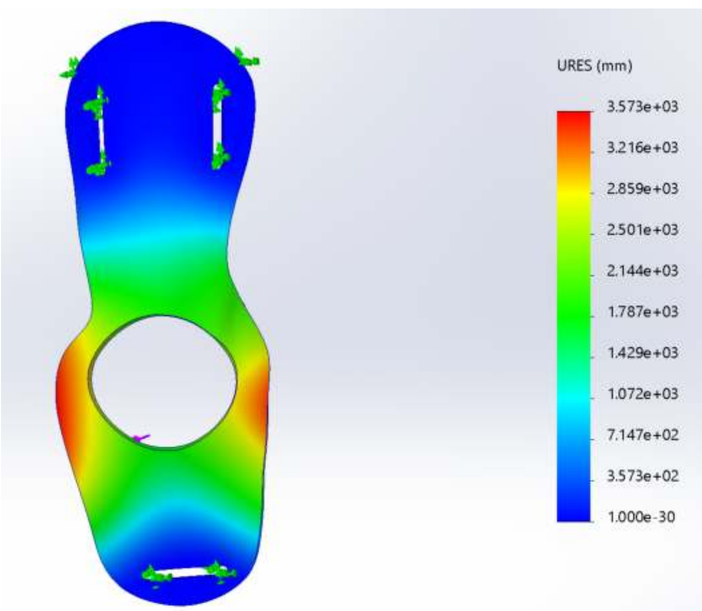


Figure 3: FEA Testing on Rigid Support Showing Weakest Areas in Red

Put the MTS raw data in the Matlab code below:

```
% Close figures and clear out other variables that have been assigned
```

```
close all;

clear all;

% Load your data file, replacing the '...' below with your filename

file_1 = "C:\Users\presl\Downloads\DAQ- Crosshead, … - (Timed) (7).txt";

data_1=readmatrix(file_1);


file_2 = "C:\Users\presl\Downloads\DAQ- Crosshead, … - (Timed) (8).txt"

data_2 =readmatrix(file_2);


file_3 = "C:\Users\presl\Downloads\DAQ- Crosshead, … - (Timed) (9).txt"

data_3 =readmatrix(file_3);


% Extract the columns of interest from your data

disp_1=data_1(:,1);

force_1=data_1(:,2);

time1=data_1(:,3);


disp_2=data_2(:,1);

force_2=data_2(:,2);

time2=data_2(:,3);


disp_3=data_3(:,1);

force_3=data_3(:,2);

time3=data_3(:,3);



% A = 28.178 mm^2


stress_1 = (force_1/28.178);
```

```
stress_2 = (force_2/28.178);

stress_3 = (force_3/28.178);


% L = 129 mm

strain_1 = (disp_1/129);

strain_2 = (disp_2/129);

strain_3 = (disp_3/129);


figure(1);

plot(strain_1, stress_1);

hold on;

plot(strain_2, stress_2);

hold on;

plot(strain_3, stress_3);

hold off;


title(' 3 Point Bending - Stress (MPa) vs. Strain (mm/mm) for 3 Rigid Supports');

xlabel('Strain (mm/mm)');

ylabel('Stress (MPa)');

legend('50% Fill', '35% Fill', '15% Fill');
```

After running the code, this Stress vs Strain curve appears for the 3 rigid supports tested with 15, 35, and 50 % fills.

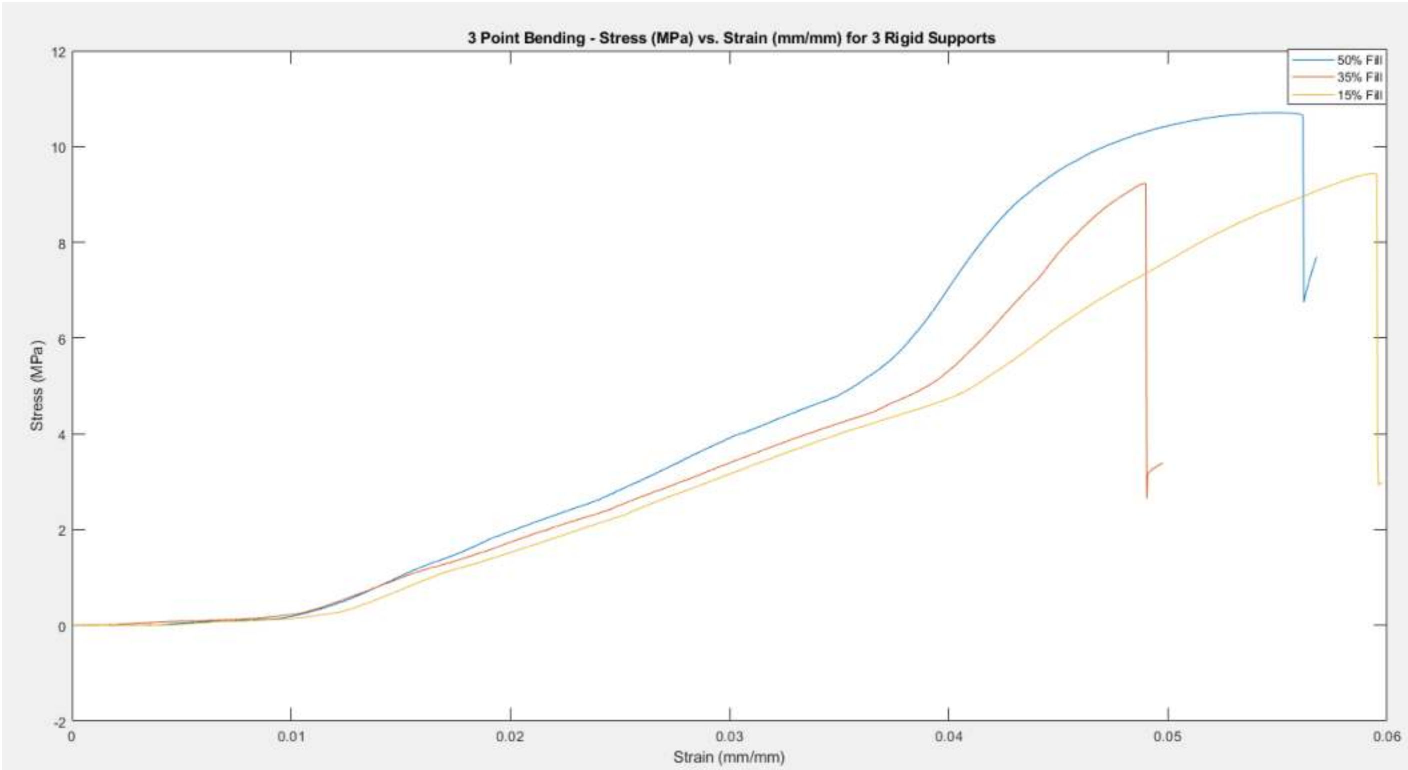


Figure 4: Stress vs Strain Curve for 3 Rigid Supports with Different Fill Percentages

From the graph in Figure 3, we can see that all three curves are almost identical, and therefore, the percent fill for the rigid support will not have a significant impact on the strength of the support. The ultimate stress for the 15, 35, and 50 % fills, respectively, are 10.71 MPa, 9.23 MPa, and 9.44 MPa. The 50% Fill does have the largest ultimate stress, but these values are all very similar and could have occurred to variance during testing. The ultimate strain for the 15, 35, and 50 % fills, respectively, are 0.0598, 0.0498, 0.0568. Using two points over the linear portions of the stress-strain curves, the elastic modulus of the 15, 35, and 50% were calculated as 163.82 MPa, 166.16 MPa, and 187.926 MPa, respectively. These values will vary slightly depending on which points are chosen from the linear portion of the curve. A higher elastic modulus indicates a material is stiffer, meaning it requires more force to deform elastically under stress, and will deform less for a given stress. The 50% fill has the highest elastic modulus of the three rigid supports. The material used in the rigid support was the PAHT-CF from the Bambu Lab printer, which offers 125 MPa strength, and 4230 MPa stiffness [1]. Our stress and stiffness (elastic modulus) values are much lower than what was described. The mechanical properties of 3D-printed parts depend heavily on print settings such as layer height, infill density, print orientation, nozzle temperature, and cooling rates. If the part was printed with a lower infill density, improper layer bonding, or in a weak orientation, it would not reach the material's theoretical strength. The maximum force that was placed of each part before breakage was 301.78 N, 260.15 N, 266.05 N, for the 15, 35, and 50 % respectively. According to earlier FEA testing, we had wanted a rigid support that would be able to withstand a force of 266 N or greater from the ankle. After doing the MTS 3 point bending test (asymmetrical loading with the load placed near the edge of the hole where the ankle would exert pressure), We found that the 50% and 15% fills were able to withstand a force of at least 266 N. The 35% fill was 6 N short of reaching this value, and this could be due to variance during testing or the 3D printing process. The 15, 35, and 50% fills were able to displace 7.72 mm, 6.42 mm, and 7.33 mm, respectively, before fracturing at a point near the edge of the hole for the ankle.

Take note that the gauge length of 129 mm has been approximated and may cause strain values that are slightly off. The gauge length was held consistent for the 3 rigid support trials, however, so the strain values in respect to the three trials are correct.

Citations:

[1] “Product Classification,” Fda.gov, 2024. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfPCD/classification.cfm?id=IQO (accessed Sep. 18, 2024).

Conclusions/action items: Analyzed elastic modulus, ultimate stress and strain, and force and displacement values for the 3 different rigid supports. Overall, the values were very similar, but the 50% fill had maximum values that indicates it will require more force and deform less for given stresses. The rigid support can support forces above 266 N, and will be able to prevent ankle inversion without breakage.

2025/03/18 - Anklebot

Presley Hansen - Mar 18, 2025, 11:17 PM CDT

Title: Anklebot helps determine ankle stiffness

Date: 2025/03/18

Content by: Presley Hansen

Present: N/A

Goals: To learn more about what the anklebot does

Content:

- a robot that measures the stiffness of the ankle in various directions

- The robot is mounted to a knee brace and connected to a custom-designed shoe. As a person moves his ankle, the robot moves the foot along a programmed trajectory, in different directions within the ankle's normal range of motion. Electrodes record the angular displacement and torque at the joint, which researchers use to calculate the ankle's stiffness.

- the ankle is strongest when moving up and down, weaker when tilting from side to side, and weakest when turning inward (most vulnerable to injury)

- Interestingly, measurements indicate that the motion of the ankle from side to side is independent of the ankle's up and down movement

- the Anklebot is designed to train and strengthen lower-extremity muscles, sensing a person's ankle strength and adjusting its force accordingly.

- Typically during the first few sessions, the robot does most of the work, moving the patient's ankle back and forth and side to side, loosening up the muscles. The robot senses when patients start to move their ankles on their own, and adapts by offering less assistance.

Figure 1: Anklebot being used on a patient

References:

https://news.mit.edu/2013/anklebot-helps-determine-ankle-stiffness-1024

Conclusions/action items: This robot measures the stiffness of the ankle in various directions and is used as a rehabilitation tool by moving the patient’s ankle back and forth and side to side, loosening up the muscles

01/26/2025 Common Types of Ankle Foot Orthosis

Kate Hiller - Jan 26, 2025, 11:22 AM CST


healthcare

Review

Commonly Used Types and Recent Development of Ankle-Foot Orthosis: A Narrative Review

1. Introduction

2. Conventional AFO Used in Clinical Practice

Download

AFO_REVIEW.pdf (1.47 MB)

Kate Hiller - Jan 26, 2025, 11:19 AM CST

Title: Common Types of Ankle Foot Orthosis

Date: 01/26/2025

Content by: Kate Hiller

Present: N/a

Goals: To learn AFO and the different types

Search Term: Pubmed: Ankle Foot Orthosis

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC8392067/

Citation:

Y. J. Choo and M. C. Chang, "Commonly Used Types and Recent Development of Ankle-Foot Orthosis: A Narrative Review," *Healthcare*, vol. 9, no. 8, p. 1046, Aug. 2021, doi: https://doi.org/10.3390/healthcare9081046.

Content:

- ankle-foot orthosis (AFO) is commonly prescribed to patients with a foot drop (like our client) or ankle/foot problems

- AFO is commonly used in patients having weakness in their ankle during dorsiflexion of plantar flexor muscle

-AFO prevents the foot from being dragged, during the swinging phase of gait clearance between the foot and the ground. Allows for stable posture by allowing heel contact with the ground during the stance phase

TYPICAL PLASTIC AFO (PAFO)

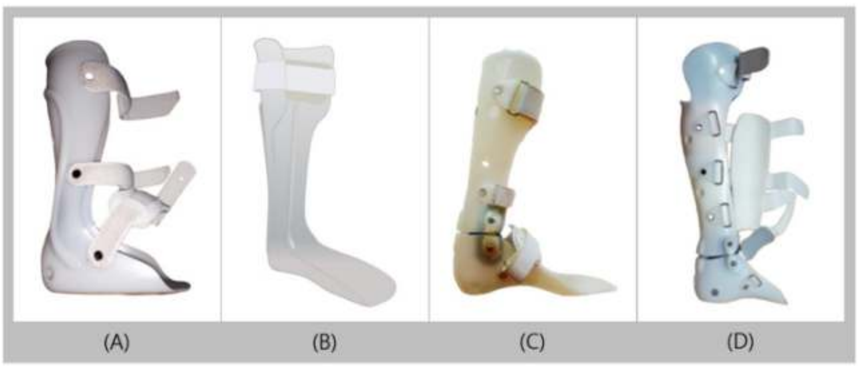
- thermoplastics: polypropylene [low cost, good aesthetics, easy clean, easy desorption (release of an adsorbed substance from a substance)]

- customized to patient

- make a positive plaster mold

- shank shell, foot plate, and velcro strap

- hinges not as common as solid ankle types



a) solid SAFO b) posterior leaf spring c) hinged AFO, d) patellor tendon-bearing AFO

SOLID AFO (SAFO)

- limit the ankle joint movement

- we don't want this one, the patient needs to be able to walk as normally as she can

- Posterior leaf spring orthosis (PLSO) (b in above image) is a SAFO but it has characteristically trim line located behind the ankle and had a leaf-shaped corrugation near the ankle

- "leaf-like creases are intended to strengthen the part of the ankle with the most amount of movement and repeated loadings"

- the creases act as a spring in the ankle to allow little dorsiflexion in mid and terminal stance

- limitations in controlling valgus/varus

HINGED AFO (HAFO)

- used when ankle movement is permitted but movement restrictions to a certain extent is required

- produced by using a hinge to connect two pieces,, hinges on the malleolus side

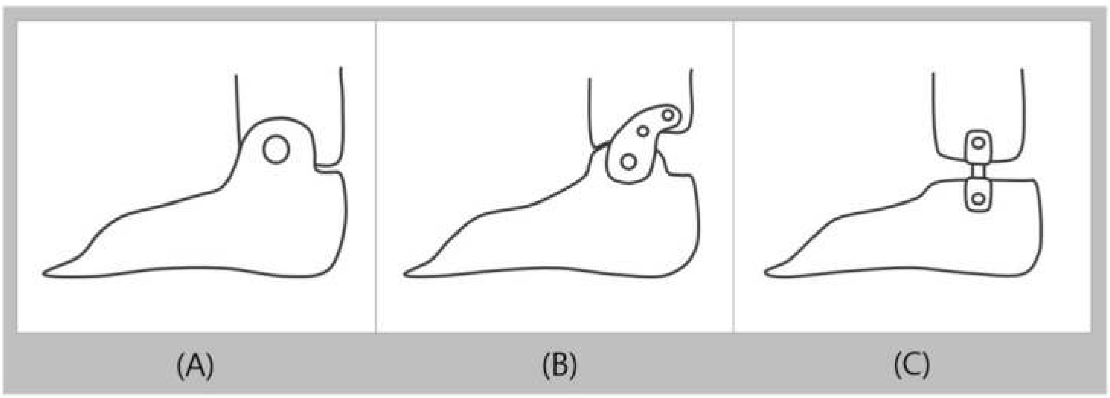
- hinge allows for dorsiflexion and makes it easier to walk on uneven surfaces

- increases ankle dorsiflexion in the terminal stance and increases ankle plantar flexion during the pre-swing phase (patients walk more naturally)

PAFO includes the overlap [limits plantar flexion by overlapping shank and foot shells, with rivett] Oklahoma [connects separate shank shell with the foot shell and back of the foot shell to allow for plantar flexion until the two pieces meet] , and Gillette joints [like Oklahoma, allows plantar flexion and dorsiflexion]

- HAFO widely used in children, presence of low muscle tone (hypotonia), high muscle tone (hypertonia), flexible pronation or supination, excessive plantar flexion

- only for patients with a sufficient control of their knee joints and should not be used for patients with severe mediolateral instability of the ankle



a) overplap b) Oklahoma c) gillette joints

- patellar tendon bearing AFO (PTB-AFO) has an additional anterior shell to support weight with the patellar tendon, which helps to reduce pain in each of the mentioned areas

- minimize pressure on the foot bc of ulcer, celcanectomy, plantar skin graft, fracture or severe trauma

- walking function in children with cerebral palsy was found to be improved when hinged AFO was used when compared to walking barefoot

WALKING BOOTS (controlled ankle movement)

WB is an orthosis that allows total contact with the anterior and posterior parts of the calf, ankle and entire foot

- has pneumatic (containing air/gas) blades can reduce edema and shear forces,

- they inflate to maintain stable surface contact between orthosis and the patient's skin

a) walking boot b) UD-Flex c) carbon fiber AFO

UD-FLEX

- is designed to be worn at the front of the floor, open heal

- allows for ankle bending

- open heel allows for the patient to receive foot ground reaction feedback when walking

- patients can use their proprioceptive sensibility, recognizing their walking pattern - more natural walking

- user needs to wear shoes larger than their normal size for PAFOs but not UD-FLEX

