BME Design-Spring 2024 - NIKHIL CHANDRA
Complete Notebook

PDF Version generated by

Ethan Rao

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Team contact Information

Caelen Nickel - Jan 31, 2024, 11:09 AM CST

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Project description

Ethan Rao - Feb 01, 2024, 4:47 PM CST

Course Number: BME 301

Project Name: Lower Extremity Loading Device During Magnetic Resonance Imaging

Short Name: MR Leg Loader

Project description/problem statement:

Hamstring strain injuries (HSIs) are the most common musculoskeletal injuries experienced in many sports and recreational activities. Prior HSIs have been shown to significantly increase patients' risk for additional injury, due in part to neuromuscular alterations. In order to research this phenomena and supplement the current rehabilitation process, a biomedical device is required. This device must be compatible with magnetic resonance imaging (MRI) and mechanically induce hamstring activation on a patient in the supine position in the MRI machine. The device will then collect knee flexion and resistance data that can be observed with the MR imaging.

About the client:

Dr. Crawford is an assistant professor in the Kinesiology Department at UW Madison (Office at 304 SMI). Before he started teaching he earned a bachelor's degree in mechanical engineering from Cedarville University and a master's degree in biomedical engineering from Ohio State University. Since then, he has accumulated other experience as well. He has brought the problem statement to the team in the hopes that the team will be able to improve upon the current designs for these loading devices and create one that allows for constant tension.

2024/01/31 Client Meeting 1

Caelen Nickel - Jan 31, 2024, 9:03 PM CST

Title: Client Meeting 1

Date: 01/31/2024

Content by: Ethan Rao

Present: Ethan Rao, Caelen Nickel, Micah Schoff

Goals: The goal of this meeting was to understand better as a team what was expected throughout the project. An additional goal was to address any questions that the team had based off of the short project intro that was provided.

Content:

Meeting Notes:

- Want to assess brain activity while some hamstring loading is occurring on the MRI table
  - This is to see the difference in brain activity between someone who has injured their hamstring before and someone who has not
- During the MRI scan the subject will be supine with their body on the inside of the machine and their legs on the outside
- Will be looking to initiate eccentric, concentric, and isometric contractions with the device
- An initial version used exercise bands
  - Not constant; the client is looking for a constant level of tension throughout
- Materials used for the prototype need to be MR compatible
  - Non-ferrous metals
  - Copper
  - Brass
- Optical motion capture set up alongside would be a plus
  - Emory version of this uses infrared imaging
- Could 3-D print the transducer mentioned to ensure the machine accounts for this being on the leg
- Want heel elevated so that it's the hamstring being activated mostly
- In relation to the constant tension, a thought was 60 degrees per second
- The MRI machine being used for this research is a 3T Magnus Scanner
  - Can have specs and other information sent if needed for the PDS or other documents
- A potential idea for the constant tension was a bellofram pneumatic
- Constant tension is the MAIN goal of the project; there likely won't be too much design differences in the physical machine

Conclusions/action items:

Based on this meeting, the team was able to better understand expectations of the project. It has definitely given ideas for the research that needs to be done this week as the team prepares to create the PDS and begin formulating ideas for designs.

2024/02/28 Client Meeting 2

Caelen Nickel - Feb 28, 2024, 9:14 PM CST

Title: Client Meeting 2

Date: 02/28/2024

Content by: Caelen Nickel

Present: Design team, client

Goals: Confirm product design specifications are accurate, go over preliminary designs and receive client feedback, ask prepared questions. Also, begin facilitating a time to obtain measurements of the MRI machine and table.

Content:

Goal: Go over PDS, discuss preliminary designs
Client: Understand how design components and research forms a single, cumulative product

- Accuracy requirements?
    - Current load cell device that is not MR compatible has a tolerance of +/- 3 N
- Desirable clinical knee flexion
    - Full extension (0°) to 110°
    - This cycle is meant to include the entire range of motion and it is intended to be cropped, but this range will include all necessary data.
    - This range is not attainable generally due to range of motion, injury, or the device. Thus, the range will be more similar to 5° to 105°.

- Discussing the preliminary designs:
    - Slider design
        - Passive activation of the hip and rectus femoris will occur, but this co-activation is not significant and thus this design has proper hamstring activation.
    - Leg stand design
        - With a leg curl in the supine position, general testing by the client with this position has been affiliated with an amount of head motion. Since this fMRI of the brain is an important component of this research, this is unacceptable.
        - Eccentric contraction with this mechanism will be difficult with such light weight
          Solutions:
            - Increased weight: in the supine position, increased torque yields increased effort. This causes tensing of the neck, increasing blood flow to the brain. With fMRI, this will appear as activation and be inaccurate
    - Block experimental design, with intervals of concentric activation, passive return, wait until baseline, concentric activation again
        - This design will take longer, and thus be more expensive as MRI use is $600/hr.

- The simpler the better!
- Slider design is preferred by the client, can decouple head/spine movement
    - Pushing against resistance will cause head movement at terminal knee flexion and maximum knee flexion due to reactionary force
    - Wedges, angles, straps, pillows are potential solutions

- Current/future needs:
    - Dimensions and measurements of the MRI, table
        - GE MAGNUS in Waisman center
        - Mock scanner
        - Client can email Waisman person and schedule from there. Must bring all non-ferrous materials!!!
    - Fabrication
        - TBD

Conclusions/action items:

As a result of this client meeting, the design team has a better understanding of project requirements and how the design of experiment is likely to be. There were two major aspects which the team failed to consider in preliminary design scoring on the mechanism design matrix. First, knee flexion should begin at 0 degrees clinical knee flexion angle and thus the leg stand design requires more flexibility than most people have, which could be a discomfort to the patient or worsen a preexisting HSI. Also, fMRI works by imaging the blood flow in the brain, and overexertion could increase blood flow in a way that does not indicate muscle activation. fMRI also requires very little head movement, and the leg stand design may not be optimal for these two points. As a result, the design team must reconsider the chosen final design.

2024/03/14 Client Meeting 3

Caelen Nickel - Mar 15, 2024, 12:07 PM CDT

Title: Client Meeting 3

Date: 03/14/2024

Content by: Caelen Nickel

Present: Design team, client, MR staff

Goals: Collect measurements on the MR table and gain a physical understanding of how the design will be adapted to the MRI

Content:

Going into the client meeting to collect information on the MRI machine, the design team was interested in mostly measurements of the MR table. We prioritized getting the height, width, length, and screw position, It order to collect measurements in an MR compatible way, I had the idea of using string and a marker, then measuring with standard methods later.
In preparation for the meeting, Micah and Ethan acquired gift ribbon, which would allow MR compatible measurement as described, but allows for more space to write as it is flat. We made sure to wear clothes with no metal as well.

Client meeting notes:
- To enter the MR room, a two page waiver and acknowledgement was required, asking about implants and metallic exposure. However, it was determined from MR staff that the rules outlined in standards we've found apply more loosely than we thought, and we got some important information regarding MR compatibility. First, smaller metal objects are allowed in the MR room when the machine is not spinning, as a safe distance is attainable within the room even with such objects. Also, the pull from the magnetic field on objects such as keys can be overcame by holding them, as demonstrated by Michael. This applies for when the machine is not in use only. While the machine is in use, no ferrous materials are allowed, and there are restrictions to non-ferrous metals as well. Since metals can affects magnetic fields despite not being magnetic themselves, to avoid artifact all metals should remain stationary during scanning.
- An in-person, visual inspection of the machine and table was very useful as well. Design ideas and the overall setup will be amended based on the features of the table, as will be discussed in the Design Process folder once the design(s) are completed. Namely, the height of the MRI opening combined with the depth of the patient during the scan limits knee flexion angle and hip movement. Nikhil got into the machine and on the table to simulate a scan, and there was limited mobility based on the MRI opening. In order to mitigate this, it has been determined to make the slider design as minimal and flat as possible. Flush to the table is ideal.
- Lastly, measurements were taken using the method described, and the results will be depicted in detailed CAD soon.

Conclusions/action items:

This meeting with the client and MR staff was imperative in mutually understanding how the device is to interact with MRI equipment and the table. Seeing specific features of the table and being able to physically inspect it allows us to understand better of how our design must exist spatially. Also, having measurements specific to this MR table is vital. From here, we can finalize our design ideas specific to the table, namely created highly detailed sketches and CAD with measurements. Then, fabrication is doable!

2024/04/10 Client Meeting 4

MICAH SCHOFF - Apr 22, 2024, 11:14 PM CDT

Title: Client Meeting 4

Date: 4/10/2024

Content by: Micah Schoff

Present: Design team & client

Goals: Finalize and get designs approved

Content:

The goal of this meeting was to finalize the few remaining questions we had with our design as well as get the stamp of approval of our design. We brought our SolidWorks models in order to give a visual to the client.

- Budget: The client gave us a ceiling of 1,000, but would appreciate if we stick around the 750 mark
- Foot mount on the slider: we went down to the lab to demonstrate the action and finalize how the foot will be mounted on the slider. We determined that the foot will be place in a boot or ankle wrap and then onto the slider. This allows us to keep the slider as is and not change dimensions.
- Total weight being used: our client does not have a maximum as it will differ a lot between subjects. We were told to build it like a linebacker will be using the device so that it will last and give the greatest range in terms of weight.
- Weight stand: the client liked our idea and requested that we build it with thicker materials so that it can withstand the new weight range.
- The client also approved all of our materials we decided on
- We also discussed ordering materials as he suggested that we go ahead and order everything ourselves, then he will get reimbursements back to us working with our team
    - we agreed with this as we were not able to order everything from one place.
-

Conclusions/action items:

This meeting was very productive as it gave us the green light to order materials and begin fabrication. This also cleared up all questions we had remaining in terms of the project. We will order materials and begin fabrication this next week.

2024/04/23 Client Meeting 5

Ethan Rao - Apr 23, 2024, 7:01 PM CDT

Title: Client Meeting 5

Date: 04/23/2024

Content by: Ethan Rao

Present: Ethan and Micah

Goals: The goal of this meeting was to get a couple more dimensions for the device moving forwards as well as discuss any concerns with the device.

Content:

Notes:

- Measurements were taken for both the height of the table as well as potential lift off the table
    - These will be used in future work to get the device to the correct height
- Suggestions from Dr. Crawford
    - Add in a secondary block in order to ensure security and activation both ways
    - Potentially add more material to clear the end of the table
    - Meeting potentially this week to discuss pulley design
- Overall, very productive, allowed for clearing up some small details heading into the poster presentation

Conclusions/action items:

As a result of this meeting, the team now has a clear path to the end of the semester and are in good shape with a finished prototype. Now, the team will move towards appropriate documentation.

2024/02/08 - Advisor Meeting 1 (Conducted on 2/2)

Ethan Rao - Feb 08, 2024, 12:08 PM CST

Title: Advisor Meeting 1

Date: 02/08/2024 (Conducted on 2/2)

Content by: Ethan Rao

Present: All

Goals: The goal of this meeting was to present the team's research to our advisor and determine areas to continue to research as the team continues to delve deeper with this project and begins formulating designs.

Content:

The meeting provided a lot of insight in relation to the research that has been conducted so far as well as what still needs to be done. The research the team has done so far has provided a lot of really great things to get started but there are still some areas that need to be researched further. A couple of the things mentioned in the meeting was researching compatible materials for the device as well as methods by which to maintain constant tension.

Conclusions/action items:

Based on this meeting, the team understands that there is more to be done in relation to research before we begin formulating designs, and the team will continue to conduct research moving towards working on the PDS and formulating designs.

2024/02/09 - Advisor Meeting 2

Ethan Rao - Feb 09, 2024, 2:04 PM CST

Title: Advisor Meeting 2

Date: 02/09/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal is to

Content:

- Professor Wally Block is a good source for finding out more about MRI
- Discussed the cyclic motion of hamstrings and what motion may be activate
  - Potentially look into making a FBD for the hamstring (PROJECT FOR NEXT WEEK
- Research some materials that will make up our device
- Find out some of the knee flexion max's (Ask client if should be a variable?)
- Kinovia is a 2-D motion capture that could help
  - Another robust motion capture method would be OpenCap (2 iPhones)
- Gear box in the MRI project could be a source of inspiration for our design
- What can we find that's nonferrous? - Question posed by advisor

Conclusions/action items:

2024/02/16 - Advisor Meeting 3

Ethan Rao - Feb 16, 2024, 2:27 PM CST

Title: Advisor Meeting 3

Date: 02/16/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of this meeting was to check over the design matrix as well as present design ideas that the team formulated over the week.

Content:

The major inclusion that was recommended by Dr. P was to add usability to the two design matrices. Overall, though it seemed that the design matrices did a pretty decent job conveying the designs the team came up with as well as the criteria that the team decided to go with moving forward. One thing that is a priority in the next week or so is meeting with the client and looking to visit the MRI room to actually get dimensions and get a good understanding of the dimensions we are working with.

Conclusions/action items:

The team was able to get useful insight from the advisors as to how to proceed in the weeks preceding the preliminary presentation. This will allow the team to use a goal oriented process to accomplish objectives in the next few weeks efficiently.

2024/03/15 - Advisor Meeting

Ethan Rao - Mar 15, 2024, 1:37 PM CDT

Title: Advisor Meeting

Date: 03/15/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal is to document some of the important notes from the advisor meeting for the team to refer to later.

Content:

- Talked about the MRI meeting extensively, important for the team to get the dimensions from the meeting
- Also discussed potential issues from the MR meeting
- Also discussed the weight situation (IMPORTANT)
  - Maybe ceramic
- Talked about usage of HDPE within the slider design (seems to be good idea)
- Materials a key issue to look into as well as fastening
- Design consultation coming up
  - How weight bearing are non-ferrous screws?
  - Will epoxy work?
- Talked about the timeline as well
- Attachment to slider will be something to discuss in the future

Conclusions/action items:

As a result of this meeting, the team has move in the right direction in terms of final design thoughts as well as the questions to ask within the design consultation.

2024/04/12 - Advisor Meeting

MICAH SCHOFF - May 02, 2024, 1:44 PM CDT

Title: Advisor Meeting

Date: 04/12/2024

Content by: Micah Schoff

Present: Everyone

Goals: The goal is to document some of the important notes from the advisor meeting for the team to refer to later.

Content:

- Talked about initial print of amplification pulley
    - maybe redesign and print at 100% infill
- Talked about dimensions of the base sheet and how we need to think about where the forces will be
    - thinking about material dimensions as well from supplier
        - thinking 24 X 24 in. sheet should be enough to cover forces on weight stand
- Talked about change acrylic to HDPE on the slider
    - better for fabrication and strength and longevity of the device
    - Will also tolerate disinfection better
- Overall, design seemed good and can move forward ordering materials

Conclusions/action items:

As a result of this meeting, the team has move in the right direction in terms of final design and should order materials over the weekend to ensure we can have the time required to fabricate. Pulley redesign will happen soon to allow from ample time to print if needed.

2024/02/12 Individual Design Meeting Notes

Caelen Nickel - Feb 27, 2024, 12:10 PM CST

Title: 2024/02/12 Individual Design Meeting Notes

Date: 02/12/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of this meeting was to pitch each individual's designs and begin formulating a design matrix.

Content:

Caelen's Design:

-
- Going away from exercise bands
- Focused on the resistance mechanisms (friction in the case of his design)
- Inspiration was the actin filaments for muscles
- Opposite of an elastic band
- Research done so far has shown the relationship
- Combines an elastic band with a slider mechanism
- Actual calculations to be determined
- Opposing elastic bands may constitute a replacement of friction

Nikhil's Design:

- Stayed on the pulley side
- Calculations are looking to be more exact
- Design 1
  - A stand holding the knee up
  - A second stand with the pulley attached
  - Could easily switch in and change the weight
- Design 2
  - This time they only use one stand
  - Pulley holding the weight
  - Similar idea
  - Discussion was had about the possibility of activation for the quads
    - However the force would always be in one direction, therefore causing a moment to always be in the direction of knee flexion
- 3rd Idea
  - Similar to other devices the team has seen with the difference being that pulleys are being utilized throughout the design

Ethan's Design

- 1st Design
  - Similar to bicycle pedals
  - Pedals would be angled in order to induce activation of the hamstring
  - Would allow for the cyclic motion we're looking for
- 2nd Design
  - Similar to Nikhil's third idea in that it is a combination of ideas we've seen in order to optimized

Micah's Design

-
- 1st Idea
    - Adjustability of the machine to account for heights
    - Notch system
- Resistance Ideas
    - Elastic bands placed in such a way that one would be activated in both directions
    - Discussion about whether or not the two bands are necessary

- No constant elastic bands???

- Ideas where the strain is linearly proportional to stress??

- Looking for more guidance in relation to the 20-30% of force

Conclusions/action items:

Based on the designs the team has presented in this meeting, the team will be able to move forward and create a general design matrix. This will allow for the team to further specify their ideas in order to come up with a generally effective solution.

2024/02/15 Design Matrix Criteria

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Caelen Nickel - Feb 27, 2024, 12:28 PM CST

Title: 2024/02/15 Design Matrix Criteria

Date: 02/15/2024

Content by: Caelen Nickel

Present: N/A

Goals: Create a set of well defined/explained criteria for the design matrix in order to evaluate preliminary designs.

Content:

Following Monday's (02/12) team meeting where design ideas were discussed and preliminary designs were identified, the group briefly discussed some ideas for criteria for the design matrix. Also, as shown in the above entry in this Design Process folder, the design team is currently pursuing a set of 2 design matrices for the mechanical design and the resistance design. The ideas for criteria were adaptability, ease of fabrication, and safety.

From these original outlined criteria, I thought it was important to have a criteria that would reward or effectively eliminate designs for not being able to function as the client needs. These client needs that I prioritized were the ability of the device to activate the hamstring well and limit co-activation of other muscles, exert constant tension, and be able to measure the resistance being applied. I originally named this criteria function since these factors outline the main functioning of the device and thus also assigned the highest weight to this criteria, but later changed it to hamstring activation in order to provide viewers with a more descriptive title. My rationale for making this the most significant criteria is that these factors considered in this criteria are the main points the client conveyed to us that must be done. If these points are not met and met poorly, the device will be at worst useless and at best inaccurate.

From here, I considered how the optimal hamstring activation, something considered in the previous criteria, is rather dependent on patient height. As a result, the design needs to be made adjustable in order to ensure optimal hamstring activation is possible for different patients. This aligned well with the adjustability criteria, and this is the criteria for the mechanism matrix. For the resistance matrix, the problem is slightly different. The client said that the resistance provided to the hamstring should be 20% - 30% of the patient's maximum hamstring strength. Clearly, this is highly variable and therefore the design must have a way to easily modulate weight. Seeing that cable stacks are easily modifiable and springs/bands are not modifiable at all (an entirely new spring/band is necessary) I saw this criteria important for separating these designs. Plus, the overall functioning of the device outlined in the previous criteria is dependent on adjustability and thus it should be weighted highly as well.

During design brainstorming, the main focus of mine was to avoid bulky, heavy designs that would result from using weights. This inspired the size category, which includes volume and mass. It ranked ahead of ease of fabrication because it affects the final product and can help ensure the device is compact, efficient, and not a burden to use.

Ease of fabrication was the next criteria, referencing how realistic the device can be built in a semester. However, I wanted to account for cost of fabrication and materials as well, so changed the name to fabrication ability. I thought about having cost be a separate category, but in ranking found that there was identical scores and justifications for the categories and it seemed redundant.