- constant state of 5 degrees of dorsiflexion, super light weight

- study found Bae at al. in 2009, UD-FLEX assists in dorsiflexion during the swing phase of walking and therefore has enabling effect on natural gait

CARBON FIBER AFO (CFAFO)

- high stiffness, tensile strength, resistance to high temperatures, low weight

- better based on energy storage capacity, light weight and durability

- not commonly used bc expensive

- solid ankle AFO or posterior leaf spring has a similar design but CFAFO has an open heel and thin shell to reduce the pressure exerted on the patient

- modern appearance

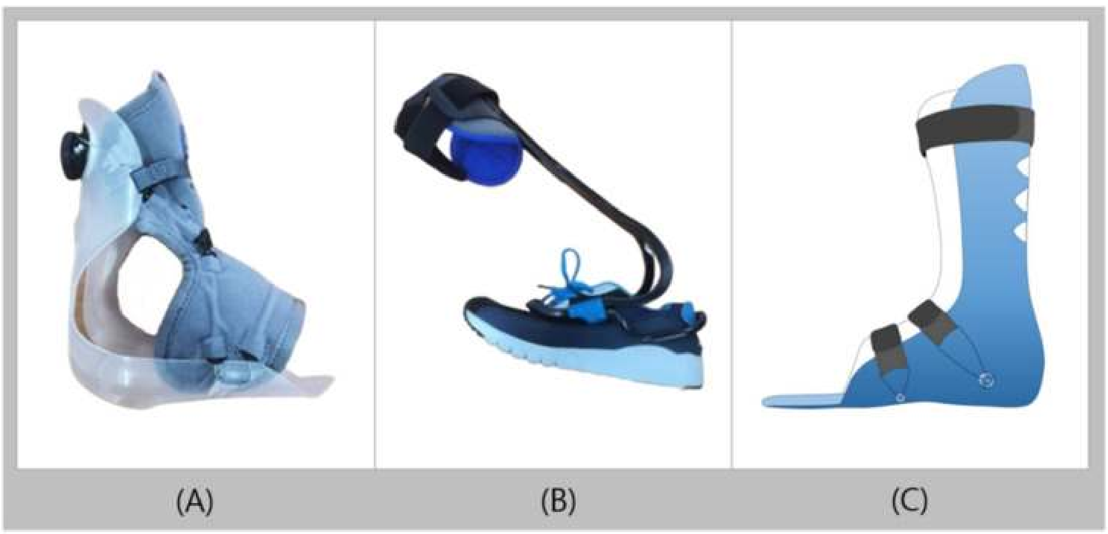
- used for foot-drop, Charcot-Marie-Tooth disease, and poliomyelitis, no spasticity is evident "n 2006, Desloovere et al. [46] compared the differences in ankle movements during walking using a CFAFO and without using a CFAFO (barefoot) in 15 children with hemiplegia. As a result, the angle at initial contact, range of motion during push-off, timing of maximum dorsiflexion in stance, angle at mid-swing, mean foot progression angle instance, and angular velocity at toe-off significantly improved when a CFAFO was worn, as compared with walking barefoot. This result signifies that the ankle range of motion improved when the participants walked using a CFAFO as compared with walking barefoot. " - overall CFAFO showed improvement on walking function

AF Servo, 2014 Europe

- BOA fit system - operating a dial

- for patients with mild foot drop, not for people who cannot raise their foot manually

- \



a) AFO Servo b) TruboMed c) 3D printed AFO

-TruboMed

- dynamic AFO to be attached to the exterior of various types of shoes

- most dorsiflexion power can be regained - restores elastic energy

- exoskeleton design

KENAF COMPOSITES

- made of natural fibers with strong durability that meets the minimum criteria for mechanical properties required for AFO

- kenaf is a woody base pant that is used as a composite

- absorbent that could reduce the possibility of skin irritation

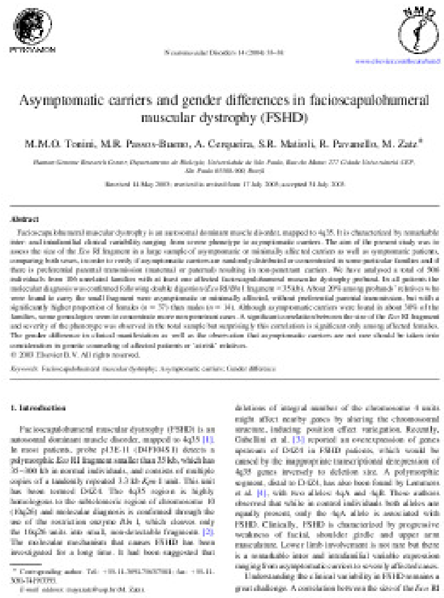
- need to reinforce with fiber with the matrix (resin) to improve durability

Conclusions/action items:

There are many different types of ankle-foot orthosis and some that are already on the market. I will need to do more research on AF Servo and TurboMed. Also, we need to find out how they are fabricated and the mechanics of the device. Additionally, I will need to look into another orthoses on the market. Our team should explore Carbon Fiber and an AFO with a hinge as we want the brace to be inconspicuous.

01/30/2025 Asymptomatic Carriers and gender differences in facioscapulohumeral muscular dystrophy (FSHD)

Kate Hiller - Jan 30, 2025, 10:29 AM CST



Asymptomatic carriers and gender differences in facioscapulohumeral muscular dystrophy (FSHD)

M.M.O. Tonini, M.R. Passos-Bueno, A. Cerqueira, S.R. Matioli, R. Pavanello, M. Zatz*

Abstract

1. Introduction

Download

gender_differences_FSHD.pdf (113 kB)

Kate Hiller - Jan 30, 2025, 10:29 AM CST

Title: Asymptomatic Carriers and gender differences in facioscapulohumeral muscular dystrophy (FSHD)

Date: 01/30/2025

Content by: Kate Hiller

Present: N/a

Goals:

Search Term: The Journal was cited in a literature review article found on PubMed "`Statland, Jeffrey M, and Rabi Tawil. "Facioscapulohumeral Muscular Dystrophy."` *`Continuum (Minneapolis, Minn.)`* `vol. 22,6, Muscle and Neuromuscular Junction Disorders (2016): 1916-1931. doi:10.1212/CON.0000000000000399"` This would be useful to look at in the future.

Link: **https://pmc.ncbi.nlm.nih.gov/articles/PMC8392067/**

Citation:

M. M. O. Tonini, M. R. Passos-Bueno, A. Cerqueira, S. R. Matioli, R. Pavanello, and M. Zatz, "Asymptomatic carriers and gender differences in facioscapulohumeral muscular dystrophy (FSHD)," *Neuromuscular disorders : NMD*, vol. 14, no. 1, pp. 33–8, Jan. 2004, doi: https://doi.org/10.1016/j.nmd.2003.07.001.

Content:

Facioscapulohumeral dystrophy is an autosomal dominant muscle disorder, mapped to 4q35 on chromosome 4

- FSHD is progressive weakness of the facial, shoulder girdle, upper arm musculature, and lower limb

- polymorphic Eco RI fragment is smaller than 35kb [kilobase], whereas in normal individuals the size is 35-300kb and multiple copies

-overexpression of genes upstream of D4Z4 in FSHD patients

- 4q35 on chromosome 4 is over-expressed when they should be turned off

- 4qA allele is associated with FSHD as well

What is this study conducting?

-characterized by inter- and intrafamilial clinical variability ranging from severe phenotype or asymptomatic carriers

- "This study compared asymptomatic or minimally affected carriers to symptomatic patients: comparing sexes- to verify if the asymptomatic carriers are randomly distributed or concentrated in some particular families and if there are preferential parental transmissions (maternal or paternal) resulting in non-penetrant carriers"

- assess the size of the Eco RI fragment

- 506 individuals form 106 unrelated families w/ at least one affected FSHD proband [individual affected by a genetic condition or concerned they are at risk]

- subjects >30 yrs old, severely affected was wheelchair confinement or severe childhood-onset

Findings

- 238 individuals of 506 carry a small ECO RI/Bln fragment with no gender differences

Table 1
Analysis of *Eco* RI fragment and clinical severity in 238 FSHD patients

Clinical severity	*N* Males: Females	Mean age (SD)			Mean *Eco* RI fragment size (kb)			Range (kb)
		Male	Female	Total	Male	Female	Total	
Group 1	14:37	58.8*(15.6)	50.9*(13.7)	53.1(14.5)	22.6(4.7)	23.9(5.3)	23.5^{a}(5.1)	12–35
Group 2	79:66	30.8^{c}(11.2)	38.7^{d}(12.4)	34.4(12.3)	21.6(4.9)	22.2(5.1)	$21.9^{a,b}$(5.0)	12–35
Group 3	20:22	17.2(16.0)	24.4(20.2)	21.0(18.5)	19.8(5.0)	19.8(6.4)	19.7^{b}(5.7)	10–33
Total	113:125	31.9^{c}(16.9)	39.8^{d}(16.8)	36.0(17.3)	21.4(4.9)	22.3(5.5)	21.9(5.3)	10–35

Different letters are assigned to groups with significant differences between means at the 5% level (a and b for fragment size comparisons among severity groups; c and d for mean age comparisons between sexes). These letters correspond to the results of ANOVA and the Tukey–Kramer tests. *In the asymptomatic group there is an ascertainment bias, because only individuals older than 30 years were included in the sample.

FSHD patients were classifies into 3 groups based on severity

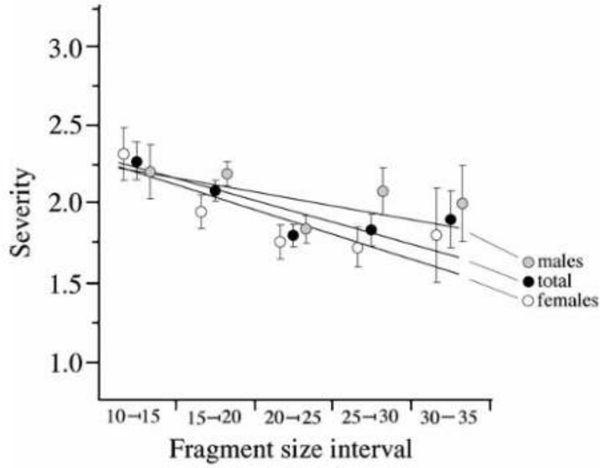


Fig. 1. Mean clinical severity and mean *Eco* RI fragment sizes. The correlation between the variables was significant in females ($r = -0.251$, $P < 0.005$) and in the total sample ($r = -0.225$, $P < 0.0001$), but not in the male sample ($r = -0.162$, $P > 0.05$). The lines correspond to the linear regression between fragment sizes and severity of individuals in the considered groups (total, males, and females samples). The dots correspond to the means of severity in the intervals of the horizontal axis and the bars represent the standard errors.

fragment size and phenotype severity had a significant correlation for all patients seperated in the clinicall classifies groups. This graph shows the correlation of small fragment size-> **higher severity no significant correlation was found for males**

- the smallest fragments tend to be found among

Mosiac [
"individual who has a genetic mutation present in some of their cells but not in all"] or isolated cases-- not familial cases

-20% of proband's relatives who were found to carry the Eco RI fragment were asymptomatic or minimally affected, w/out preferential parental transmission [where a trait is more frequently inherited from one parent (maternal/paternal), not equally passed down

** higher proportion of females (n=37) carried this fragment than males (n=14)

- asymptomatic carriers were found in 30% of families

- **there is a higher number of individuals that are carriers but do not show symptoms**

- a significan**t correlation was found between the size of Eco RI fragment and severity of the phenotype** (physical symptoms) seen in the total sample, but **only affected females was the correlation significant**

- in genetic counseling of affected patients or "at risk" relatives should take into account gender differences

- was found that Brazilian FSHD families have a significantly greater proportion of females who remain asymptomatic or minimally affected

-there are two type FSHD 1 and FSHD 2

[Zatz M, Marie SK, Cerqueira A, Vainzof M, Pavanello RC, Passos Bueno MR. The facioscapulohumeral muscular dystrophy (FSHD1) affects males more severely and more frequently than females. Am J Med Genet 1998;77:155–61.] **this was from 1999 however

Males vs. Females

- in the study, the proportion of males and females did not differ in regards of inheriting abnormal fragments

- the mean size of ECO RI did not differ in males compared to females in any group or whole sample

-Maarel et. all [van der Maarel S, Deidda G, Lemmers RJ, et al. Padberg GW, Frants RR. De novo facioscapulohumeral muscular dystrophy: frequent somatic mosaicism, gender-dependent phenotype and the role of mitotic transchromosomal repeat interaction between chromosomes 4 and 10. Am J Hum Genet 2000;66(1):26–35.] reported gender differences among mosiac cases, more significant for males than females

- mosaic males were typically affected while mosaic females were asymptomatic

Asymptomatic carriers

- size of family needs to be taken into account

- t**he observation of some genealogies with multiple asymptomatic carriers supports the hypothesis that epigenetic mechanisms (gene modification) protect individuals from the poor effects of the FSHD allele is more common in some families**

Parental Transmission

- it was found that in severe cases and children of mosaic patients who are not infrequent cases are more **often maternal inherited-** found in this study and others 54.8% maternally inherited, 16.1% paternal inherited

- **no significant correlation between in mean fragment size of maternal and paternal inheritance**

Conclusions

- 20% of relatives to FSHD patients who carry a deleted ECO RI fragment remain asymptomatic or minally affected with a higher proportion of female than males

-Asymptomatic carriers were found in about 30% of the families.

-A significant correlation between the size of the Eco RI fragment and the severity of the phenotype was observed in the total sample. ** only significant for females, not males--- other genetic or epigenetic mechanisms cause the severity of the phenotype

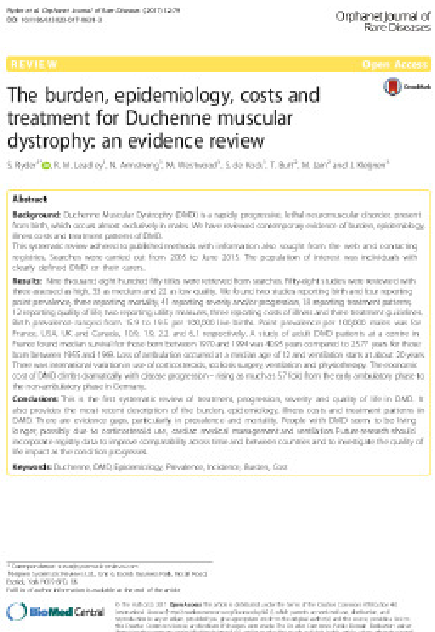
- need to consider gender for FSHD for genetic counseling

Conclusions/action items:

This study was extremely informative on what exactly causes FSHD and how phenotype severity and fragment size are related. They study families with at least one FSHD patient. Some main findings include 20% of individuals who carry a deleted ECO RI fragment remain asymptomatic or minimally affected with a significantly higher proportion of females than males. They found that there is no observation of transmission more from mother or father. Asymptomatic carriers were found in 30% of families. Lastly, a correlation between fragment size and severity of phenotype was found for the total sample and only statistically significant for females and not males. Next, I need to look at the environmental impact of FSHD or our AFO brace and look into the cited articles.

01/30/2025 Economic Burden of Muscular Dystrophy

Kate Hiller - Jan 30, 2025, 7:02 PM CST


Orphanet Journal of Rare Diseases

REVIEW Open Access

The burden, epidemiology, costs and treatment for Duchenne muscular dystrophy: an evidence review

Abstract

Keywords: Duchenne, DMD, Epidemiology, Prevalence, Incidence, Burden, Cost

Download

economic_burdens.pdf (1.28 MB)

Kate Hiller - Jan 30, 2025, 7:02 PM CST

Title: Economic Burden of Muscular Dystrophy

Date: 01/30/2025

Content by: Kate Hiller

Present: N/a

Goals: To learn about the economic burdens of Muscular Dystrophy disorders

Search Term: Pubmed: Economic Burden of FSHD

Link:
https://pmc.ncbi.nlm.nih.gov/articles/PMC4141999/#:~:text=The%20total%20societal%20burden%20was,at%20between%20%2458%2C440%20and%20%2471%2C900.

Citation:

E. Landfeldt *et al.*, “The burden of Duchenne muscular dystrophy: An international, cross-sectional study,” *Neurology*, vol. 83, no. 6, pp. 529–536, Jul. 2014, doi: https://doi.org/10.1212/wnl.0000000000000669.

Content:

evidence review: https://pubmed.ncbi.nlm.nih.gov/28446219/

** This article is specifically on Duchenne Muscular Dystrophy, however, FSHD is still a Muscular Dystrophy (muscle degeneration disorder. Therefore, we can look at the economic burdens of DMD as they should be similar to FSHD

- The main difference between DMD is that is more common in males and appears at birth

Objective

This study analyzes the total cost of the illness and the economic burden of DMD

Who were they studying?

- they gather data from patients from Germany, Italy, UK, and the US. They contacted patients through Translational Research in Europe-Assessment and Treatment of Neuromuscular Diseases registries and invited them to complete a questionnaire online.

They used health care use, quality of life, work status, informal care, and household expenses to estimate the cost of DMD from the perspective of society and caregiver households

- wanted to look past just direct medical costs

STATS

1 in 2,000 [Europe] and 1 in 1,250 [US] are affected by rare diseases -- these diseases are commonly life-threatening and chronic

study criteria

patients needed to fit this criteria:

1) male

2) DMD diagnosis

3) age 5 or older

- patients were divided into 4 groups based on age and ambulatory status [ability to walk and move around independently] 1- young and early to 4- late and 16yrs or older

Analysis

cost of care: calculated from a societal perspective nads assuming subjects use a similar amount of resources for any given period--accounting for country-specific prices

Indirect cost: (societal loss of production) estimated productivity loss due to unemployment or impaired productivity while working

intangible costs: (pain, anxiety, social handicap) assigned monetary value to loss of quality of life for patients in relation to age and sex-specific mean quality of life to the general population.