Lastly, I included safety because this is a necessary consideration in any design. The main way that designs could pose risk is with the incorporation of ferrous material. However, this is known and no design is intended to have ferrous material in it, so basing safety off of this would be useless. Also, if there is ferrous material, not only is the design unsafe, but it is completely useless and most likely destroyed and thus would be a 0 in most other categories. Therefore, to avoid redundancy I did not use ferrous materials in the safety criteria. Testing will be necessary to verify no ferrous materials unknowingly were used.

Conclusions/action items:

Using these criteria and the definitions for them, the designs can be scored and thus ranked. Also, these descriptions/details will be included in the design matrix document and the preliminary report. Some alterations might be made to the definitions and scoring as more information from the client is learned, new research is done, and discussions are had.

Caelen Nickel - Mar 07, 2024, 11:20 PM CST

Title: 2024/02/15 Design Matrix Criteria (Edit)

Date: 02/27/2024

Content by: Caelen Nickel

Present: Design Team, Advisors

Goals: Update the design matrix to reflect how easy/hard a design is to use.

Content:

Following the Friday (2/16) advisor meeting where the initial design matrix was discussed, one of the main takeaways was that it would be beneficial to include a criteria comparing how easy/hard a design is to use. This makes sense as an important part of the design is how the MR technician, researcher, or patient interacts with the device in order to use it. Designs that are difficult to use would not be favorable by the mentioned parties and thus are less likely to be implemented.

This new criteria was added to the matrix under the straightforward name of "Ease of Use" and was weighted at 15, which is third behind hamstring activation and adjustability. The reasoning for this is that hamstring activation is the core purpose of the device and ease of use doesn't matter if the device can't effectively activate patients' hamstrings. Since adjustibility is tied into the correct level of activation and knee flexion angle, this criteria was also above ease of use.

Conclusions/action items:

The inclusion of this criteria more effectively evaluates designs in the design matrix and is important for ranking and thus choosing a design. This will be used to choose the design and it will be important to make sure that the design is easy to operate as mentioned. This design matrix and its criteria will be discussed in the preliminary presentation and report.

2024/02/21 Diversity and Inclusion in Design

Caelen Nickel - Feb 27, 2024, 12:11 PM CST

Title: 2024/02/21 Diversity and Inclusion in Design

Date: 02/21/2024

Content by: Everyone

Present: Everyone

Goals: The goal of this entry is to effectively consider the 7 principles of universal design as well as other diversity and inclusion principles within the design that the team is starting to formulate currently.

Content:

Components that Can be Improved:

- Adjustability in the amount of support for the knee
- Adjustability in the amount of weight utilized when activating the hamstring
- Including a label or video that goes through correct usage
- Making sure that the device is appropriately transportable

Which of the 7 Principles We are Addressing by Improvements:

- Adjustability in the amount of support for the knee allows for equitable use depending on if someone has had previous knee issues or lower extremity injuries (1)
- Flexibility in use and low physical effort are addressed through the amount of weight utilized as it ensures that the proper 20% of maximal hamstring activation for different people as well as the low physical effort that should be exerted when using the device (2,6)
- Including a label or video improves perceptible information as it will give users the correct way to use a device that could potentially be dangerous if utilized incorrectly (4)

How these improvements are going to be made:

- Adjustability in both the amount of support for the knee and changing the weight utilized can be made by making minor adjustments the design
- Including a label or video can be done by the team taking the time to create the video or label to allow for correct usage
- Making sure to choose materials that are low weight will allow for appropriate transportation

Conclusions/action items:

As a result of this entry, the team was able to take into consideration the 7 principles of universal design to determine how to better incorporate elements of diversity and inclusion within the design.

2024/03/15- Team Design of Pulley System

Ethan Rao - Mar 15, 2024, 1:17 PM CDT

Title: Team Design of Pulley System

Date: 03/15/2024

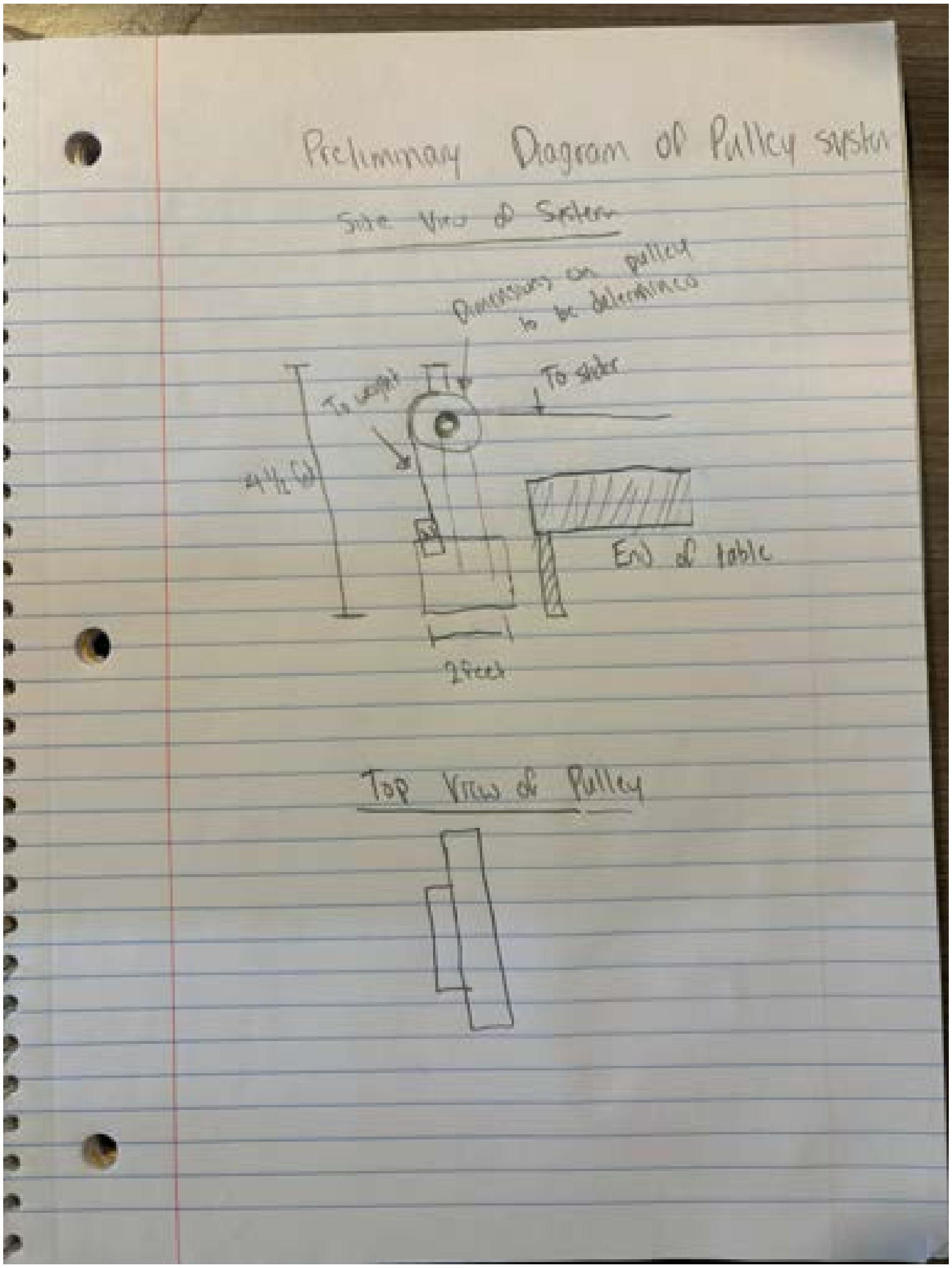
Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal is to keep a drawing of the imagined pulley system to refer to as the team makes calculations and works through some of the fabrication steps. NOTE: Dimensions for the pulley will be determined within calculation.

Content:

Image of Design:



Description of Design:

The design is based on a rectangular base that will make up the bottom of the design, with two posts going up from the base up to the pulley. The pulley will be attached to a cylindrical rod/axle. Additionally, there will be four cross bases that support the posts allowing for better safety and support for the design. The pulley itself will be made of two with one attached to the slider design and the other attached to the weight.

Conclusions/action items:

As a result of this the team now has an idea of how the pulley system will work within the context of the device. This will allow for a clearer path when fabricating and essentially allow for more progress faster.

2024/03/15- Team MRI Dimensions Meeting

Ethan Rao - Mar 18, 2024, 10:14 PM CDT

Title: Team MRI Dimensions Meeting

Date: 03/15/2024

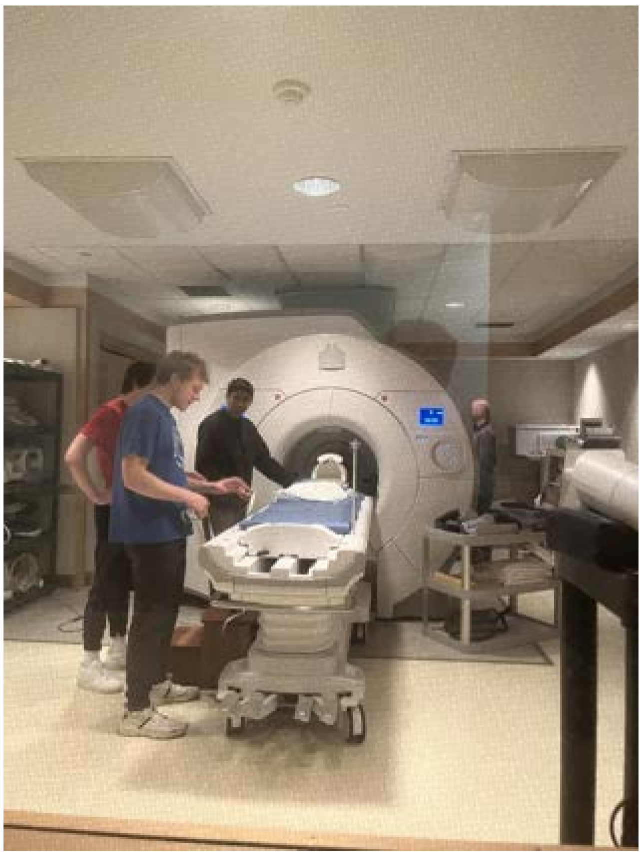
Content by: Micah Schoff

Present: Whole Team

Goals: The goal of this is to show how we collected dimensions as well as show what was discussed within the meeting with our Client at the Weisman Center with the GE Magnus MRI machine.