- this study used $75,000 for a willingness-to-pay for a quality-adjusted life-year

- calculated each hour of informal care --Human Capital Approach looks at leisure time and was valued as 35% of country-specific national mean gross wage

-The economic burden on the household for caring for a boy with DMD was calculated for caregiver households.

- estimated loss of household income as a result of working fewer hours or having to stop work completely

Results

42% response rate (770 completed out of 2,346 patients invited)

Table 1 Demographic characteristics of the study participants (n = 770 patient-caregiver pairs)

	Germany	Italy	United Kingdom	United States
Patients				
No. (%)	173 (100)	122 (100)	191 (100)	284 (100)
Age, y	13 (9-17)	12 (8-17)	12 (8-17)	12 (9-17)
Ambulatory class, n (%)				
Early ambulatory (age 5-7 y)[a]	30 (17)	31 (25)	46 (24)	48 (17)
Late ambulatory (age 8-11 y)[a]	49 (28)	35 (29)	62 (32)	110 (39)
Early nonambulatory (age 12-15 y)[b]	47 (27)	24 (20)	34 (18)	49 (17)
Late nonambulatory (age 16 y or older)[b]	47 (27)	32 (26)	49 (26)	77 (27)
Ventilation support, n (%)	26 (15)	24 (20)	35 (18)	41 (14)
Caregivers				
No. (%)	173 (100)	122 (100)	191 (100)	284 (100)
Sex, male, n (%)	28 (16)	42 (34)	41 (21)	50 (18)
Age, y	45 (40-49)	45 (41-50)	44 (39-50)	43 (39-50)
Relationship to the patient, n (%)				
Parent to the patient	169 (98)	121 (99)	188 (98)	275 (97)
Other relative of the patient	3 (2)	1 (1)	3 (2)	7 (2)
Friend or partner of the patient	1 (<1)	0 (0)	0 (0)	2 (<1)
Employed, n (%)	102 (59)	73 (60)	105 (55)	189 (67)
Reduced working hours or stopped working completely because of relative's DMD, n (%)	74 (43)	35 (29)	93 (49)	77 (27)

Data presented as n (%) or as median (interquartile range)

- patients used a wide variety of healthcare resources (medical devices, aids, medications, tests, assessments and admissions to hospitals.

- large number of physician visits and other health care practitioners [physiotherapists]

-informal care was extensive in all countries [caregivers' non-paid care and their leisure time devoted to providing care]

-only <4% were part of the workforce and caregivers had to reduce their hours or stop working

- the mean loss in work time and productivity while working was:

20% germans | 24% Italian | 29% UK | 27% US

Table 2 **Per-patient annual costs of DMD (in 2012 international dollars)**

	Germany	Italy	United Kingdom	United States
Hospital admissions[a]	2,080 (1,020-4,950)	1,420 (900-2,470)	2,300 (1,500-3,720)	2,220 (900-5,050)
Visits to physicians and other health care practitioners	3,850 (3,410-4,340)	2,590 (1,970-3,440)	8,230 (6,360-13,150)	18,210 (15,450-22,260)
Nurse	40 (10-80)	40 (10-220)	550 (300-1,160)	1,270 (650-2,530)
General practitioner	110 (80-160)	40 (30-60)	340 (220-670)	230 (180-340)
Specialist physician	330 (280-410)	170 (130-240)	3,290 (2,380-7,100)	3,730 (3,140-4,840)
Psychologist or therapist	50 (30-110)	50 (30-120)	160 (80-390)	720 (430-1,220)
Physiotherapist or occupational therapist	2,810 (2,480-3,180)	2,210 (1,610-3,020)	3,290 (2,420-5,820)	9,920 (8,220-12,030)
Other health care practitioner[b]	500 (360-700)	70 (50-120)	600 (370-1,400)	2,350 (1,740-3,200)
Tests and assessments	2,400 (2,180-2,680)	600 (530-690)	1,580 (1,450-1,750)	2,860 (2,660-3,070)
Medications	1,020 (770-2,000)	1,550 (890-4,650)	930 (820-1,070)	2,070 (1,720-2,710)
Nonmedical community services[c]	8,920 (6,890-12,400)	2,740 (1,640-5,380)	19,250 (13,240-28,670)	7,610 (6,030-9,790)
Aids, devices, and investments[d]	5,560 (4,160-7,460)	1,850 (970-4,450)	7,520 (5,690-9,790)	7,930 (6,210-10,260)
Informal care	18,530 (16,440-20,580)	13,160 (11,270-15,280)	14,340 (13,030-15,990)	13,370 (12,060-14,930)
Total direct cost of illness	42,360 (38,640-46,880)	23,920 (20,420-28,300)	54,160 (47,310-63,510)	54,270 (48,740-62,220)
Indirect cost of illness (production losses)	20,770 (17,670-24,250)	18,220 (15,430-21,380)	18,700 (16,280-21,150)	21,550 (18,490-24,720)
Total annual cost of illness	63,140 (57,600-69,710)	42,140 (36,940-47,730)	72,870 (64,350-84,150)	75,820 (69,350-85,270)
Intangible costs	45,860 (41,630-50,160)	37,980 (32,400-43,550)	46,080 (42,360-50,050)	45,080 (41,100-48,260)
Total burden of illness	109,000 (100,390-119,510)	80,120 (71,030-89,190)	118,950 (108,280-132,710)	120,910 (111,460-130,770)

per patient annual costs of DMD (2012)

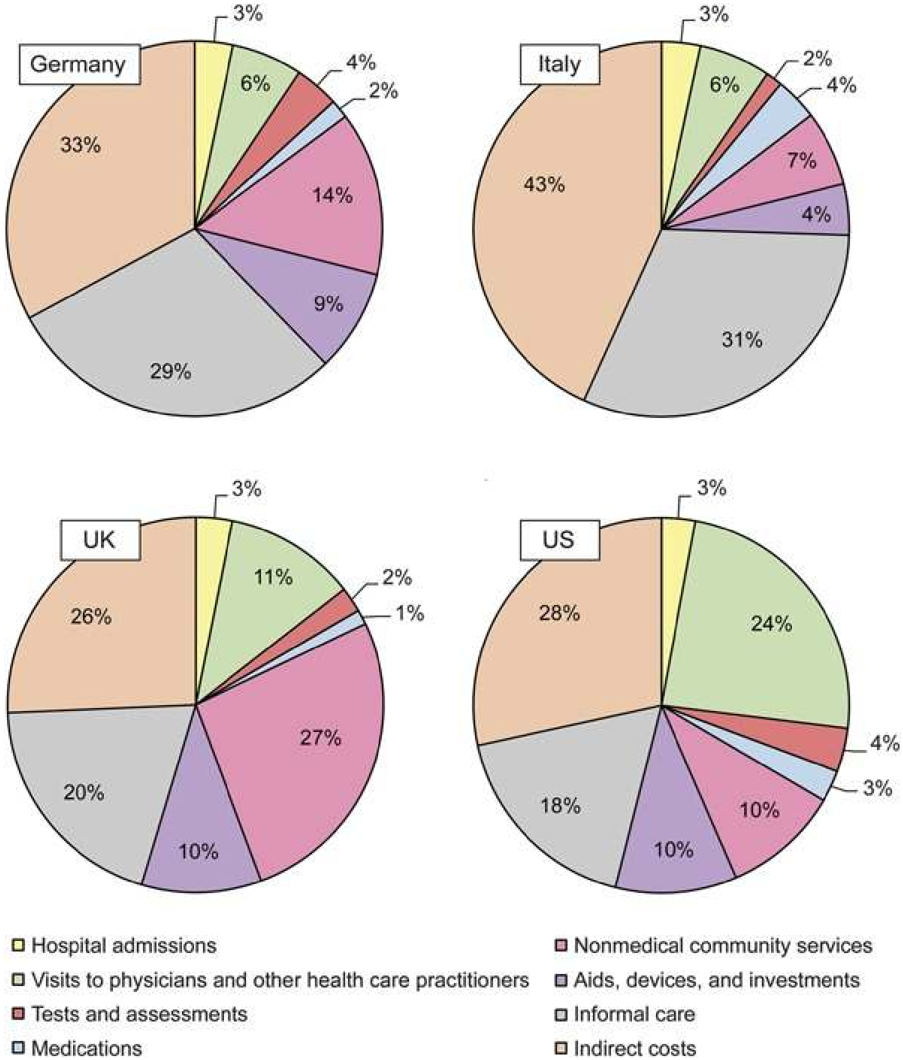
Mean per patient annual direct medical cost:

Germany: $11,240

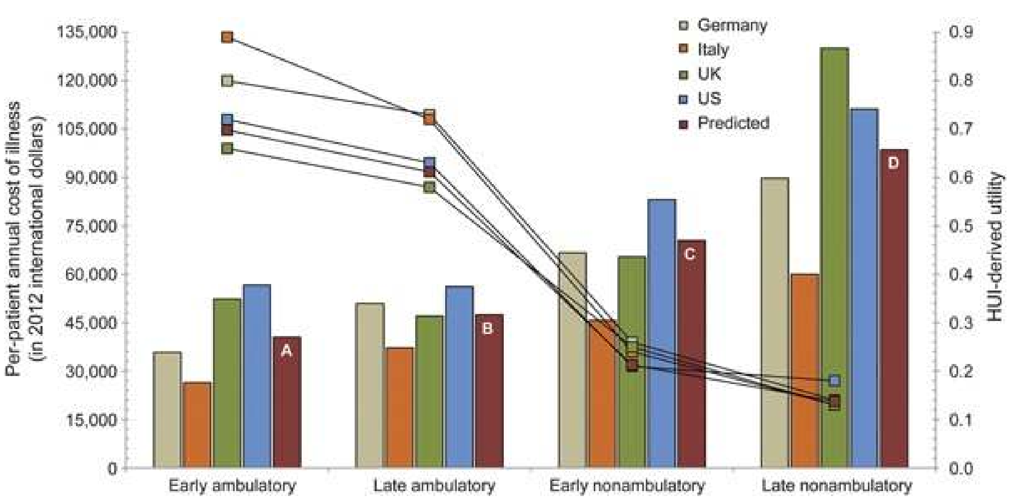
Italian: $7,300

UK: $15,940

US: $28,590



This includes emergency and respite care, personal assistants, nannies, and transportation services, wheelchair adaptability home reconstructions, devices



Mean per-patient annual cost (bar graph) or illness and mean proxy-assessed patient utility (connected markers)

HUI-derived utility is a health-related quality of life score calculated using Health Utilities Index

Quality of life: [intangible costs]:

mean proxy-assessed Health Utilities Index-derived utility for patients [0 indicates death, 1 perfect health]

Germany: 0.45

Italy: 0.52

Uk: 0.43

US: 0.45

respectively the mean index for caregivers: 0.79, 0.84, 0.82, 0.81

Total Economic Burden of Illness [including patient and caregiver quality of life]

Germany: $278,058,000

Italy: $154,465,00

UK: $200,478,000

US: $1,217,373,000

Table 3 **Per-patient annual household burden of DMD (in 2012 international dollars)**

	Germany	Italy	United Kingdom	United States
No. (%) living with caregiver	165 (95)	121 (99)	188 (98)	280 (99)
Total out-of-pocket payments	5,940 (4,240-8,990)	7,550 (3,600-16,470)	3,490 (2,220-5,570)	14,390 (10,300-22,970)
Insurance premiums	150 (60-290)	10 (0-30)	10 (0-30)	6,210 (2,820-14,580)
Copayments for medical services	90 (60-140)	1,160 (130-450)	60 (30-140)	930 (750-1,140)
Copayments for medications	490 (240-1,450)	1,490 (350-4,440)	100 (60-140)	1,470 (1,120-2,070)
Copayments for community services	380 (190-870)	650 (300-2,480)	140 (60-290)	710 (360-1,630)
Out-of-pocket payments for investments[a]	4,830 (3,150-7,670)	4,250 (480-2,350)	3,180 (2,020-5,710)	5,060 (3,130-8,540)
Income loss	1,190 (730-1,880)	620 (310-1,130)	750 (440-1,200)	840 (500-1,360)
Loss of leisure time	17,910 (16,210-20,110)	12,440 (10,710-14,980)	13,590 (12,410-14,980)	11,700 (10,520-12,630)
Intangible costs	45,160 (40,650-49,850)	37,830 (30,220-41,760)	45,770 (42,070-49,670)	45,080 (41,100-48,260)
Total per-patient annual household burden	70,190 (63,760-76,830)	58,440 (50,200-68,900)	63,600 (58,790-68,370)	71,900 (65,520-81,520)

Abbreviation: DMD = Duchenne muscular dystrophy.
Data presented as mean (95% confidence interval), rounded to nearest 10, if not otherwise stated.
[a] Include nonreimbursed payments for medical and nonmedical aids and devices, as well as investments to and reconstructions of the home (e.g., adaptations for wheelchair accessibility).

Per-patient annual household burden of DMD in monetary values

- Italy significantly less because of lower resource use and tariff prices

- other studies found US to be around $24,000 for annual direct medical costs

- estimated the total societal burden at between $80,120 and $120,910

Conclusions/action items:

This study compared international economic burdens of muscular dystrophy, specifically the US, UK, Germany, and Italy. The US had the highest annual medical costs at $28,590. The quality of life scores were lower for patients than for caregivers. Total economic burden varies from $154M (ITALY) to $1.2B (US). The estimated per-patient financial burden was $80,000-$120,000. This information is important to our project as it is important to create cost-effective medical treatments to relieve financial burdens and increase quality of life.

01/30/2025 Epigenetic Factors

Kate Hiller - Jan 30, 2025, 7:55 PM CST

Title: Epigenetic Factors

Date: 01/30/2025

Content by: Kate Hiller

Present: N/a

Goals: To learn about how environmental factors affect FSHD and its severity

Search Term: NIH

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC4432493/

Citation:

C. L. Himeda, T. I. Jones, and P. L. Jones, "Facioscapulohumeral Muscular Dystrophy As a Model for Epigenetic Regulation and Disease," *Antioxidants & redox signaling*, vol. 22, no. 16, pp. 1463–1482, Jun. 2015, doi: https://doi.org/10.1089/ars.2014.6090.

Content:

Personally, I have learned a little about epigenetics in biology and how environmental factors like ancestors and the environment that someone grows up in affect gene expression.

They were researching how does genetic background and environmental factors affect the severity, progression, and manifestation of the disease

FSHD is primarily an epigenetic disease

DUX4-fl is a therapeutic drug with insufficient evidence that its expression alone in adult skeletal muscle is enough to cause to block the disease

They used mouse models- but there are limitations because DUX4-fl is primate-specific

- they found that mutations in epigenetic regulators lead to FSHD

- Monozygotic twin studies show phenotypic variability, showing non-genetic influences like epigenetic regulation and environmental factors.

- the twin studies also found that environmental factors help influence penetrance nad severity

-oxidative stress, inflammation, and physical activity may interact with epigenetic mechanisms to influence FSHD progression

- environmental and genetic factors can change epigenetic state that was established during development

- environmental factors have proven to drive major epigenetic changes like fetal alcohol syndrome

- maternal diet can affect methylation and expression of metastable epiallele in mice

"This high variability within the clinical spectrum suggests that multiple genetic, epigenetic, developmental, and environmental factors likely play integral roles in the development and progression of FSHD pathology."

Conclusions/action items:

FSHD is an epigenetic disease in which genetic background and environmental factors can influence the onset and severity of the disease. The researchers found that mutations in the epigenetic regulators play a part in the onset of FSHD. They explored blocking DUX4-fl expression as a therapeutic therapy to stop the progression of the disease, but there was not enough evidence to conclude if it was true or not. Some environmental factors that could affect FSHD and other epigenetic diseases are oxidative stress levels, physical activity, and inflammation. Next, further research should be looked into FSHD and environmental safety.

2/7/2025 Reviewing Previous Semester Work

Kate Hiller - Feb 11, 2025, 5:21 PM CST

Inconspicuous Ankle Foot Orthosis (AFO) for teen

FINAL REPORT

Fall 2024 BME 200/300 Lab 304

Team Name:
AFO Group

Team Members:
Anya Hadim (Team Leader)
Lucy Hockerman (BSAC)
Presley Hansen (Communicator)
Alex Conover (BPAG)
Grace Neuville (BWIG)

Client
Debbie Eggleston

Advisor:
Dr. Brandon Coventry

11 December, 2024

1

Download

Team_AFO_Group_Final_Report.pdf (6.34 MB)

Kate Hiller - Feb 11, 2025, 5:21 PM CST

Title: Reviewing Previous Semester Work

Date: 2/7/2025

Content by: Kate

Present: N/a

Goals: To review all the work completed by the previous team by reading their Final Report

Content:

Client Info:

The client was Debbie Eggleston who is a physical therapist and activist for FSHD/

- They used to work with U of Michigan to diagnose the patient

- The prototype budget was $300 dollars

PDS

- Strap brace Design

- Bungee Brace - this is the one they went with

- The design features a rotator dial with a bungee cord to adjust the dorsal angle

- The device looks similar to an athletic brace so it fits the inconspicuous ankle design

- Hinge Design

Criteria: Support, Discreetness, Safety, Flexibility, Ease of Attachment and Removal, Customizability, cost, and Ease of Manufacture

- they tried to create their design in SolidWorks, but it proved to be very difficult

Material Desing:

- their final design consisted of 6 different designs

FOOT SLEEVE: blend of nylon, polyester, and latex --- compression sleeve, it will absorb sweat

Nylon is selected for its low elongation, strength, high-temp resistance, and light weight

Latex: flexible, durability, strength

Polyester: durability and strength

- supportive piece was made out of PLA reinforced with carbon fiber, having properties of being lightweight, sturdy, thin profile, superior energy return capabilities.