Content:

Image of Dimension taking process:



We met 3/14 to see the machine and take dimensions as well as test the motion we proposed in order to get insights on how it would work. This was very impactful for the team as Nikhil was actually able to go into the MRI machine. This allowed the team to see how the proposed movements would work in the context of the project. This will allow for improvement on the efficacy of the design in carrying out its task.

Conclusions/action items:

This meeting was very helpful as the team was able to see the MRI machine as well as get the dimensions necessary to move forward with the project.

2024/03/22 - Slider System Design

NIKHIL CHANDRA - Apr 28, 2024, 5:33 PM CDT

Title: 2024/03/22 - Slider System Design

Date: 3/22

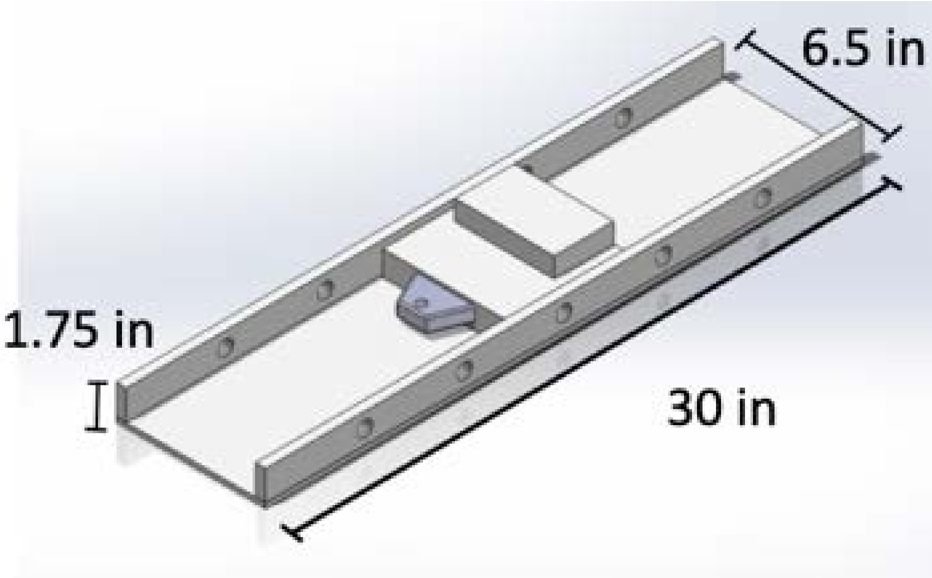
Content by: Nikhil Chandra

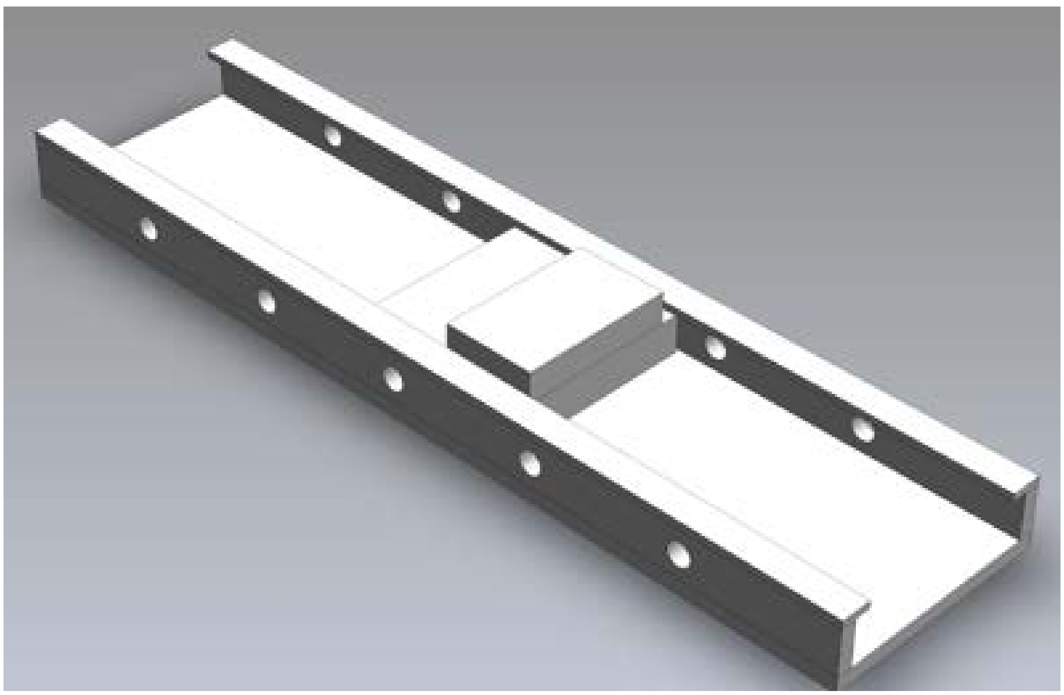
Present: Nikhil Chandra, Micah, Ethan

Goals: In this meeting we made some more iterations to our initial brainstormed idea for the structure of the slider design then fully designed the system in solidworks.

Content:

Shown below is the CAD for the slider system. Specifically we used rectangular sections for the side rails, and the bottom base for ease of fabrication and we will potentially use felt to further minimize friction if necessary after appropriate testing. Specifically an individual will place their heel on the divot of the slider bar and will pull the slider inwards towards their glutes. As they perform knee flexion against an outwards cable force they will active their hamstrings. Currently there is a threaded hole on the bottom bar of the slider bar where we can thread in a hook for the cable to be attached to. We also have holes on the side rails of the slider for a peg to be put through to act as a stop for the slider to ensure if they let go, the bar does not slide off the slider and crash into the pulley.





Conclusions/action items:

With a design for the slider system, we need to solidify our materials choice for the base, side rails and fasternes and develop a fabrication protocol.

2024/04/2- Show and Tell Feeback

MICAH SCHOFF - Apr 05, 2024, 1:06 PM CDT

Title: Team Show and Tell Feeback

Date: 04/1/2024

Content by: Micah Schoff

Present: Whole Team

Goals: Document and Discuss with team the feedback we received at show and tell.

Content:

The Friday before spring break we met with 3 different teams to discuss our design and get feedback on our call to action. We talked about materials for the project and weights. We got feedback on how to make our pulley system which included using glass or ceramic bearings. The groups seemed to like out weight amplification through the different moments/radius pulley system. In terms of materials for the project all of the groups agreed with the use of HDPE as well as epoxy. For the weight groups suggested the use of water, but we noted that water will be messy and hard to adjust for the operators. They suggested just finding a high density ferrous materials and that it doesn't need to be a weight of any sort. We agreed with this for the weight as we could just used HDPE or something along that line in order to meet the weight requirements.

In terms of fabrication groups also said a band saw and drill press is most likely the easiest way to fabricate this device, unless we can use the laser printer. Regardless of which process we use we will still need to do post-processing in order to make sure the device does not have sharp edges.

Conclusions/action items:

Overall the Show and Tell provided some useful feedback or perspectives that we did not think about. We will be sure in implement this feedback into the designs.

2024/04/2- Weight Stand & Pulley

Ethan Rao - Apr 29, 2024, 8:55 PM CDT

Title: Weight Stand and Pulley Thoughts on Materials

Date: 04/1/2024

Content by: Micah Schoff

Present: Whole Team

Goals: The goal of this entry was to do some thinking in terms of design as well as how these materials would best fit the designs that we have come up with recently.

Content:

Item	Link	Dimensions	Price	
Adjustable-Speed V-Belt Pulley	https://www.mcmaster.com/6213K59/	with 4", 3.5", 2.5" and 2" OD Grooves, for 3/4" Shaft Diameter	3D Printed at Makerspace	
Structural FRP Fiberglass Rod	https://www.mcmaster.com/8543K78/	2 Feet Long, 3/4" Diameter	$16.92	
Plastic Ball Bearing	https://www.mcmaster.com/6455K12/	with Glass Ball, Trade No. R12, for 3/4" Shaft Diameter	$21.72	
HDPE Sheet	Makerspace	36 X 24 in	Makerspace	

Conclusions/action items:

As a result of this entry, the team now knows what materials are necessary going forward that fit this specific portion of the design.