Proposed Final Design

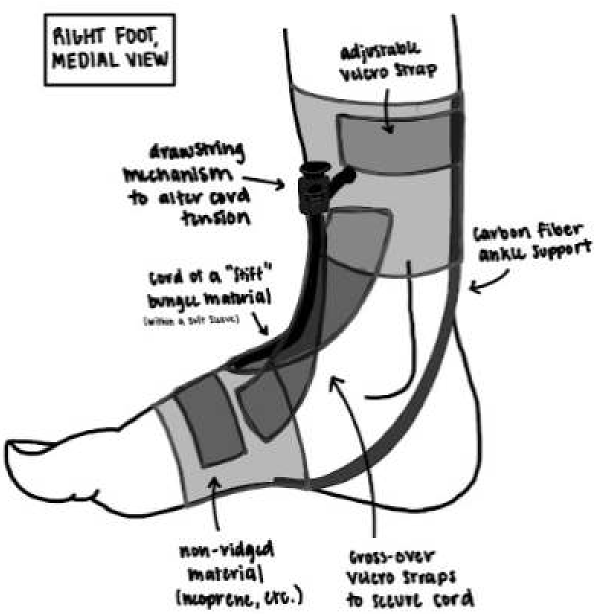


Figure 8: Proposed Final Design Sketch

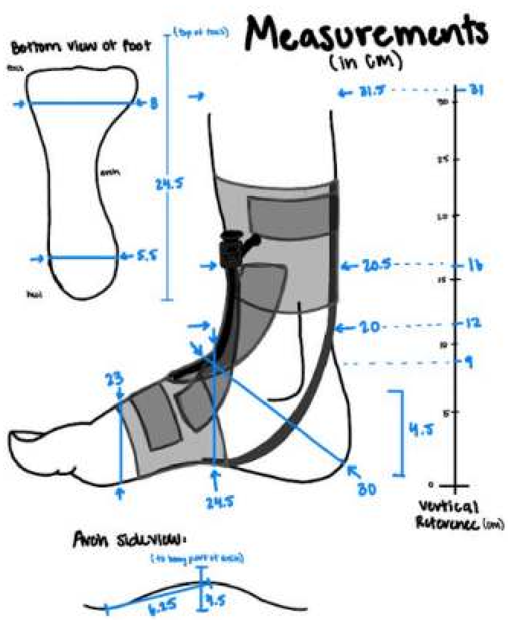


Figure 9: Proposed Final Design

This is the final designed they fabricated

- carbon fiber AFOs are capable of supporting 1,000 N, but very expensive

- The bungee component aspect of the design includes 100lb max tensile strength at 1/8 in diameter. Materials include nylon, polyester, and latex

Methods:

- SolidWorks for the rigid piece and then 3D printed using Bambu Labs printer

- initial testing in SolidWorks (strength, functionality)

- There is a gel-padded compression sock will remain separate from the rigid support

- They have a white cast of the patient's foot that was used as a reference for fabricating the brace

Final Prototype

Figure 12: *Bungee Brace*

Components of the Final design:

compression sock, gel pads (at key pressure points) for comfort, nylon-reinforced carbon fiber, LockLace system

The rigid support origin is behind the calf, around the ankle bone, and terminates at the end of the ankle bone

The velcro straps are to be adjusted to secure the entire brace around the ankle

TESTING

1) testing of the max tensile strength of the bungee cords to pick which bungee cord will be used in the design. Results: thicker diameter had max tensile strength of 176lb and was chosen

2) SimulationXPress Analysis Wizard in SolidWorks to evaluate structural integrity of the 3d-printed PLA +CF prototype. Failure of the material was deemed unlikely

3) Assessing Effects on a Healthy Individual using Runesi and a IMU clipped to the back of the subject for biomechanical analysis. They evaluated Dynamic instability, ground time contact, impact magnitude, cadence (number of steps a person takes per minute), and the gait cycle of the subject over time.

- they found that in their design the cord-lock system had slipped when they compared dorsiflexion angles from the beginning and end of the gait analysis testing

- the testing subject was a teammate and she noted a high comfort level and discomfort arose from the compression sleeve and not the rigid support

4) Bayesian Estimation Statistics used to find a credible interval for the data collected

Conclusions/action items:

This review of the past semester's final report was very informative in understanding the limitations and successes of the previous semester. I learned what worked and didn't work and I can now use this knowledge to improve and move forward with this semester's design process.

2/18/2025 Foot Drop Simulator

Kate Hille

Title: Foot Drop Simulator

Date: 2/18/2025

Content by: Kate

Present: n/a

Goals: To learn about gait and foot drop

Reference:

“Access Library Resource — UW–Madison Libraries,” *Wisc.edu*, 2025. https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S1350453316301230?vi
18, 2025).

Content:

-This study was focusing on foot drop patients who experienced a stroke

- interested in their foot drop analysis and terminology to better understand for our testing

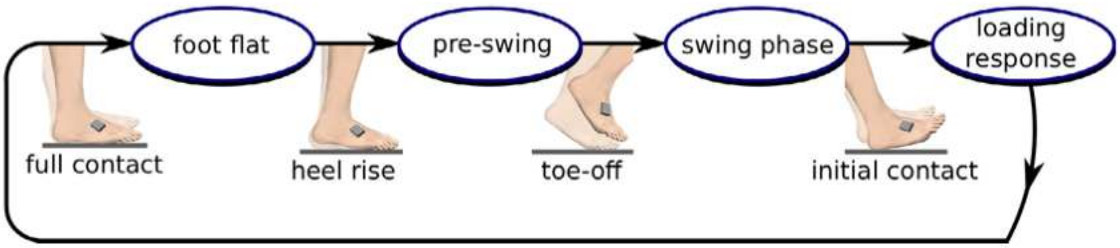
- foot drop leads to pathiological gait with an increased risk of fall

- treatment for foot drop is lifted (dorsiflexed) position by an orthosis

- this promotes muscle atrophy and joint stiffness

- this study was using FES (electrical stimulation) instead of orthosis

foot inversion, eversion, and pitch angles



4 stages of gait cycle the study was looking at

Fig. 3. Definition of the foot pitch angle (corresponding to dorsiflexion) and the foot roll angle (corresponding to eversion/inversion) of the foot. Note that both angles are defined with respect to level ground and that their signs are defined such that both the pitch and the roll angle of the patients are smaller than those of healthy subjects at the same moment of swing phase.

Roll angle and pitch angle could be something we look at for testing analysis: comparing inital angles to angle with the brace

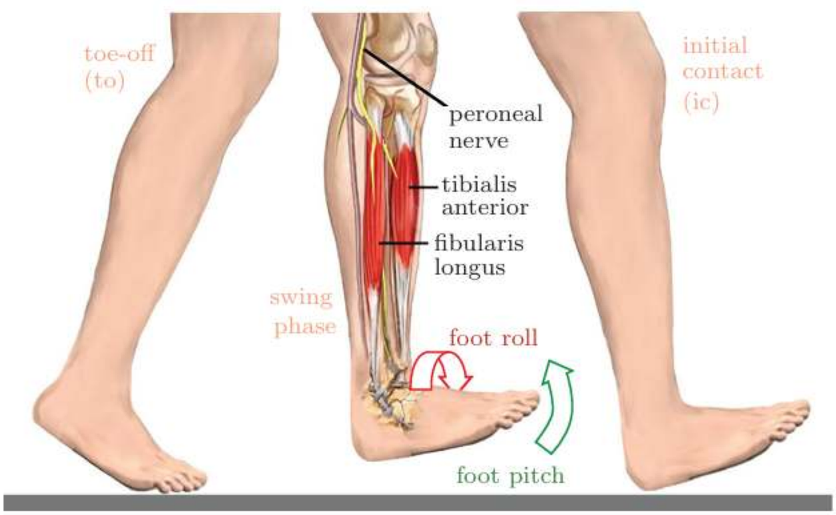
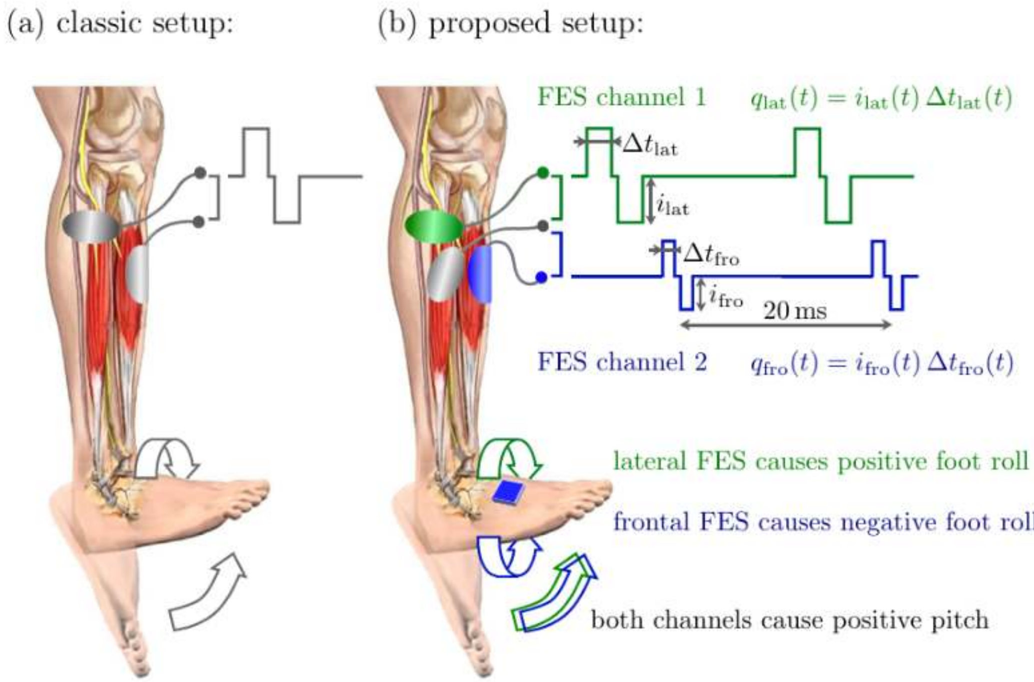


Fig. 5. During swing phase, i.e. between toe-off and initial contact, the foot is raised by m. tibialis anterior whose tendon is attached to the inner edge of the foot and by m. fibularis longus that lifts the outer edge. Since the ankle joint exhibits two degrees of freedom, the activation of both muscles must be balanced to generate a straight (physiological) foot lift.



Conclusions/action items:

While this study does not directly relate to FSHD, its main concern is about foot drop. This article provided great information about gait and pitch of the foot will be utilized in our preliminary presenation.

Kate Hiller - Feb 22, 2025, 12:52 PM CST

FES can be used to stimulate stroke patients that suffer from foot drop syndrome during the heel strike phase of the gait cycle. By stimulating the peroneal nerve during the swing phase of the paretic (weak) foot. The FES will stimulate the leg to prevent ankle inversion through a positive roll and support dorsiflexion through a positive food pitch. Some drawbacks is that FES may stimulate action potentials in afferent nerves, causing patient discomfort. Additionally, non-zero net current through the body could cause electrolysis and tissue damage long term. Therefore, while using FES, this parameter should not be violated. Electrodes are placed on the medial tibialis anterior and medial fibularis longus. Some limitations include that stimulating different channels will cause different foot movements, therefore for each subject an optimal balance of the channels is required. Lastly, varying placement of the electrodes on the shin led to varying results in the successfulness of curing foot drop.

2/22/2025 DUX4 Gene

Kate Hiller - Feb 23, 2025, 11:2

Title: DUX4 Gene

Date: 2/22/2025

Content by: Kate

Present: n/a

Goals: To learnn specifically what the DUX4 gene/protein does to cause FSHD for the preliminary report

Link: https://medlineplus.gov/genetics/gene/dux4/#:~:text=Hypermethylation%20of%20the%20D4Z4%20region,copies%2C%20or%20one%20of%

References:

[1] "DUX4 gene: MedlinePlus Genetics," *medlineplus.gov*. https://medlineplus.gov/genetics/gene/dux4/

Content:

- DUX4 is located at the end of chromosome 4 in a region known as D4Z4

- D4Z4 region consists of 11-100 segments (3,300 DNA base pairs) 3.3kb long

- The D4Z4 region is usually hypermethylated-- has a large number of methyl groups attached to the DNA, with silences the genes

-hypermethylated regions of DNA have fewer active genes

-hypermethylation of the D4Z4 region keeps DUX4 genes silences all the time

- no protien is produce form these gens

-DUX4 is silences in most adult cells and tissues

- when DUX4 is activated again, it damages muscle cells by interupting signal transduction and destroying cells.

Conclusions/action items:

FSHD can be caused by the hypermethylation of the D4Z4 region which houses the DUX4 gene that should be sileicnes after fetal development. Reactivat this gene destroys muscle cells leading to FSHD diagnosis.

2/10/2025 Dynamic Walk Fillauer LLC

Kate Hiller - Feb 10,

Title: Dynamic Walk Fillauer LLC

Date: 2/10/2025

Content by: Kate

Present: Kate

Goals: To learn about existing AFO designs on the market for brainstorming ideas

Link: **http://fillauer.com/products/dynamic-walk-single-side-medial/**

Reference:

"Dynamic Walk, Single Side Medial | Fillauer LLC | Orthotics and Prosthetics Manufacturer," *Fillauer LLC | Orthotics and Prosthetics Manufacturer*, Sep. 21, 2023. http://fillauer.com/products/dynamic-walk-single-side-medial/ (accessed Feb. 10, 2025).

Content:

This is the Dynamic Walk AFO Series

They have a variety of designs

This is thier "Standard" Deign

- this Dynamic Walk AFO is designed to allow people with dorsiflexor paresis or paralysis [our client struggles with dorsifelxion] to confidently walk

- It appears that the brace is in dorsiflexion (or already folded so that it is "spring loaded") for the person. This works to counteract the plantar flexion of the
naturally in

- they also have a wide-ankle design that has a wider base for people with wider feet

This is thier "Custom" design that features a velcro strap to adjust the fitting of the brace to the patient's calf

- They also have designs with a single PEEK rod on either the lateral or medial side of the ankle

SHAPING OF THE BRACE

- the braces of the Dynamic Walk series are able to heat the carbon fiber material of the design to reshape the brace to each patient's foot shape

- To reshape, spot head the carbon fiber with boiling water or heat gun up to 250 degrees Fahrenheit or 121 degrees Celsius

- You are not able to reshape the PEEK rods or the carbon fiber PEEK attachments

- The patient's shoes cannot put pressure on the PEEK RODS

- The patient can cut the bottom plantar platform to fit the shape of their foot

<u>PEEK RODS:</u>

PEEK, “PEEK Virgin Natural Unfilled Sheet, Rod & Tube | Boedeker,” *Boedeker.com*, 2025. https://www.boedeker.com/Product/PEEK-Virgin-Natural?utm_source=google&utm_medium=cpc&utm_campaign=PEEK&utm_content=peek%20rod&utm_term=peek%20rod&gad_source=1&gclid=CjwKCAiA5Ka9BhB5EiwA1ZV
eAKXI14NMw9ddtZ_e25_fUbQOMRJx3tkHnkk7UehoCvRIQAvD_BwE (accessed Feb. 10, 2025).

PolyEtherEther-Ketone

- higher performance thermoplastic

- chemical and water resistant

- non-flamable

Tensile strength: 16,000 psi

Compressive strength: 20,000 psi

Flexure strength: 25,000 psi
- expensive

DESIGN

- lightweight, easy donning and doffing, fit into normal shoes

This video demonstration shows the effectiveness of the standard brace for someone with weak dorsifelxion and a good example of foot drag from weak dorsiflexion: https://www.youtube.com/watch?v=yA2cI_IH8zo

Conclusions/action items:

This brace provides a different perspective on current AFOs on the market. This brace incorporates different material types into the brace. The PEEK rods already bent shape forces the foot into dorsiflexion. This is a unique design take and important to consider when brainstorming ideas for the design matrix.

2/11/2025 Boa Laces

Kate Hiller - Feb 11, 2025, 8:37 PM CST

Title: Boa Laces

Date: 2/11/2025

Content by: Kate

Present: N/a

Goals: To learn more about the mechanics of boa laces and whether it is plausible to use them for our brace

references:

BOA Fit System, "BOA | How It Works | Li2," *YouTube*, Sep. 20, 2023. https://www.youtube.com/watch?v=5rag0Cjnj5M (accessed Feb. 12, 2025).

"BOA® Fit System | Dialed In," *www.boafit.com*. https://www.boafit.com/en-us

Content:

- there is a fast release mechanism by pulling up on the nob

- they are sold for ski boots, running shoes, hiking boots, clears, fishing, hiking, workwear, helmets, and braces

- they are a thin but strong wire with a dial mechanism that you spin to tighten

- this dial is dynamic with respect to being able to choose the tightness.

- we could potentially buy a replacement boa lace system and thread the wire through the brace in order to support the foot during dorsiflexion and to prevent inversion

- It also does not slip, fixing the problem of the bungee cord

-We can also weave it in a way that mimics an athletic ankle take to anchor the foot and prevent inversion

-The kit comes with micro-adjustable dials, super-strong lightweight laces, and low-friction lace guides

- the S-series is used in medical applications and helmets

- we may want to use L-Series for its multidirectional precision fit and fast release

Components of the boa laces we would buy

They have some ankle braces with boa laces:

This brace is too bulcky for our client, but we could use the idea of using the boa laces

Conclusions/action items:

The Boa laces could potentially be an important component to our brace design It could be used to provide dorsiflexion assistance and ankle stability. We could integrate the laces into the brace in a way that resembles an athletic ankle tape. Additionally, the laces are very lightweight but strong which will aid in keeping the brace inconspicuous. These laces also allow for a fast release for easier doffing of the brace.

02/02/2025 Medical Device Reporting COFR Title 21

Kate Hiller - Feb 02, 2025, 1:42 PM CST

Title: Medical Device Reporting COFR Title 21

Date: 02/02/2025

Content by: Kate Hiller

Present: N/a

Goals: To learn about medical device reporting standards for PDS

Search Term: Reporting

Citation:

"Federal Register:: Request Access," *Ecfr.gov*, 2024. https://www.ecfr.gov/current/title-21/part-803 (accessed Feb. 2, 2025).

Link: https://www.ecfr.gov/current/title-21/part-803

Content:

Code of Federal Regulations, Title 21, Chapter 1 Part 803:

- Medical Device Reporting (MDR)

-use of risk assessments for biocompatibility evaluations for a proposed medical device

- FDA will contact you if they need additional information about your medical device reporting

-reporting includes the manufacturers, importers, operators, distributors

- you must report deaths or serious injuries that a device has or may have caused or contributed to, establish and maintain adverse event files, and submit summary annual reports

- the report helps us to protect the public health by helping ensure that devices are not adulterated or misbranded and are safe and effective for their intended use

- medical device distributors must maintain records of incidents, but they are not required to report these incidents

- must have MDR event files

- use voluntary reports to the FDA or in written format use Form FDA 3500A

- user facility must submit MDR reports to the manufacturer

Conclusions/action items:

The Code of Federal Regulations, Title 21, Chapter 1, part 803 discussed the use and requirement of Medical device reporting. The manufacturer, distributor, and user facility must be able to document MDR event files for the developers to keep track of incidents to protect public health. This includes reporting serious deaths or injuries that the device has caused or contributed to. This is important to look at as we are developing a new medical device that is trying to be patented.

02/02/2025 Risk Management ISO 14971

Kate Hiller - Feb 02, 2025, 12:46 PM CST

Title: Risk Management ISO 14971

Date: 02/02/2025

Content by: Kate Hiller

Present: N/a

Goals: To learn about risk management for PDS

Search Term: Risk

Citation:

Iso.org, 2022. https://www.iso.org/obp/ui/#iso:std:iso:14971:ed-3:v1:en

Link: https://www.iso.org/obp/ui/#iso:std:iso:14971:ed-3:v1:en

Content:

ISO 14971: Application of risk management to medical devices

- the method for the evaluation of the overall residual risk and the criteria for its acceptability are required to be defined in the risk management plan

- includes gathering and reviewing data and literature for the medical device and for similar medical devices

- the overall residual risk has to be evaluated and judged acceptable

- analysis of risk and risk management is important for medical devices including risk to the patient, operator, and property

- this standard stated that the concept of risk involves the probability of occurrence of harm and the severity of its consequences

- the concept of risk involves the probability of occurrence of harm and the severity of its consequences

- risk-benefit analysis - ensure the benefits outweigh the residual risks of the rigid ankle brace

- need to estimate risk, like severity and probability (FMEA)

- identify potential hazards or risks to the patient

- look into FDA 21 CFR 820 if marketed in the US

Conclusions/action items:

This standard describes the importance of risk management and the analysis of risk of the medical device. This includes the patient, operators, manufacturers, and property. This device is classified as a class II medical device. The concept of risk of risk involves the probability of occurrence of harm and the severity of its consequences. The team will have to complete risk management analysis of the device such as FMEA.

2/28/2025 To Pad or Not to Pad

Kate Hiller - Mar 01, 2025, 2:41 PM CST

Title: To Pad or Not to Pad

Date: 2/28/2025

Content by: Kate

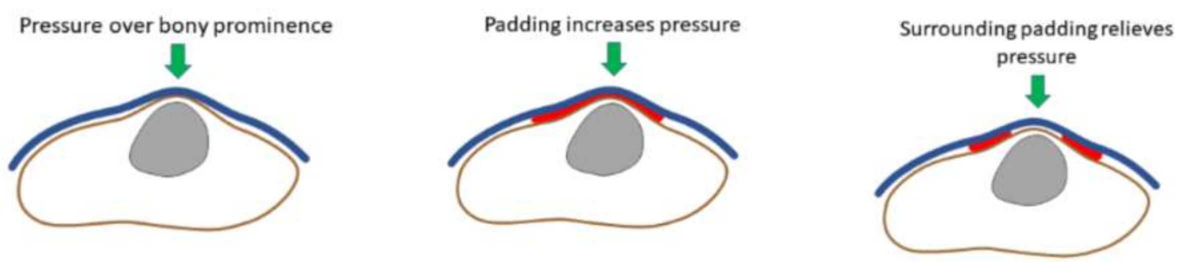
Present: n/a

Goals: To learn about how we should pad the brace around the patient's ankle bones

Reference:

"To Pad, or Not to Pad…That is the Question!," *bracelab.com*. https://bracelab.com/clinicians-classroom/to-pad-or-not-to-pad-that-is-the-question

Content:



- Looking at the above figure, need to support or insert materials around the bone

- The ankle protrusions on each side of the leg are not level or parallel, the medial ankle bone is higher than the lateral ankle bone-- we will need to print two different rigid supports for each piece

- padding will need to be placed around each boney protrusion to reduce pressure around that point

- for our design, we cut out a hole for the boney ankle protrusion and are adding padding all around the edges and under the rigid support.

Conclusions/action items:

We need to figure out exactly what padding we are going to use for our brace.

3/15/25 Motion Analysis

Kate Hiller - Mar 18, 2025, 2:15 PM CDT

Title: Motion Analysis

Date: 3/15/25

Content by: Kate

Present: n/a

Goals: To learn more about the software that we would potentially use for the client in-person testing

Link: https://www.motionanalysis.com/

Content:

- used for animal studies, animation, and gaming, clinical evaluation, research, sports performance, studio camera tracking, VR

- Cortez software 9.5

- motion capture camera

- small, thin motion capture dots

- pressure platform, calculate force of the joints, joint moments

- in video they put 1002 tracker dots on the body

- able to generate a skeleton from the dots

- the markers are active LED markers

Cortex 9.5 Software

- **skeleton builder** = calculations of bones, with precisely defined joint centers

-calcium solver

- **KinTools RT** = self-contained full-body kinetics and kinematics measurement and custom model creation tool - Skeleton builder

- motion composer = tool used to gather, integrate, and present interactive motion capture data ain seamless manner

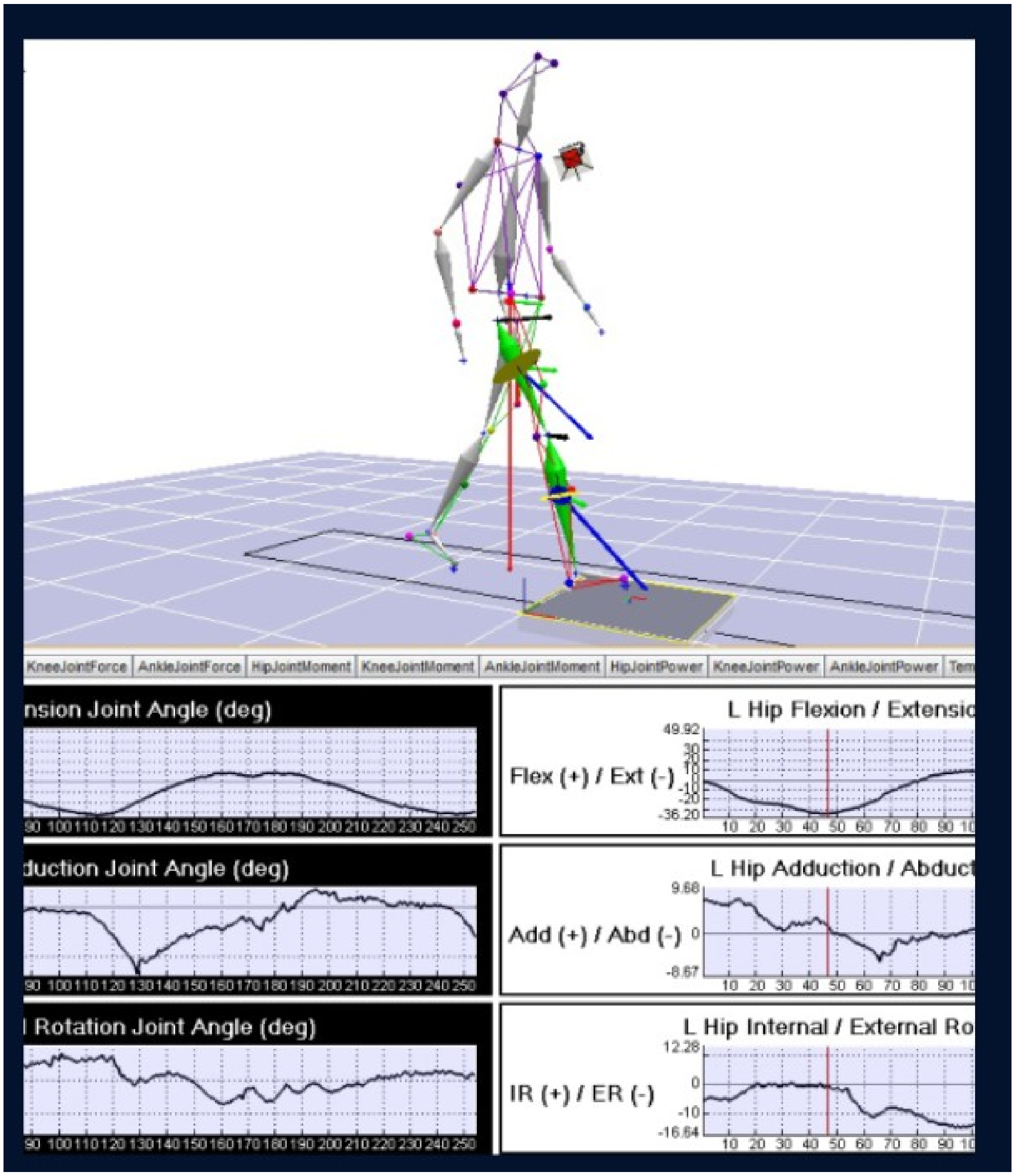
- DV Reference = allows the simultaneous capture and play=back of reference video data from a stationary or moving DV camera

- continuous calibration = the tool is self-diagnostiing, self-correctinf camera calibration, higher accuracy of the camera

- anything you can put a marker on, the system can track

Measurements

- flexision, adduction, and rotation joint angles



Cortex Software

Also have BaSix software (12 cameras, 6 markers)

Cortex Software uses unlimited range of cameras and reflective passive markers (reflective objuectsm reflect typically infrared back to camera)

- cortex allows you yo create 3D trajectories and models a subjects anatomical movements

Images of the tracking dots

Conclusions/action items:

We need to get incontact with the lab to see exactly what software and equipment they have and will allow us to use. We need to set up some testing protocol as well.

3/18/25 Ultrasound Imaging of patients with FSHD

Kate Hiller - Mar 18, 2025, 3:19 PM CDT

Title: Ultrasound Imaging of Patients with FSHD

Date: 3/18/25

Content by: Kate

Present: n/a

Goals: To learn about what is going on with the muscles through imaging for patients with FSHD, what is actually going on inside the muscle

Source: PubMed

Link: https://pubmed.ncbi.nlm.nih.gov/28764967/

Reference:

"Access Library Resource — UW–Madison Libraries," *Wisc.edu*, 2025. https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S0301562917302843?via%3Dihub (accessed Mar. 18, 2025).

Content:

- looking at ultrasound imaging of muscle contraction of the Tibialis Anterior in Patients with FSHD

- tibialis anterior weakness is associated with ankle inversion/sprain ankles

- pathophysiological mechanisms leading to muscle weakness in most neuromuscular disorders are not understood completely

- Dynamic Ultrasound Imaging (B-mode image sequences) in combonination with speckel tracking is easy way to visualize and quantify muscke deformation

- imaging can be used to differentiate the stages of FSHD

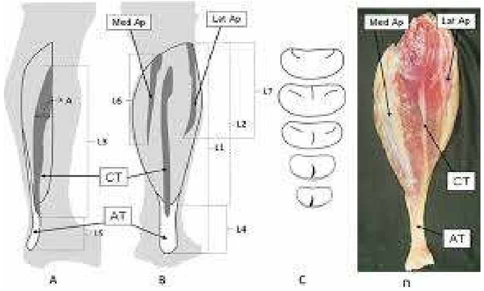
- study uses speckle tracking technique to 2-D ultrasound image sequences to quantify the deformation of the tibialis anterior muscle in patients with FSHD and healthy ones

- deformation patterns were compared with muscle ultrasound echo intensity analysis (measure of fat infiltration and dystrophy) and clinical outcome measures

- the study used 4 FSHD patients : 2 have severe peroneal weakness (a condition where the peroneal muscles, located on the outer side of the lower leg, are weakened) and two had mild peroneal weekness

- patients with severe peroneal weakness showed a different motion pattern of tibialis anterior, with less displacement fo the central tendon region

- healthy patients showed a non-uniform displacement pattern with central aponeurosis showing the largest displacement



(white part) aponeurosis

- dynamic muscle ultrasound of the tibialis anterior muscle in patients with FSHD revealed a distinctively different tissue deformation patterns among people with and without tibialis anterior weakness

- we can use this information to study the effects of muscle pathology in relation to strength, force transmission, and movement generation

- Study conducted in the Netherlands, patients were DNA-confirmed diagnosis of FSHD

August 2016- December 2016

-used Medical Research Council (MRC) grading system to get manual muscle testing scores of the tibialis anterior muscle

- age-adjusted clinical severity scale and FSHD evaluation score were assessed

- the walking on-heels test of the Motor Function Measure was used as a specific functional measurement for tibialis anterior muscle strength

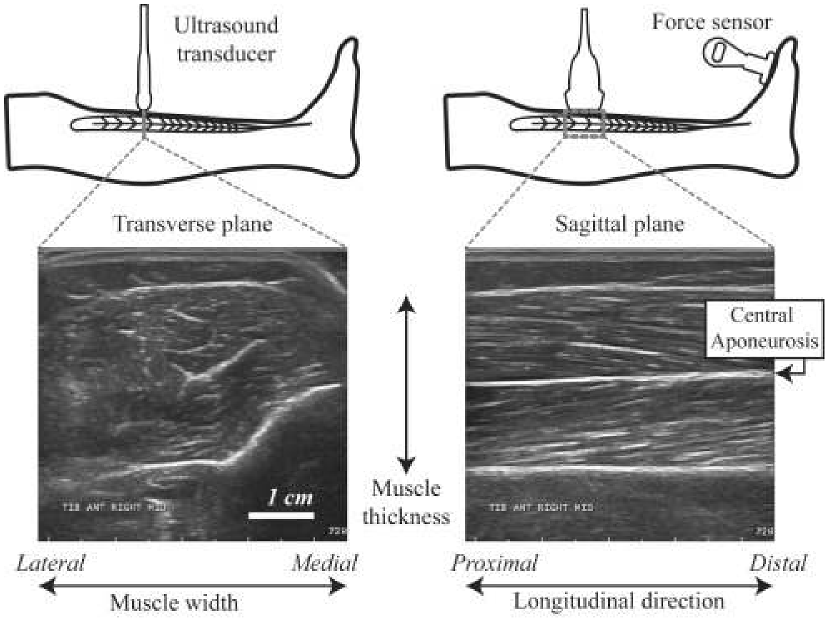
- Studies show tibialis anterior is the most early and severely involved muscle in FSHD

- Examinations were performed on the MyLab Twice US system using 3-13 MHz broadband linear transducer with an axial and lateral image resolution of 0.3 mm and 0.9 mm

- patients examined in the relaxed, supine position

- looked at the muscle belly of tibialis anterior with a standardized transducer location at 1/3rd of the distance on the line from the interior aspect of the patellas and lateral malleolus

- Images of both legs and in the sagittal and transverse plane was taken



Images acuired through isometric contraction

- muscle atrophy was determined using gray-scale analysis (**echogenicity**) of static US (ultrasound) data in the transverse plane

Speckle tracking of dynamics muscle Ultrasound

- tissue displacement was computed using customized MATLAB-based 2-D displacement estimation and track algorithm

- it estimates displacement between two consecutive frames by cross-correlating 2D segments of ultrasound data using a grid of nodes within the region of interest

- displacement maps were overlaid on B-mode images to visualize muscle motion

- echogenicity or quantitative gray-scale analysis

- z-scores were generated based on literature values of mean gray scale values to measured

- z-score >2 (a gray value larger than the value for 95% of the population) was considered abnormal

Table 1 summarizes the clinical data of the patients and healthy controls. Four patients with genetically confirmed FSHD were included with clinical FSHD scores ranging 2–12. Two patients (3 and 4) had peroneal weakness (MRC ≤3) and two patients only had mildly peroneal weakness on clinical examination.