2024/04/05 Pulley Weight Stack Design

NIKHIL CHANDRA - Apr 28, 2024, 5:54 PM CDT

Title: 2024/04/05 Pulley Weight Stack Design

Date: 4/5

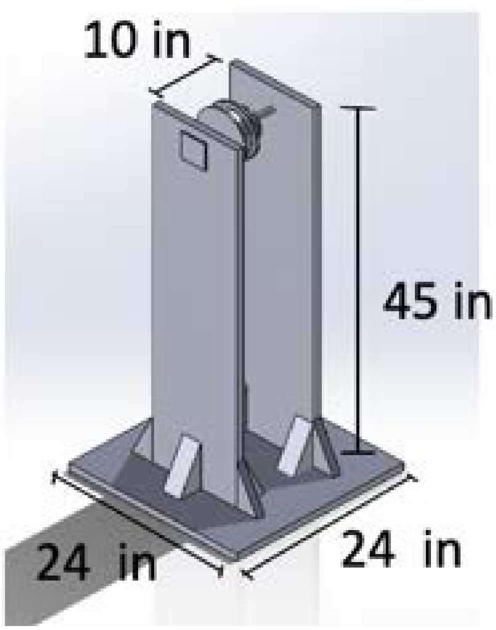
Content by: Nikhil Chandra

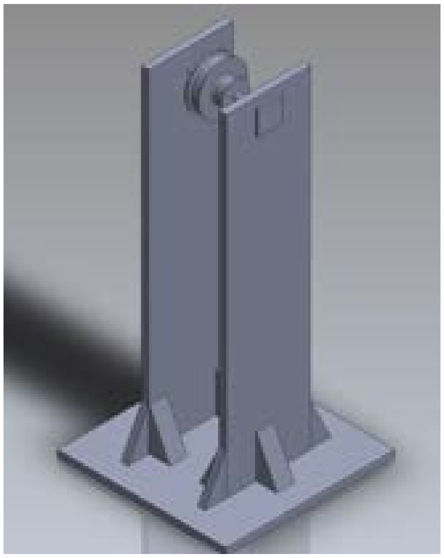
Present: Nikhil Chandra, Micah, Ethan

Goals: In this meeting, we wanted to further solidify our brainstormed idea for what the pulley weight stack system is going to look like and then develop the design fully in solidworks.

Content:

Below is the pulley weight stack system that we designed in solidworks. Each of the dimensions were iteratively chosen and estimated to be level with the MRI table and not too far from the end of the table. Specifically in this design, there are two vertical posts with bearings that will be inlaid resting against a square sheet. There will be a compressive fit between the bearings and the shaft and the shaft and the pulley. The vertical posts are longer in length towards the length of the pulley to ensure stability as the pulley is more likely to tip in the direction along the length of the MRI table.





Conclusions/action items:

With a design for the pulley system, we need to further discuss material choices specifically for the shaft and then develop a fabrication protocol.

2024/04/06 Initial Pulley Design: McMaster Carr

NIKHIL CHANDRA - Apr 28, 2024, 6:21 PM CDT

Title: 2024/04/06 Initial Pulley Design from McMaster Carr

Date: 4/6

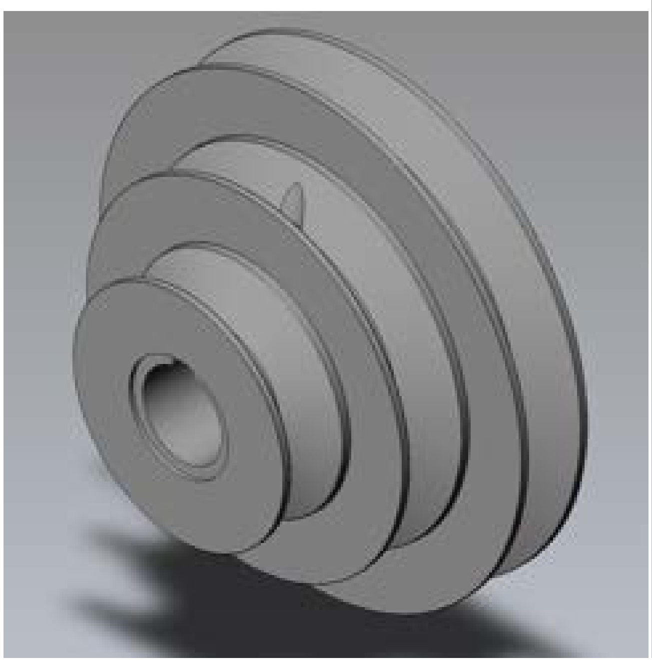
Content by: Nikhil Chandra

Present: Nikhil Chandra, Ethan, Micah

Goals: In this meeting, we discussed and retrieved a solidworks model for an adjustable speed pulley from McMaster Carr and discussed its fabrication.

Content:

Below is the solidworks design for the pulley design we collectively decided to proceed with for fabrication. This decision was made for a couple of reasons. The design achieves our desired force amplification with multiple radii ratios of 2:1 and 3:1. It has a ¾ inch shaft diameter which aligns with the plastic bearing hole dimensions we found allowing for a compressive fit between these components and the shaft. And by not having to redesign the pulley, we can focus our fabrication efforts on the pulley and weight stack system and the slider design.



We are going to proceed with 3d printing the design first at a 10% infill to validate that the complex geometry of the pulley can be effectively printed.

Reference to McMaster Carr purchase:

https://www.mcmaster.com/6213K49/

Product ID: 6213K49

Product Title: “Adjustable-Speed V-Belt Pulley with 4", 3" and 2" OD Grooves, for 3/4" Shaft Diameter”

Conclusions/action items:

With a design for the pulley decided upon, we will now proceed with 3d printing the pulley and validating the print before 3d printing it at a 100% infill to support the high load of an attached weight and amplified force.

2024/04/11 - Pulley 3D Print Failure, Redesign and Brainstorming

NIKHIL CHANDRA - May 02, 2024, 2:51 PM CDT

Title: 2024/04/11 - Pulley 3D Print Failure, Redesign and Brainstorming

Date: 4/11

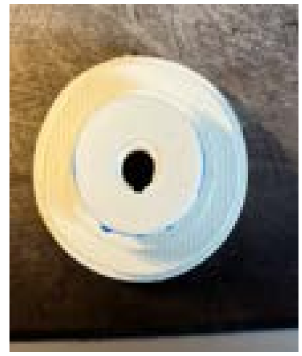
Content by: Nikhil Chandra

Present: Nikhil, Micah, Ethan, Caelen

Goals: To discuss as a team the initial 3D printed pulley prototype at a 10% infill, its limitations, and the potential for a redesign.

Content:

- Images of the 3D printed pulley are shown below from various angles
- The notable problems with the print include:
    - Inaccuracy with dimensions, the shaft hole is ovular rather than circular
    - The 3d print itself was sloppy with many loose threads at the V belt inner diameters
    - The 3d print was also just notably small and although we knew the dimensions prior, being able to size it in real life gives us intuitive doubts about its potential performance
- To overcome these challenges we have decided as a team to redesign the pulley rather than borrinw a design from McMasterCarr
    - Specifically, the design from McMaster Carr is unnecessarily complex that potentially contributed to the sloppied 3d print, and instead simplifying the design and geometry of the pulley may significantly improve the accuracy of the print
    - In addition, we want the redesign to be significantly larger with higher cross sectional areas that can better distribute a load potentially greater than 100 lbs
    - The redesign should still be a step pulley that allows for a radii ratio of 2 for a 2 times amplification.



Conclusion:

With a team decision that we need to redesign the pulley ourselves as opposed to borrowing the design from McMaster Carr after the failed 3D print, we will move forward with a redesign.

2024/04/16- Ethics in Engineering Activity

Ethan Rao - Apr 16, 2024, 9:16 PM CDT

Title: Ethics in Engineering Activity

Date: 04/16/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of this entry is to outline some ethical considerations that the team must make as they continue forward towards the final design as well as a simple action plan to implement these considerations.

Content:

-
    - What components of your design have ethical dimensions (be specific and list at least 2)?
        - One of the components of the design that has ethical dimensions are the usability aspects of the device. This device should be usable by people of different weights, heights, and strengths. Therefore, the design should account for these differences among other things to be usable by a majority of the population.
        - Another component that has ethical dimensions is the collection of data during testing. This data must be collected accurately as well as appropriately in order to ensure the safety and viability of the device for the client. The device will be used in research studies that could have the potential to serve as basis for revising hamstring strain injury rehabilitation, so the overall device functioning and the measurements it takes/allows must be accurate in order to yield accurate conclusions.
    - How will your team address the ethical dimensions? (What is your action plan?)
        - In order to address the usability aspects of the design, the team will have to do a number of things. The first is to give constant thought to this criteria as the team fabricates different aspects of the design as they may impact the usability in different ways. The other could be to place a system of checks/tests that ensure the usability of each portion before incorporation into the final design. Prior to fabrication and testing, preliminary designs were made and evaluated based on criteria which are relevant to the components of the design which have ethical dimensions, such as accuracy and adjustability.
        - The action plan in terms of this is fairly simple. It requires the team to be honest and accurate throughout the testing process. However, it does require that the team carry out sufficient testing of each portion of the design to ensure viability within the application. This in itself will ensure that the data provided will give a good idea to both our client as well as potential subjects of how effective the device is as well as how safe it is for usage.

Conclusions/action items:

As a result of this, the team will be able to better approach the ethical considerations necessary in order to ensure this device is as inclusive/effective/safe as possible.

2024/04/17 - Pulley 3D Printed Redesign Evaluation and Comparison

NIKHIL CHANDRA - May 02, 2024, 2:59 PM CDT

Title: 2024/04/17 - Pulley 3D Printed Redesign Evaluation and Comparison

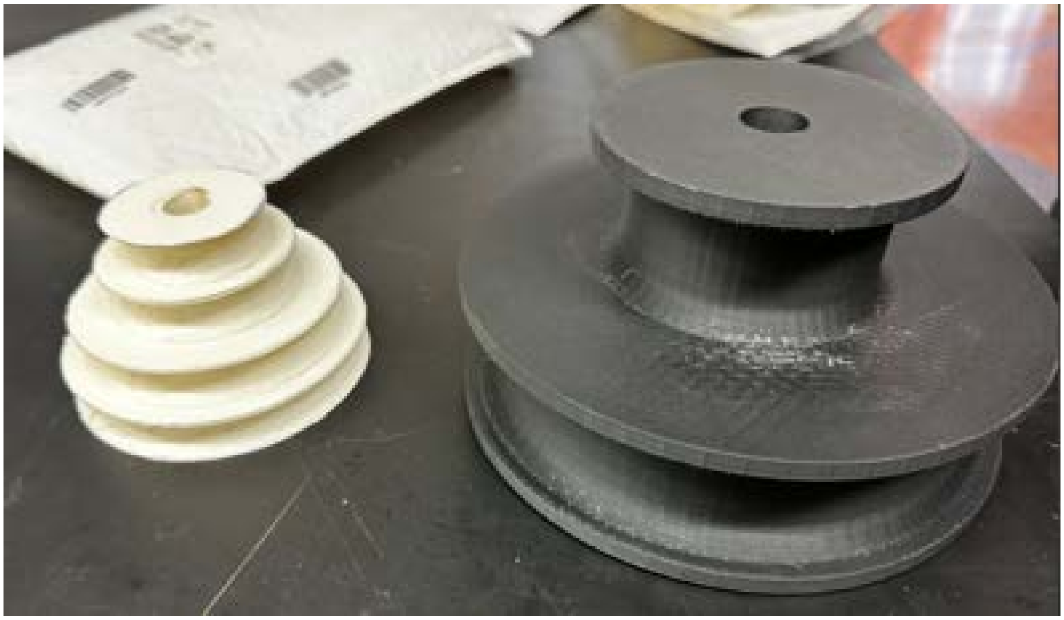
Date: 4/17

Content by: Nikhil Chandra

Present: Nikhil, Micah, Ethan, Caelen

Goals: To evaluate the 3D print of the new pulley and how well it satisfies the expected design and whether there ought to be any post-processing or fabrication of the pulley.

Content:

- The below images show the comparison between the 3D printed pulley given the new re-design and the 3D printed pulley given the smaller design from McMaster Carr
- Since we printed the redesigned pulley using the Bambu printers, the print was significantly more accurate and accurately matched every one of our desired dimensions.
- The shaft hole is circular and there are no notable cracks, or problems with the 3D print
- Overall the 3D print matches our expected design and at a 100% infill maximizes the potential strength we can achieve for the pulley
- 

Conclusion/Action-Items:

The 3D printed redesign of the pulley was successful with accurate dimensions and no notable cracks or imperfections. We can now proceed with the fabrication of the rest of the pulley and weight stack system.

2024/04/18 Slider Hook Team Discussion and Design

NIKHIL CHANDRA - Apr 28, 2024, 6:09 PM CDT

Title: 2024/04/18 Slider Hook Team Discussion and Design

Date: 4/18

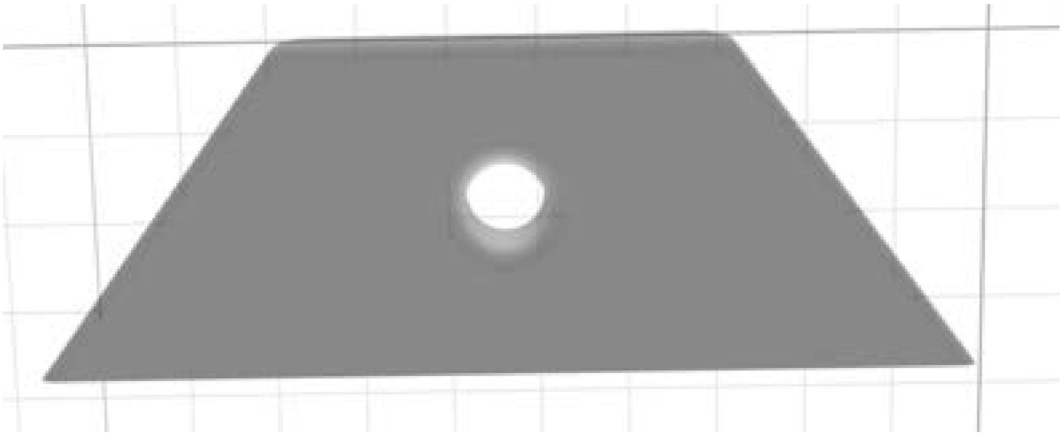
Content by: Nikhil Chandra

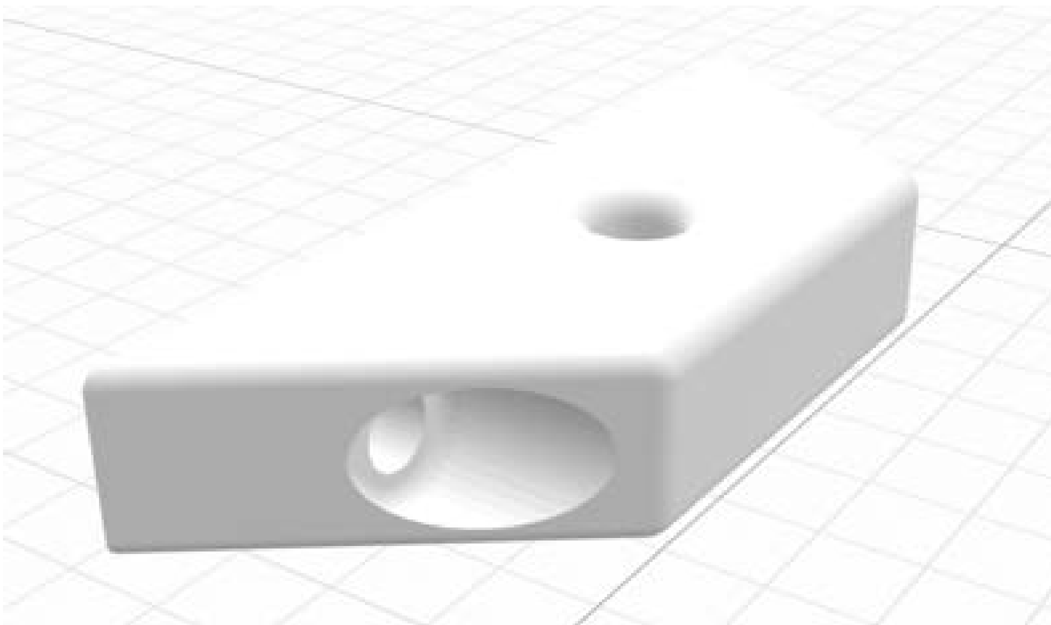
Present: Nikhil Chandra, Ethan, Micah, Caelen

Goals: Here I finished designing the slider hook in about 30 minutes as an alternative solution to secure the cable to the slider bar since we could not find a threaded hook that was sufficiently strong, I wanted to show the design to the team and have a brief discussion before I proceed with 3d printing.

Content:

Below is the design for the slider hook, where a cable will wrap through the hole, and the holes on the side are not threaded and are where threaded screws will rest(they will be secured to threaded holes that we will make in the slider bar). With the team we verified the dimensions and idea behind the hook, and we will proceed with 3d printing the slider hook at a 100% infill to ensure sufficient strength in supporting the cable force. The below design was designed in solidworks and displayed in Xcode:





Conclusions/action items:

With a design for the slider hook that has been discussed and verified by the team, we can now proceed with 3d printing and continued fabrication of the rest of the slider and pulley and weight stack system.