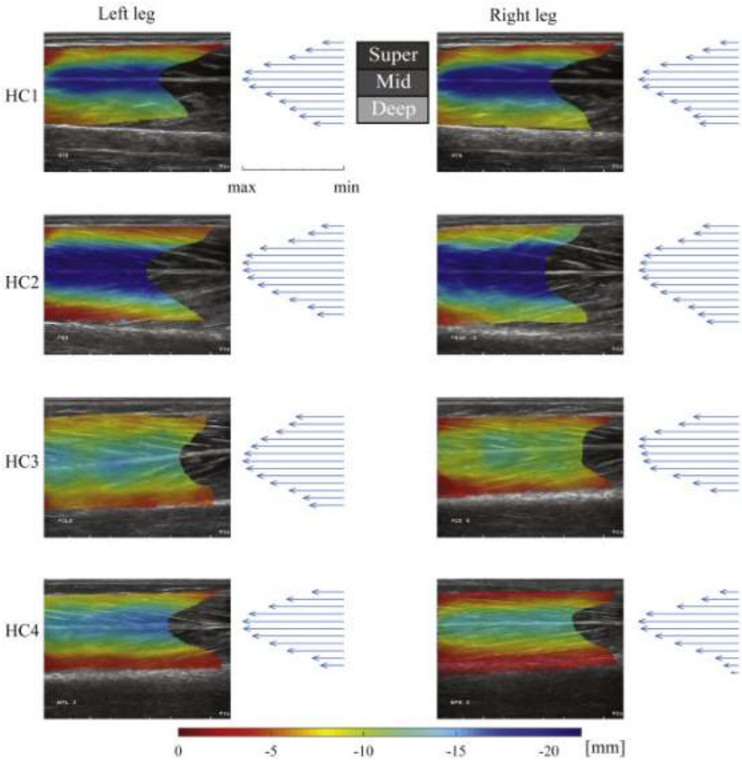
Table 1. Clinical data of patients and healthy controls

Subject no.	Age	Gender	MRC score [left, right]	FSHD score
HC1	24	Man	-	-
HC2	32	Man	-	-
HC3	47	Woman	-	-
HC4	27	Woman	-	-
pat1	31	Woman	[5,5]	2
pat2	24	Man	[4,4]	3
pat3	50	Man	[3,3]	8
pat4	37	Man	[2,3]	12

FSHD = facioscapulohumeral muscular dystrophy; HC# = healthy volunteer number; pat# = patient number.

HEALTHY PATIENTS

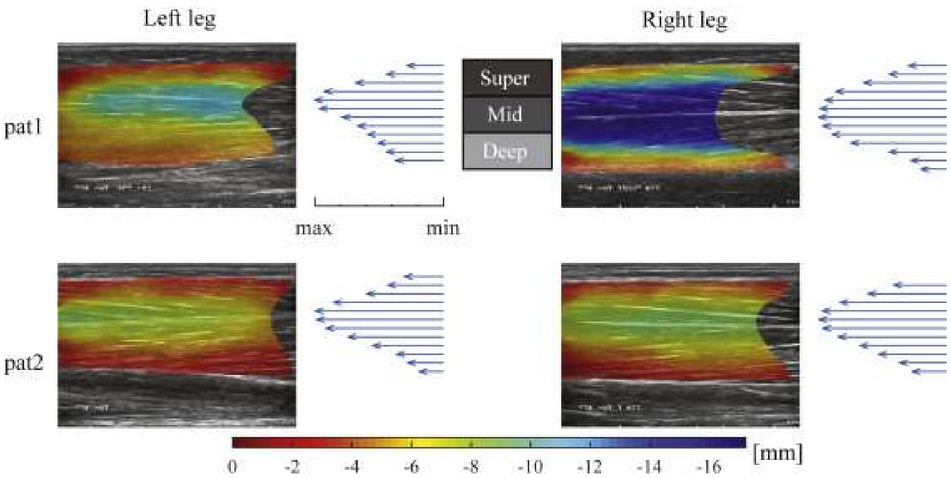
- non-uniform deformation pattern was observed across the thickness of the muscle



Darker color means larger displacemet

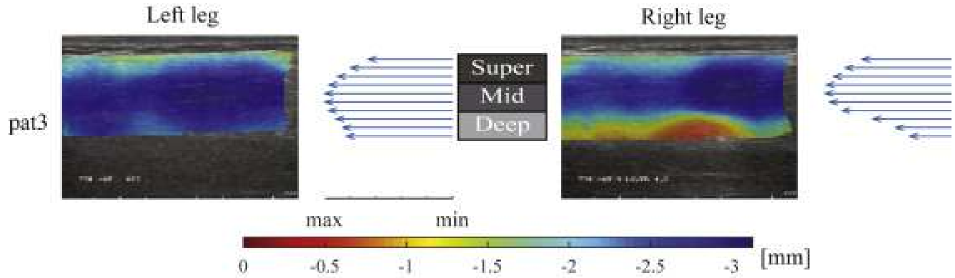
- arrows mean averaged normalized muscle displacement across the thickness of the muscle, mid-region at central aponeurosis shows largest displacement

MILD TIBIALIS ANTERIOR WEAKNESS

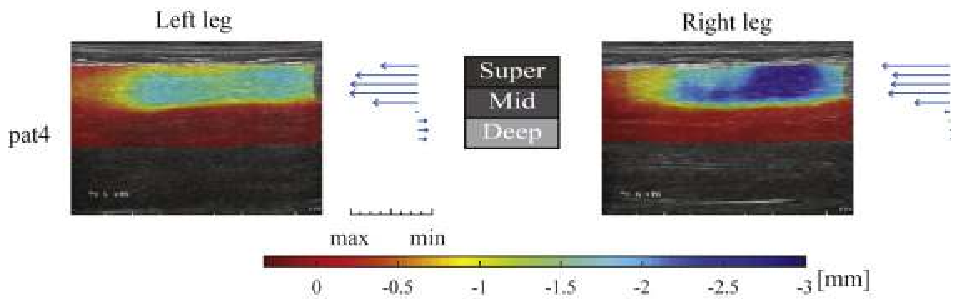


similar deformation patterns as healthy patients, average tissue displacement was lower than healthy

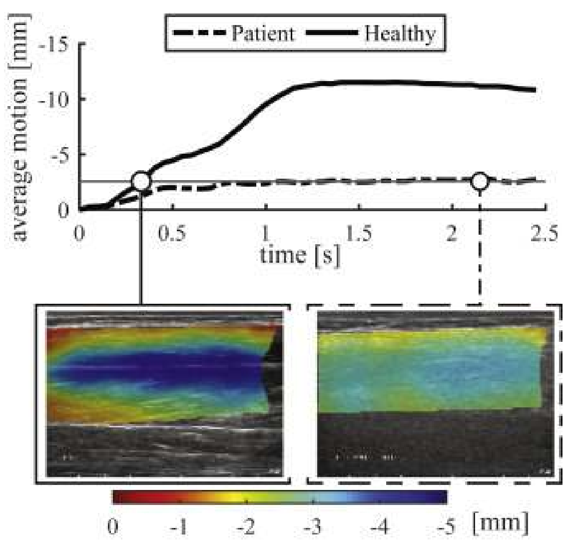
SEVERE TIBIALIS ANTERIOR WEAKNESS



There is no signicicant variation in movements between layers of the muscle, nearly all regions experience the same amount of deformation



Patient 4 shows almost no motion in the deep region of the muscle, with a tendancy in the opposite direction than the contraction



comparing health patient to patient three with severe peroneal weakness

- Displacement patterns within the muscle are varied, indicating that for similar muscle activity, a difference exists in behavior (from activation patterns, fiber composition, etc)

Results:

Table 2. US findings: Gray-scale analysis (z-score) and muscle deformation findings

Subject no.	Leg	Peroneal weakness	Force (N)	z-score	Muscle motion (mm)	Muscle tissue displacement findings
HC1	Left	No	175	−2.19	−10.5	Non-uniform deformation pattern, with the muscle region at central aponeurosis showing the largest displacement. The muscle displacement profile shows a parabolic shape.
	Right		200	−2.41	−11.1	
HC2	Left	No	165	0.83	−11.4	
	Right		164	0.05	−11.9	
HC3	Left	No	140	−0.07	−9.1	
	Right		145	0.38	−7.7	
HC4	Left	No	170	−0.36	−9.2	
	Right		140	−0.17	−6.8	
pat1	Left	Mild	102	−0.46	−6.0	Similar to healthy patients: largest displacement at central aponeurosis.
	Right		130	−0.36	−10.2	
pat2	Left	Mild	79	1.44	−4.7	Similar to healthy patients: largest displacement at central aponeurosis.
	Right		70	0.21	−5.13	
pat3	Left	Severe	33	3.60	−3.1	Homogenous/uniform displacement pattern. Parabolic profile is diminished.
	Right		14	2.70	−2.6	
pat4	Left	Severe	10	3.80	−0.9	Homogenous and uniform displacement pattern in superficial region and inverted displacement in deep region.
	Right		13	4.47	−1.6	

FSHD patients have higher z-scores, less muscle motion, less force generation, and peroneal weakness

"Severely affected muscles most notably show decreased motion of the central tendon aponeurosis of the tibialis anterior, which strongly suggests a decrease in force transferred to this central tendon and, hence, a decrease in force output when attempting to flex the ankle. In the most severely affected patient, a part of the muscle even showed a very small paradoxical movement, suggesting that this part of the muscle no longer actively participated in the contractile process, but was rather moved in a passive fashion as result of other still contractile muscle parts."

Conclusions/action items:

This study helps visualize muscle motion for patients with FSHD compared to Healthy patients. This study is limited to its small sample size. Patients with severe peroneal weakness showed less muscle motion, and force generation, even some part of the muscle no longer participates in muscle contraction.

2/7/2025 Team Design Meeting Drawing

Kate Hiller - Feb 11, 2025, 5:41 PM CST

Title: Team Design Meeting Drawing

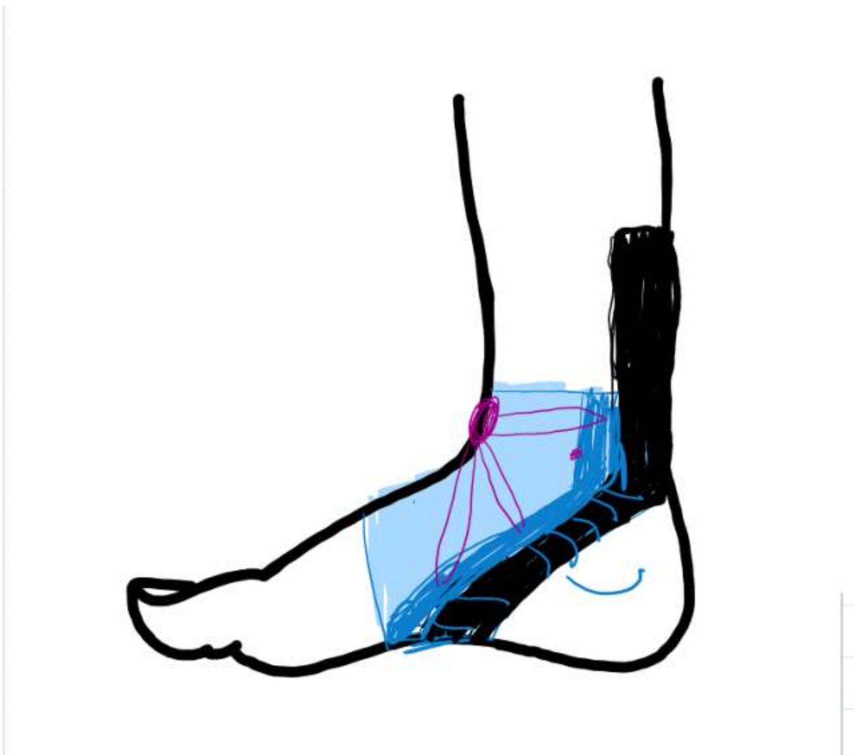
Date: 2/7/2025

Content by: Kate

Present: Whole Team

Goals: To brainstorm a new idea for the ankle brace

Content:



These are very rough sketches of the brace I came up with.

The black is a rigid support to support the ankle from inversion (ankle rolling) by stabilizing from each side of the foot/ankle.

The darker blue is a thicker/stiffer fabric that is sturdy or used for thicker braces that have sewing, kind of like the material a backpack is made of in respect to its strength/non-stretchiness

The light blue is a mesh or thin compressive sleeve material

The dark pink is a Boa lace mechanism: https://www.boafit.com/en-us

- it is commonly used in hiking boots and is an easy mechanism for tightening shoes, or in this case, braces.

- the boa would be like shoe laces that are threaded through the dark blue, thicker material and embedded into the compressive sleeve.

The patient would have to slide on the brace like a sock and tighten it using the boa mechism

One adaptation the team discussed was putting the boa "lock" or contracting system on the back of the leg to be more discrete.

Conclusions/action items:

This idea is complicated as it includes having to sew and use multiple materials. Some drawbacks are that we only have a budget of 100 dollars and this design includes multiple types of materials and we would have to order boa laces. We are looking into potentially using boa laces to replace the "bungee" aspect of the design we end up moving forward with. This idea was inspired by ankle braces I have used before to prevent ankle rolling when playing soccer.

2/9/2025 Design Matrix Drawing

Kate Hiller - Feb 11, 2025, 5:31 PM CST

Title: Design Matrix Drawing

Date: 2/9/2025

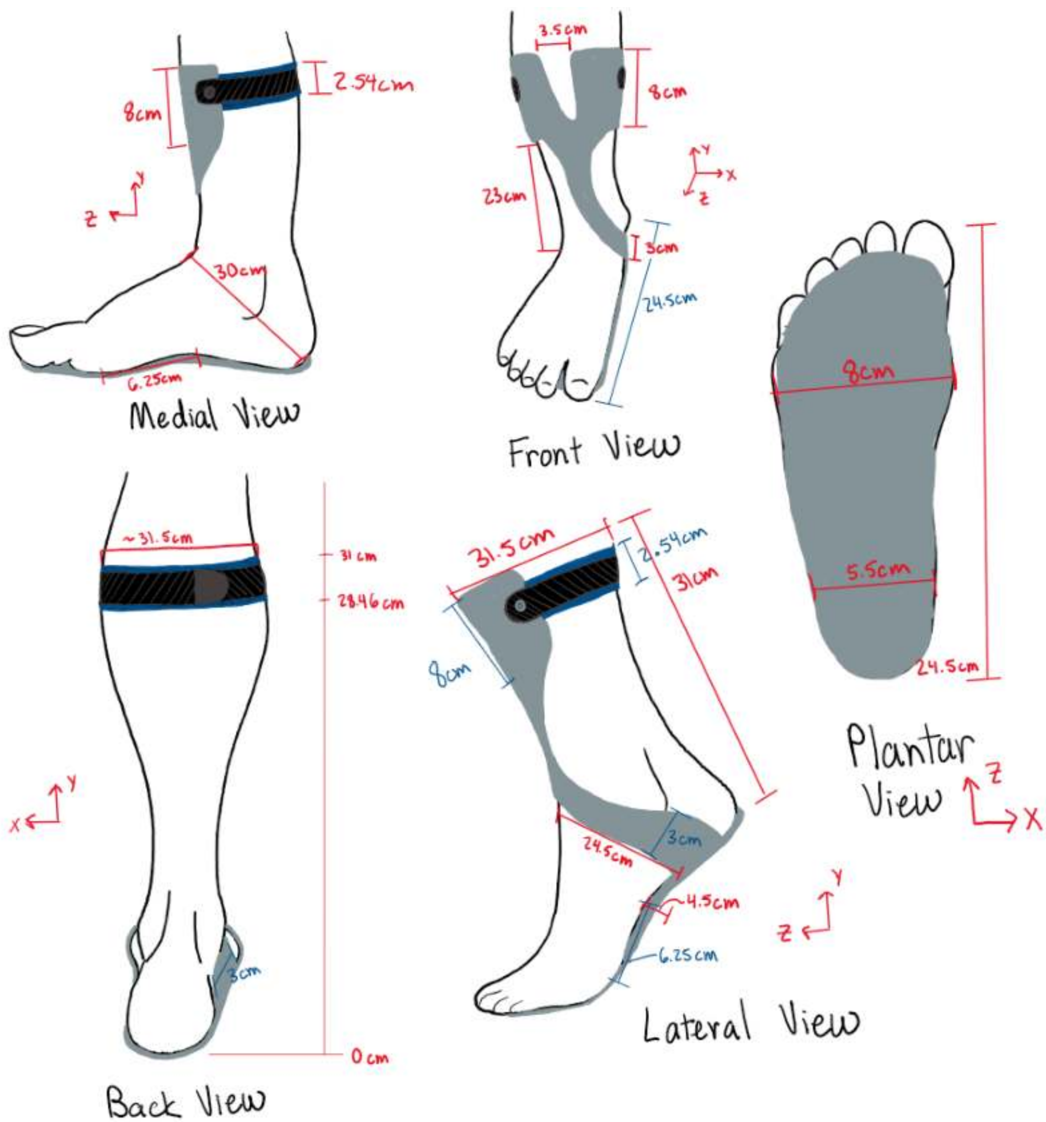
Content by: Kate

Present: N/a

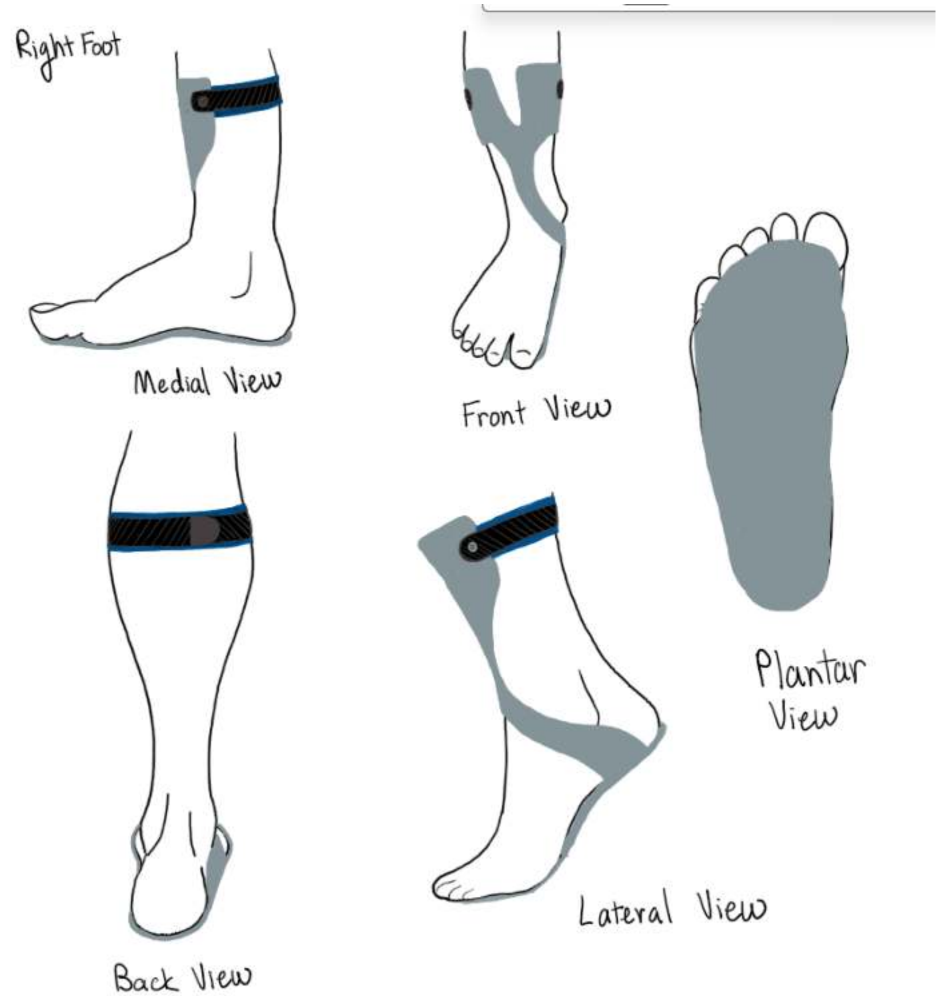
Goals: To combine ideas of the team and literature research and draw the Calf Hug Design