2024/04/14 - New Pulley Redesign

NIKHIL CHANDRA - May 02, 2024, 3:17 PM CDT

Title: 2024/04/14 - New Pulley Redesign

Date: 4/14

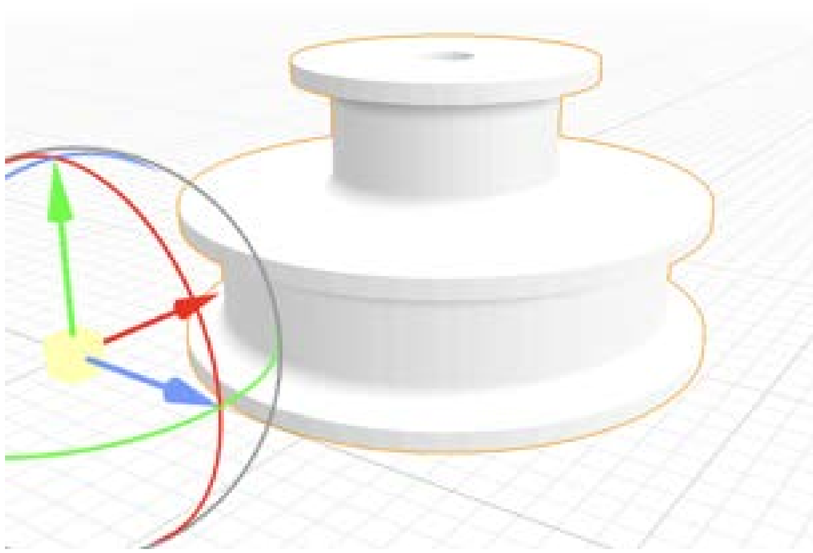
Content by: Nikhil Chandra

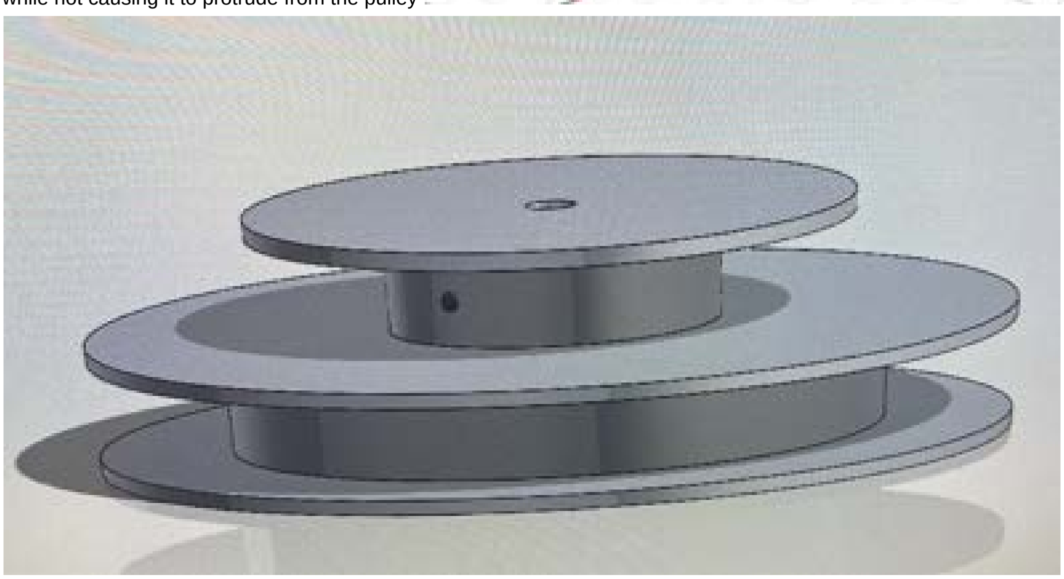
Present: Micah, Nikhil, Ethan Caelen

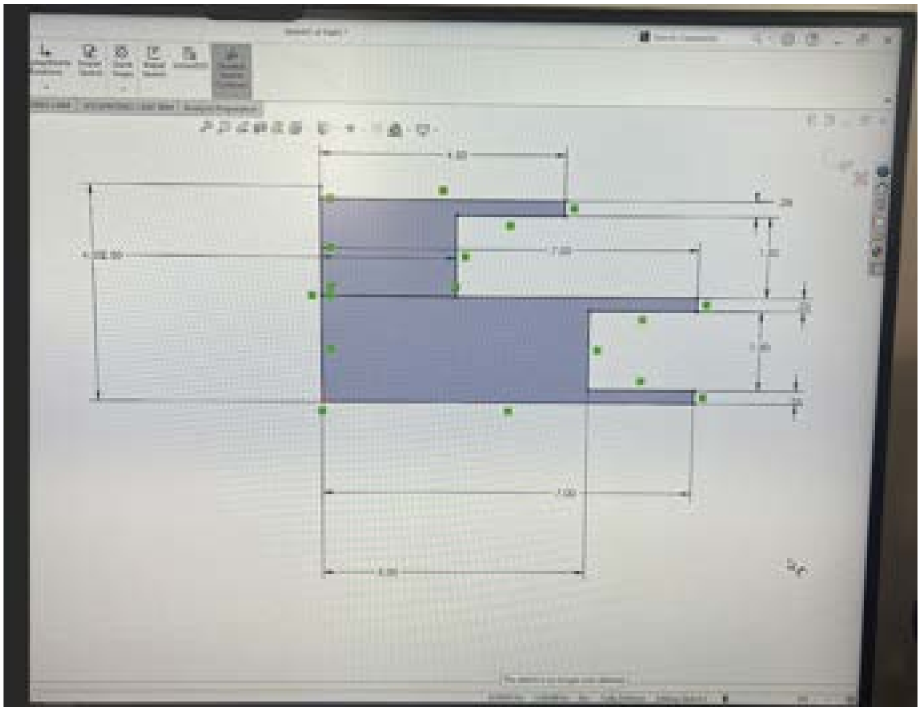
Goals: To show the redesign of the new pulley by Micah and discuss it as a team before moving into 3D printing.

Content:

- The below are images of the redesigned pulley and dimensions
- Notably the pulley has two steps with a radii ratio of 2 to 1 allowing for a 2 times amplification of weight.
- We significantly expanded the radii of the pulley where the inner radii of the larger step is 5 in allowing for the load to be distributed over a larger cross sectional area
- The width of the pulley where the cable rests for each step was also expanded to 1.5 inches allowing more cables to potentially be wrapped while not causing it to protrude from the pulley





- 

Conclusions/action items:

With the redesign of the pulley to be larger and simpler while still maintaining a 2 times force amplification, we can now proceed with 3d printing the pulley using the Bambu printers at a 100% infill to maximize strength.

NIKHIL CHANDRA - May 02, 2024, 3:18 PM CDT

Download

Final_Pulley_Design_2_.SLDPRT (594 kB)

2024/03/18- Preliminary Materials List

Ethan Rao - Mar 18, 2024, 10:12 PM CDT

Title: Preliminary Materials List

Date: 03/18/2024

Content by: Entry by Ethan Rao; Chart/Material Acquisition by Micah Schoff

Present: Ethan Rao

Goals: The goal of this entry is to document the preliminary list of materials that the team came up with for the report.

Content:

List of Materials

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link
Heel Slider										
HDPE	Plastic Sheet: 0.5 in Thick, 12 in W x 48 in L, Black, Opaque, 4,600 psi Tensile Strength	Zoro	1ZAX7	Grainger	1ZAX7	N/A	2	$49.38	$98.76	Grainger
Epoxy	J-B WELD Epoxy Adhesive: KwikWeld, Ambient Cured, 10 fl oz, Tube, Dark Gray, Paste	J-B WELD	8271	Grainger	14G802	N/A	1	$23.17	$23.17	Grainger
PLA	PLA is a 3D printable material measured in grams	N/A	N/A	Makerspace	N/A	N/A	50	$0.08	$4.00	Makerspace
Felt	Wool felt strip with acrylic adheseive	Zoro	2FGZ7	Grainger	2FGZ7	N/A	1	$0.14	$0.14	Grainger
HDPE Rod	Plastic Rod: 8 ft Plastic Lg, Off-White, Opaque, 4,500 psi Tensile Strength, 2.75 ft-lb/in	Grainger	22JL41	Grainger	22JL41	N/A	1	$19.00	$19.00	Grainger
Synthetic Winch Line	Synthetic line with tensile stregth of 10,000 lbs. Used for cable. 50 ft	Ucreative	Mfr	Amazon	Mfr	N/A	1	$19.99	$19.99	Amazon
								TOTAL:	**$165.06**	

Based on one my individual entries, there is still some work to be done in terms of materials. The team is hoping to finish up this work by the end of the week in order to be able to get all of the materials ordered prior to Spring Break.

Conclusions/action items:

As a result of this entry, the team now has a preliminary list of materials to be used in the final design. However, there is still some work to be done as mentioned, so there will be more in depth material entries to be added later this week.

2024/04/25 - Final Expenses

MICAH SCHOFF - Apr 22, 2024, 11:16 PM CDT

Title: Team Material Expenses

Date: 2/16/2024

Content by: Micah Schoff

Present: Team

Goals: Track all team expenses here.

Content:

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link
HDPE 12 x 48 x 1	Moisture-Resistant HDPE Sheet	King Plastic Corporation	King KPC HDPE	McMaster-Carr	8619K493	4/13	2	$91.54	$183.08	https://www.mcmaster.com/catalog/8619K493
HDPE 24x24x1	Moisture-Resistant HDPE Sheet	King Plastic Corporation	King KPC HDPE	McMaster-Carr	8619K494	4/13	1	$91.54	$91.54	https://www.mcmaster.com/catalog/8619K494
Plastic Glass Ball Bearings	Plastic Ball Bearing with Glass Ball, Trade No. R12, for 3/4" Shaft Diameter	N/A	6455K12	McMaster-Carr	6455K12	4/13	2	$21.72	$43.44	https://www.mcmaster.com/catalog/6455K12
Nylon Screws	Nylon Socket Head Screws	N/A	95858A744	McMaster-Carr	95858A744	4/13	1	$13.84	$13.84	https://www.mcmaster.com/catalog/95868A744
HDPE Rod	Plastic Rod: 4 ft Plastic Lg, Off-White, Opaque, 4,500 psi Tensile Strength, 2.75 ft-lb/in	Grainger	22JL44	McMaster-Carr	22JL44	4/13	1	$24.74	$24.74	https://www.grainger.com/product/APPROVED-VENDOR-Plastic-Rod-4-ft-Plastic-Lg-22JL44?findingMethod=orderHistory&opr=ODOH
Synthetic Winch Line	Nylon Rope,100 Feet White Nylon Rope,1/4 Inch Solid Braided Rope	JIJIA	JS-Z08021-F1	Amazon	B07V1TN41Q	4/14	1	$9.99	$9.99	https://www.amazon.com/dp/B07V1TN41Q?psc=1&ref=ppx_yo2ov_dt_b_product_details
Carbon Fiber Rod	Black Carbon Fiber Rod Stock 1 ft. L, 3/4" Dia.	Zoro Select	BULK-CR-CF-9	Zoro	G7285584	4/17	1	$46.99	$46.99	Zoro Select Black Carbon Fiber Rod Stock 1 ft. L, 3/4" Dia. BULK-CR-CF-9 | Zoro
								TOTAL:	**$414**	

l										

Conclusions/action items: Continue to update this as expenses are added.

2024/04/25 - HDPE Material Choice

MICAH SCHOFF - Apr 28, 2024, 9:32 PM CDT

Title: HDPE for Slider

Date: 4/24/2024

Content by: Micah Schoff

Present: Team

Goals: Discuss material choice for slider and weight stack.

Content:

Our team deiced to use HDPE (High-Density Polyethylene) for our slider design and structural components of the weight stack. Specifically on the slider this material was chosen as it is relatively frictionless. This is pivot as within our design we wanted to minimize friction to allow for easier calculations in terms of resistance on the Hamstring. Its exceptional durability and resistance to wear guarantee longevity, even with frequent use. Additionally, its lightweight nature contributes to the overall efficiency of our design. The simplicity of working with HDPE allows us to fabricate our designs with precision, catering to our project's specific needs. Moreover, HDPE's non-porous surface makes it effortless to clean and disinfect, ensuring compliance with strict hygiene standards within the research setting.

This also goes for the weight stack design. Using HDPE will give us the strength required to meet PDS criteria while also being able to fabricate the design.