Content:

Calf Hug Design



The drawing with measurements



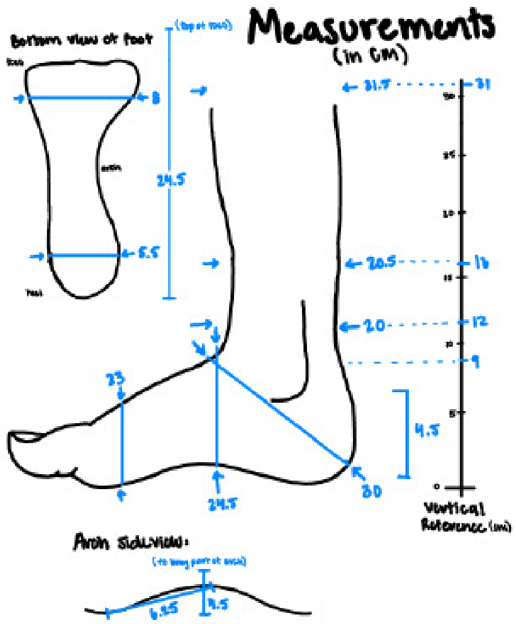
Calf Hug design with no measurments

The design measurements were calculated using the patient's foot measurements she collected herself are attached to this entry

Conclusions/action items:

This design is will be used as one of the final three designs of the design matrix and compared to the other design. This design is inspired by the previous semester's design and carbon fiber AFOs already on the market. This design proves to be challenging as it needs to be precisely fitted to the patient so that there is no irritation to the patient and it could limit the range of dorsiflexion.

Kate Hiller - Feb 11, 2025, 5:30 PM CST



[Download]

Lecture_Notes_.pdf (159 kB)

2/25/2025 3D scanning

Kate Hiller - Feb 25, 2025, 2:01 PM CST

Download

IMG_4140.MOV (6.52 MB)

Kate Hiller - Feb 25, 2025, 1:59 PM CST

Title: 3D Scanning

Date: 2/25/2-25

Content by: Kate

Present: Kate, Sadie, Maddie and Lucy

Goals: To 3D scan the client's brace to generate a mesh to build off of in a software like Onshape or SolidWorks

Content:

-The team met at the makerspace to use the 3D scanner to scan our device

- The maker space got a new 3D scanner this week and it was the only one available

- we used Creality Raptor X

The scanner we used, image taken from Creality website

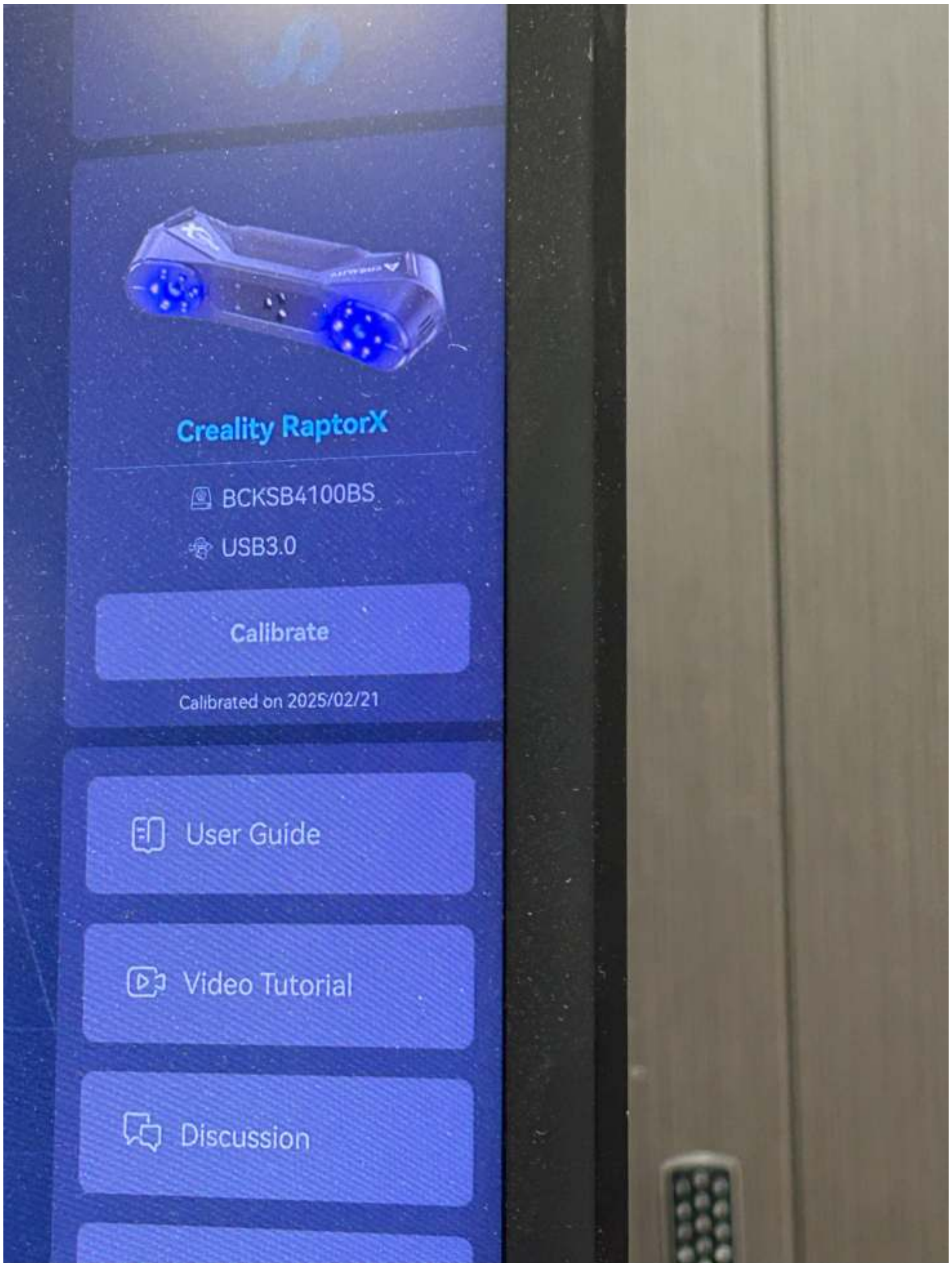


Image of type of Creality Device

In the above image, Matt is showing the team how the 3D scanner works. Everyone present had the opportunity to scan the cast. He is in optimal range and it can be seen on the computer screen with the verticle graph with the upticks being in the green portion. Additionally, it is important that we dont more the turntable while the scanner is off as it will mess up the system.

In the middle of the computer screeen, you can see the developing 3D scan. When the scan is red, it means that we need to go over that portion of the scan again. Additionally, the areas where the scan is green means that it is a complete scan. In the previous pictures, you can see that the cross-section of the cast is facing upward, meaning we scanned the inside. The cast is placed on a turn table with tracker dots so the scanner can orientate itself. However, it is important to note not to have to many tracker dots as it confuses the software. We scanned it by holding the handheld tracker still and turning the platform the cast was resting on. To get the remaining red sections, we held the turnable stationary and move the scanner ourselves. It is important that the scanner is at an optimal distance away from the object. Whether or not we are in the optimal distance could be seen on the scanner itself and on the cumputer screen on the far left vertically. We also scanned both of the insides of the casts.

After the scan is complete, we had to do manual touch ups. We used a laso tool to cut out the dots/mesh that was not the cast. Then we used a smoothing function and hole filler to create a complete mesh. This mesh is an stl file that we will put into SolidWorks, OnShape, or a conjoining meshing software to bout our device from.

Conclusions/action items:

We will use our 3D scanned mesh .stl file to create our rigid support of the device in a CAD software.

3/5/25 Sewing and Attachment

Kate Hiller - Mar 18, 2025, 10:37 AM CDT

Title: Sewing and Attachment

Date: 3/5/25

Content by: Kate

Present: Maddie and Kate

Goals: To exhange out the lateral outer rigid support side of the brace and try out padding methods

Content:

-current padding methods include using a thin foam that could cause irritation if the patients sweats as it would rub on the ankle bone and could cause irritation

- we found padding in the maker space and we cut the width down, for future reference we should use a heated wire to cut (found in wendt basement)

- we are having difficulties with attachment of the foam to the rigid support

ideas:

- pesely has this takey clear dots used to hang balloons (same material found in pakaging and magazines)

- glueing - could cause irritation is clumpy areas

- sewing

creating a sleeve that the padding and rigid support fit into

- we ended up resewing the straps back on the rigid supports

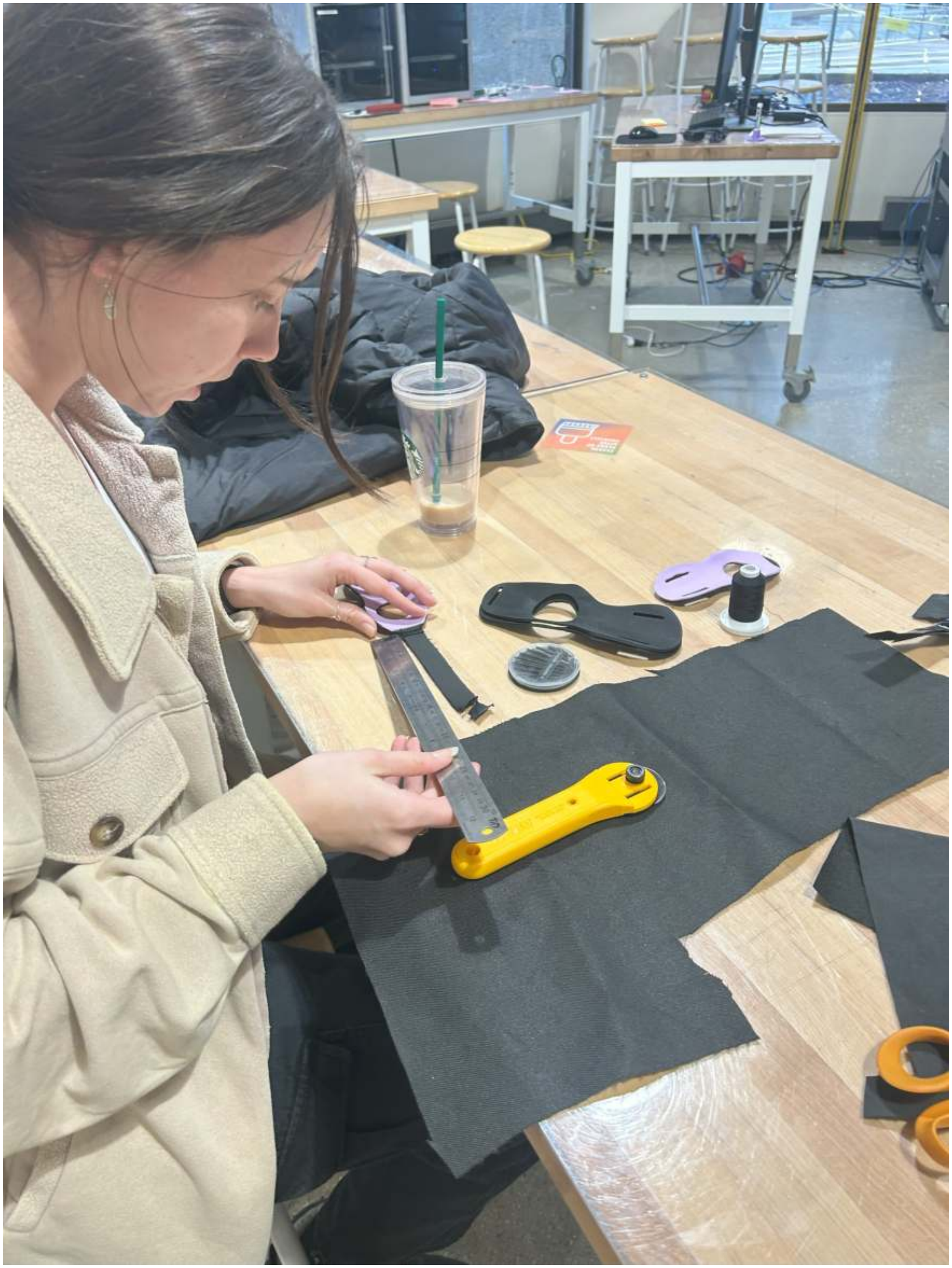
- it fits maddies foot

- the brace originally had two inner sides and we changed them out

- we will meet with the team to brain storm padding

- we did not add the gel pad because we dont want to add more layers/pressure on the ankle bone

The white material is new foam that we found and tried to cut in half with box cutters



Maddie measuring out strap length using material we found at the maker space. The purple part rigid support is the original foam we tried to use

Close-up of the brace. To attach the white foam we had sewing into the foam and into the holes of the rigid support. It is very sloppy and we will regroup with the team to brainstorm better attachment ideas

Conclusions/action items:

After putting the brace on, Maddie noted areas of discomfort at the bottom of the rigid supports by the bottom of her ankle bone.

3/17/25 Draft of MTS 3 Point Bend Test

Kate Hiller - Mar 18, 2025, 10:41 AM CDT

Title: Kate

Date: 3/17/25

Content by: Kate

Present:

Goals: To write testing protocol for MTS testing

Content:

This is the current draft:

1. Obtain three 3D printed rigid supports with infills of 15%, 35%, and 50%
2. Record the mass of the sample with scale and dimensions of the samples. Examine the sample for defects that could potentially lead to failure or errors.
3. Know the maximum possible load for the sample. Choose a proper load cell and fixture that are correct for the sample.
4. Insert the three point bending attachment pieces on to the MTS Criterion Model 43 Machine
5. Attached steel bars via rubber bands to the two end pieces
6. Open Test suite on the adjacent computer
7. Set values for testing rate 0.05 mm/mm, 10 hz, and 191 mm gauge length
8. Set the Safety Stops.
9. Lock the machine.
10. Place the sample into the fixture.
11. Rotate the emergency switch to the right, and it should pop outwards.
12. Double click the lock button, and the light should turn green.
13. Zero the load by right-clicking on the load cell on the software and hitting “zero signal”.
14. Use the wheel to scroll down until the top clamp is barely touching the sample. Carefully watch the load values and wait for a small spike in load as the fixture makes contact with the sample.
15. Record the test rate.
16. Lock the MTS machine by pressing the lock button on the hand controls.
17. Zero the crosshead and the load using the same process as before (Step 13).
18. Press the play button on the computer screen to start the test trial.
19. Enter the sample’s measured diameter.
20. Allow the MTS machine to run until sample failure, the curve on the graph flattens, or until the load almost (but does not) reach load cell capacity or fixture capacity.
21. Press Stop. Kill the switch or press the stop button if something goes wrong.
22. Repeat testing trails using the same steps above for each rigid support with a different infill.
23. Export the data by right-clicking on the trial and selecting the proper file location.
24. Power off the machine, return components, and clean up the sample and surrounding area.

Conclusions/action items:

I will need to revise and go through this again adding more details

3/17/25 3 Point Bend Testing

Kate Hiller - Mar 18, 2025, 10:50 AM CDT

Title: 3 Point Bend Testing

Date: 3/17/25

Content by: Kate

Present: Maddie, Sadie, Presley and Kate

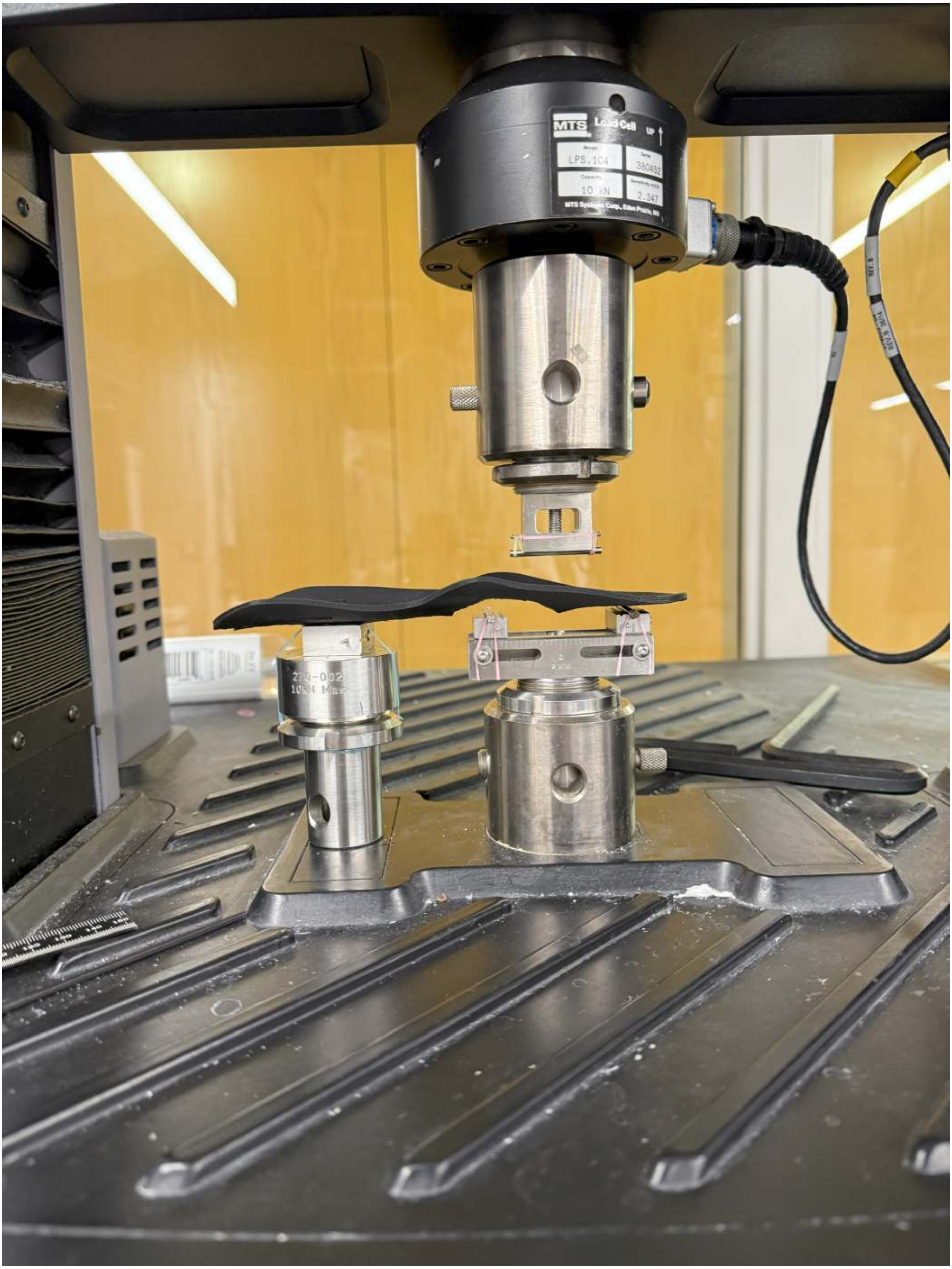
Goals: To carry out thre point bend testing on the rigid support to find maximum load the rigid support can withstand.

Content:

- since this is an irrgeular shape, we tried to apply force where the brace would experence the most force from ankle incversion (at the bottom of the cutout)

- We were hoping the brace will withstand forces of 266N and we tested threee different infills (15%, 30%, and 50%)

- All specimens failed in the exact same area and the 50% infill specimen withstood the most force


MTS
Load Cell
UP
Model
LPS.104
Serial
380452
Capacity
10 kN
2.347
MTS Systems Corp., Eden Prairie, MN

MTS setup

Every specimen failed in this area

- we will create stress-strain plots to analyze material properties and yield stress/critical loads

Conclusions/action items:

We took the raw data into MATLAB and analyze material properties. The only infill of 30% failed (fractured) before 266N, it failed at 260N. The 15% failed at exactly 266N. There are many variables that could have effected our data collection, such as the irregular shape of the brace and our set up.

4/4/25 Force Plate Testing Prep

Kate Hiller - Apr 16, 2025, 11:47 AM CDT

Title: Force Plate Testing Prep

Date: 4/4/25

Content by: Kate

Present: Presley and Kate

Goals: To create force plate testing protocol and run through it, making sure it works

Content:

The is the final force plate testing protocol:

<u>**Recording Data with the Force Plates:**</u>

a. **Pre-Test Measurements**

i. Measure the subject's foot length in centimeters.

b. Power on the amplifier boxes for each force plate you intend to use (**Figure 1a**)

Figure 1. A.) Amplifier boxes for the in-ground force plates. The blue arrow indicates where the power switch is. **B.)** Bertec Acquire 4 software for data collection of force plate data.

c. Log in to the motion capture control computer using your CAE login

d. Open the Bertec Acquire 4 Software (**Figure 1b**)

e. Allow the software several minutes to identify the force plates. Ensure the force plates and all channels are selected (figure 8)

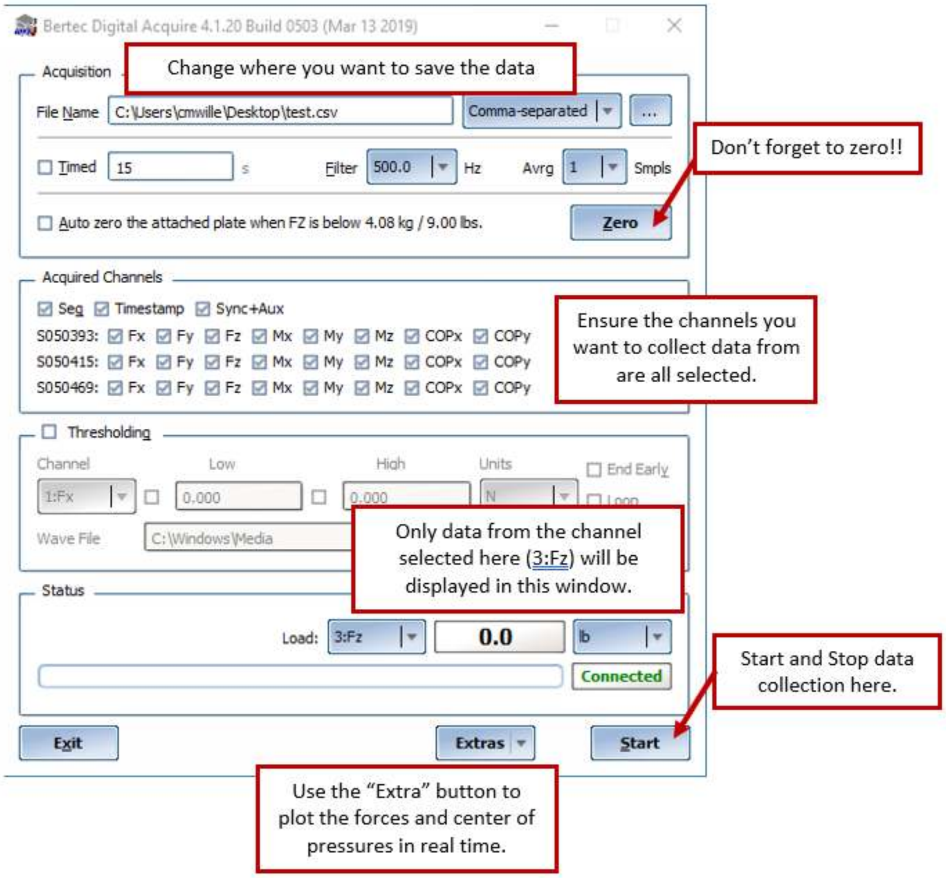


Figure 8. Annotated user interface for Bertec Acquire 4.

f. In the Acquisition box in **Figure 8**, select the time box and input 30 seconds. This ensures each text runs for exactly 30 seconds.

g. Zero the force plates (**Figure 8**)

h. Ensure the data is saved in the desired location:

   i. Under acquisition, rename each test with a descriptive title for each trial (see below), making sure it is a .csv file

i. Follow the instructions for trial 1

j. Press start to begin recording

k. The test will automatically end after 30 seconds

l. Data will be saved in a .csv file format, and output data will be in Newtons and meters

m. Repeat steps 1, j, k, and l for each trial listed below

TRIALS

1. One footed stance – eyes open – no brace (OFEONB)
   a. Zero the force plates
   b. Place your right foot in the center of the force plate **without the brace** on and keep your **eyes open**
   c. Stand on the force plate for thirty seconds without placing their left foot on the plate
2. One footed stance – eyes open – with RED brace (OFEORED)
   a. Zero the force plates
   b. Place your right foot in the center of the force plate **with the brace** on and keep your **eyes open**

    c. Stand on the force plate for thirty seconds without placing their left foot on the plate
3. One footed stance – eyes open – with **BLACK** brace (OFEOBLACK)
    a. Zero the force plates
    b. Place your right foot in the center of the force plate **with the brace** on and keep your **eyes open**
    c. Stand on the force plate for thirty seconds without placing their left foot on the plate
4. One footed stance – eyes closed – no brace (OFECNB)
    a. Zero the force plates
    b. Place your right foot in the center of the force plate **without the brace** on and keep your **eyes closed**
    c. Stand on the force plate for thirty seconds without placing their left foot on the plate
5. One footed stance – eyes closed – with RED brace (OFECRED)
    a. Zero the force plates
    b. Place your right foot in the center of the force plate **with the brace** on and keep your **eyes closed**
    c. Stand on the force plate for thirty seconds without placing their left foot on the plate
6. One footed stance – eyes closed – with **BLACK** brace (OFECBLACK)
    a. Zero the force plates
    b. Place your right foot in the center of the force plate **with the brace** on and keep your **eyes closed**
    c. Stand on the force plate for thirty seconds without placing their left foot on the plate
7. One footed stance – eyes open – with wedge – no brace (WEDGEEONB)
    a. Place your 10 degree wedge on the marked tape section of the force plate
    b. Zero the force plates
    c. Place your right foot **without the brace** onto the wedge
    d. Place your left foot on the force plate adjacent to the wedge in the marked foot zone
    e. Stand in this position for 30 seconds
8. One footed stance – eyes open – with wedge – with red brace (WEDGERED)
    a. Place your 10 degree wedge on the marked tape section of the force plate
    b. Zero the force plates
    c. Place your right foot **with the brace** onto the wedge
    d. Place your left foot on the force plate adjacent to the wedge in the marked foot zone
    e. Stand in this position for 30 seconds
9. One footed stance – eyes open – with wedge – with **BLACK** brace (WEDGEBLACK)
    a. Place your 10 degree wedge on the marked tape section of the force plate
    b. Zero the force plates
    c. Place your right foot **with the brace** onto the wedge
    d. Place your left foot on the force plate adjacent to the wedge in the marked foot zone
    e. Stand in this position for 30 seconds

Conclusions/action items:

The team plans to test 4/12 with one of the team members as the subject, as the client is unable to make it. The team will create stabilograms of the data to analyze pathlengths and see if the brace allows for better balance shown by a more stable COG.

01/29/2025 Library Session 1

Kate Hiller - Jan 29, 2025, 2:16 PM CST

Title: Library Session 1

Date: 01/29/2025

Content by: Kate Hiller

Present: N/A

Goals: To learn about article searching, source evaluation, and citation management

Content:

- second library session is in March

-Activity

1) look for info on google

AFO brace:

https://thriveorthopedics.com/?srsltid=AfmBOooFMmXWr2qfrrHxrxdTnhnheA1A16SU3FEMFWKGNDGouVjygYMQ

FSHD

https://www.hopkinsmedicine.org/health/conditions-and-diseases/fsh-muscular-dystrophy

gait analysis: https://pubmed.ncbi.nlm.nih.gov/39502673/

PubMed, Scopus, Science Direct

ISO Standard 8551:2020

- Use UW Madison databases, there are many ways to filter and find different databases (Scopus - engineering discipline)

- ways to filter database: filter year, sort by newest date published, cite by highest - -influential,

find it link - full article available via UW Madison library

use Zotero!

you should evaluate your sources as you are researching

don't just grab the top article, exercise judgment, who wrote it? authorship, currency, quality, relevance,

Read Laterally! - opening things up about that source, use Reddit or social media to see more information as well

when you don't have access, you can request access to the article through UW Madison libraries, just make sure you give them a little time to find it

kuhlthau's information search process

Dave Bloom

Anne Glorioso

Erin Thomas

Ariel Andrea

They have an "Ask a Librarian" chat -> real librarians not AI

Conclusions/action items:

2/25/2025 Diversity and Inclusion Lecture

Kate Hiller - Feb 26, 2025, 2:05 PM CST

Title: Diversiity and Inclusion Lecture

Date: 2/26/2025

Content by: Kate

Present: N/A

Goals: To learn about how to consider diversity plays a role in engineering

Content:

Dicersity

- ethnicity

- culture

-socioeconomic status

- skill sets

-what you ate for breakfast

What does universal design mean?

- useable by all with no adaptations needed

- making multiple versions or sizes

designing broadly and inclusively - not for the average use

7 principles of universal design

1) equitable use

2) flexibility in use

3) simple and intuitive to use

4) perceptible information

5) tollerance for error

6) low physical effort

7) size and space for approach and use

How does it relate to ethics?

- making for profit or benifit of patient

- enviromental impacts

- collecting data ethically--- human testing

-- is it safe for patient use

BME code of ethics

Rise and Stride: Ethics Discussion

Date: February 26, 2025

What components of the design could be improved:

- Flexibility of Use: straps allow for the patient to customize effectiveness and comfort of the design
- Provide the patient with an assembly guide
- Patient-specific modeling
- Improve the ease of application. The current compression sleeves require significant strength to place over the ankle

Which of the 7 principles are you addressing:

- Flexibility of Use
- Low physical effort
- Tolerance for errors: address velcro wearing down

How can we make these improvements:

- Quick release straps
- Magnetic closures for the strapping mechanism
- Instruction videos
- Choose a elastic material for the straps
- Create a fixture to help assemble the brace and apply the compression sock
- Make the rigid support adaptable to any foot scan

Conclusions/action items:

We can use this discussion to apply to our design

Kate Hiller - Feb 26, 2025, 2:03 PM CST

Kate Hiller - Feb 26, 2025, 2:03 PM CST

3/19/25 Elevator Pitch

Kate Hiller - Mar 19, 2025, 1:42 PM CDT

Title: Elevator Pitch

Date: 3/19/25

Content by: Kate

Present: N/a

Goals: To learn about what makes a good pitch and executive report

Content:

Attention Grabber - hook

- Title, very brief we only have 1 minute

Introduction

Hi I am and the project is

Value proposition

- How to product solves a specific proble
- Dont show them everything you have done
- Demonstrate what we have
- No background information
- Target customer

Benefits

- Highlight the key benefits of your product

Call to action

- We are struggling with _____, what are your suggestions

Do: eye contact, concise and focused, alter pitch for different audiences

Dont: overwhelmed with unnecessary details, forget to listen, sound rehearsed or robotic

Executive Summary

- Elevator pitch into a one-page document
- Saying more with less
- Due week after break
- Key findings
- Key results

Conclusions/action items:

Write the elevator pitch and executive summary with the team

4/2/25 Ethics lecture

Kate Hiller - Apr 09, 2025, 1:31 PM CDT

Title: Ethics Lecture

Date: 4/2/25

Content by: Kate

Present: Team

Goals: To consider ethical considerations

Content:

Conclusions/action items:

4/9/25 Engineering Judgement

Kate Hiller - Apr 09, 2025, 1:43 PM CDT

Title:

Date:

Content by:

Present:

Goals:

Content:

Attitude

behaviors

cognitive

They have a survey to find feedback

Conclusions/action items:

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

SADIE ROWE - Jan 29, 2025, 12:53 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

BME Design-2024-notebook

Lucia Hockerman - Jan 24, 2025, 1:15 PM CST

Download

Team_AFO_Group_Final_Notebook.pdf (6.43 MB)

Appendix: Design Process

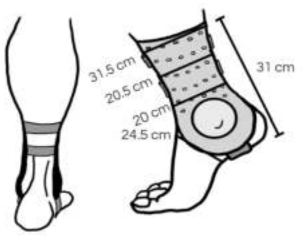
Lucia Hockerman - Apr 30, 2025, 2:53 PM CDT

Initial Brainstorming: Preliminary Designs and Design Matrices

Using research and client requirements, the team decided on three preliminary designs:

Preliminary Design #1: Pivot Pro

Brief Description: The Pivot Pro incorporates a rigid support modeled to the patient's ankle anatomy. It wraps around the back, upper portion of the heel and underneath the posterior arch of the foot. The rigid support travels up the back of the calf and connects to an elastic strap holding the design in place. The hinge allows the underfoot plate to rotate to allow for dorsiflexion and plantarflexion. The hinge will be compact to reduce bulk in the shoe and discomfort for the patient.



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

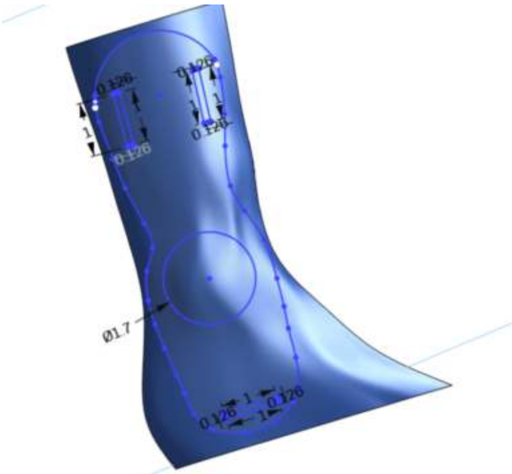
Winner: We support U design

Material options and fabrication methods were also discussed and determined through a material design matrix:

Material Choice #1: Carbon Fiber reinforced PLA composite (CF-PLA)

Fabrication Method: 3D-printing

Create CAD Model: Using OnShape, a CAD model of the brace was developed.



Assemble First Prototype: The supports were 3D printed using CF-PLA at the Makerspace. The team then sewed together velcro straps and added scrap foam to finish the first prototype.

Final Prototype:

Based on a comfort assessment and discussion to test various support lengths, the team refined the inversion support CAD model and added a double-layered mesh foam. A similar fabrication method to the first prototype was used. The team labeled and sent the full brace to the client for testing.