Conclusions/action items: Overall, our decision to utilize HDPE for our slider design and weight stack not only enhances functionality but also prioritizes practicality and disinfection, making it an excellent choice for our project.

2024/04/25 - 3D Printed Components Selection

MICAH SCHOFF - Apr 28, 2024, 9:52 PM CDT

Title: 3D printing for pulley and brackets

Date: 4/24/2024

Content by: Micah Schoff

Present: Team

Goals: Discuss material choice for pulley and brackets.

Content:

Our decision to utilize PLA for printing our amplification pulley and brackets stemmed from careful consideration of both cost-effectiveness and material versatility. PLA emerged as the best choice due to its affordability and availability here at the makerspace. Its relatively low cost compared to other materials allowed us to stay within budget constraints without compromising on quality. Additionally, PLA's versatility provided us with the strength needed to achieve the desired functionality and design intricacies of our pulley and brackets. Its ease of printing and compatibility with various 3D printers made it a practical option for our project. We were also able to control the level of infill that we printed with for this project allowing us to adjust strength of the parts for their intended use. for the pulley we selected a 100% infill to allow us to ensure that the part would not break as this would be the major piece that will be enduring forces.

Conclusions/action items: By choosing PLA, we not only ensured cost efficiency but also utilized the material's strength to create durable and precisely engineered components for our amplification system.

2024/04/25 - Bearings Materials Selection

MICAH SCHOFF - Apr 28, 2024, 9:59 PM CDT

Title: Bearings

Date: 4/24/2024

Content by: Micah Schoff

Present: Team

Goals: Discuss material choice for bearings.

Content: In order to reduce friction within the motion of the pulley we decide to implement bearings int our design. The bearings are on the shaft as the pulley rotates with the shaft. Since the device will be within and MRI environment, we were not able to use ferrous bearings. We were able to find plastic casing glass ball bearings. These bearings were the best option as the glass ball bearings is able to carry more weight than a plastic ball bearing. The only issue here is that there still is a limit to the weight on the glass ball bearings. Each bearing can have roughly 35 N of force distributed on it. With this there are plans to either add mor bearings to distribute the load onto or look into a higher load glass ball bearing.

Conclusions/action items: Overall, the glass ball bearings are a good fit in terms of materials, however, further work into implementing more or finding higher load alternatives could benefit the device.

2024/04/25 - Carbon Fiber Rod

MICAH SCHOFF - May 03, 2024, 1:32 PM CDT

Title: Carbon Fiber Rod for Load Bearing

Date: 4/25/2024

Content by: Micah Schoff

Present: Team

Goals: Discuss material choice for load bearing rod.

Content:

Originally we had selected a plastic HDPE rod for the load bearing rod that the pulley would sit upon. Through running bending calculation we found out that the material strength needed to be much higher. Instead of HDPE we selected carbon fiber. Carbon fiber has a greater tensile strength range of 3500 to 5000 MPa making it very strong. This allowed us to have a factor of safety of 3 for the maximum amount of weight on the device. This is not only pivotal for safety of the researchers and subjects, but also allows for reliability.

Conclusions/action items: Overall, Carbon fiber provided us with a solution that perfectly fit the application we were looking for while allows us to reach a factor of safety of 3. Further this also allows this device to achieve its reliability and repeatability.

2024/03/11- Fabrication Timeline

Ethan Rao - Mar 11, 2024, 5:29 PM CDT

Title: Fabrication Timeline

Date: 03/11/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of the meeting today was to put together a timeline for future goals in the semester. This will allow the team to stay accountable as we move forward with the project.

Content:

March 24th

Materials and order materials, Design Meeting
Calculations

- **Force analysis, FBD**
- Fatigue analysis
- Critical stress and failure theories
- FEA

March 31

- Design of the slider system
- Design of the pulley system
- Fabrication Strategy/Plan

April 1 - Fabrication

April 19th - Testing

April 26th: Finish everything

Poster/Final Report

Conclusions/action items:

As a result of this meeting the team has been able to put together a rough timeline going forward. This will keep the team working effectively towards an effective prototype to provide at the end of the semester.

2024/03/18 MR Measurements

Caelen Nickel - Mar 18, 2024, 9:24 PM CDT

Title: 2024/03/18 MR Measurements

Date: 03/18/2024

Content by: Caelen Nickel

Present: BME Design Team for initial measurements, Caelen for final measurements

Goals: Obtain measurements for the MR table in order to fabricate a device

Content:

Hole 1 outer diameter: 1 3/8 in.

Hole 1 inner diameter: 5/8 in.

Table total width: 26 1/2 in.

Table inner width: 17 3/8 in

Table height: 35 3/4 in

1 unit bedding: 15 1/2 in.

Handle width: 1 3/8 in.

Handle height: 2 1/4

Longer measurements such as table length are to come, the ribbon is straightening.

Conclusions/action items:

As a result of scheduling a time to measure specifications of the MR table, most measurements have been numerically obtained. This is vital for the creation of detailed CAD, as well as producing a prototype.

2024/04/09- Procedure for Fabrication of Slider Portion of Design

Ethan Rao - Apr 09, 2024, 5:54 PM CDT

Title: Procedure for Fabrication of Slider Portion of Design

Date: 04/09/2024

Content by: Everyone

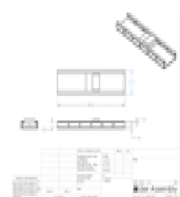
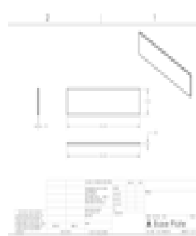
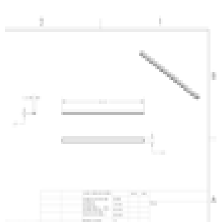
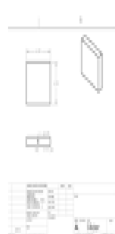
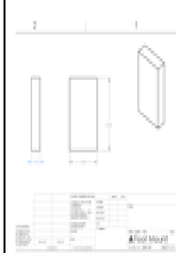
Present: Everyone

Goals: The goal of this entry is to clearly lay out the steps the team took to fabricate the slider portion of the design.

Content:

Slider Fabrication Protocol

Name of fabrication step/portion of prototype: Cutting the Parts of the Slider Design
Date to be completed: 04/19/2024
Team member(s) fabricating: Micah Schoff, Nikhil Chandra, Ethan Rao, Caelen Nickel
Detailed sketch of portion of prototype being fabricated:

Slider Assembly: 	Base Sheet: Part 1 	Side Runners: Parts 2 & 3 
Vertical Limit: Parts 4 & 5 	Slider: Parts 6 & 7 	Foot Mount: Parts 8 & 9 

List of Materials Needed:

- Material 1: Sheet of High Density Polyethylene (HDPE)
    - Quantity: 2
    - Dimensions: 48 in. long by 12 in. wide
    - Manufacturer/Part Number: Zoro (PN:1ZAX7)
    - Purpose: The purpose of this material in the protocol is to provide the material with which the team plans to fabricate this section of the device out of.
- Material 2: Wool Felt Strip with Acrylic Adhesive
    - Quantity: 1
    - Dimensions: 12 in. length by 1 in. width
    - Manufacturer/Part Number: Zoro (PN: 2FGZ7)
    - Purpose: The purpose of the felt is to create as close to a frictionless surface as possible for the slider to move across.
- Material 3: Bandsaw
    - Quantity: 1
    - Manufacturer: Global Industrial (PN:28-400) or any found in TEAM Lab [1]
    - Purpose: The purpose of the bandsaw is to cut the HDPE into the correct dimensions as specified by the drawing the team created.
- Material 4: Scissors
    - Quantity: 1
    - Manufacturer: Clauss (PN: 22UM87) or any other handheld scissors that will cut felt [2]
    - Purpose: The purpose of the scissors is to cut the felt to the dimensions specified by the drawing the team created

Detailed bulleted steps of fabrication:

1. Following the dimensions on SolidWorks drawing (see “Detailed Sketch” above) mark cuts on a 48 in. x 12in. sheet of HDPE using a marker
    a. Part 1: 1 base sheet of HDPE (30 in. long by 7.5 in. wide by 0.5 in. height)
    b. Part 2 and 3: 2 side runners of HDPE (30 in. long by 0.5 in. wide by 1.5 in. height)
    c. Part 4 and 5: 2 vertical limits of HDPE (30 in. long by 1 in. wide by 0.25 in. height)
    d. Part 6 and 7: 2 slider of HDPE (6 in. long by 6.25 in. wide by 0.5 in. thick)
    e. Part 8 and 9: 2 foot mounts of HDPE (3 in. long by 5 in. wide by 0.5 in. thick)
2. Place each respective piece of HDPE on the bandsaw
3. Set the bandsaw to the appropriate speed (~1000 ft/min.) [3]
4. Turn on the bandsaw
5. Move the piece of HDPE slowly through the bandsaw following each mark of the cut
6. Turn off the bandsaw
7. Remove newly cut piece from the bandsaw
8. Sand newly cut piece if necessary to remove unnecessary material
9. Repeat Steps 2-8 for each Part referenced in Step 1
10. Mark cut for felt lining on a piece of felt (3.7 in. wide and 3 in. long)
11. Cut one piece of felt using scissors
12. Utilize these now cut pieces for assembly (Refer to Assembly for Slider Design Protocol)

Conclusions/action items:

Due to the level of detail that this procedure provided the team, fabrication went very well. This will allow the team to now shift focus on assembly as well as building of the slider design.

2024/04/09- Fabrication of Slider Portion of Design

Ethan Rao - Apr 09, 2024, 6:07 PM CDT

Title: Fabrication of Slider Portion of Design

Date: 04/09/2024

Content by: Ethan Rao

Present: Ethan Rao and Micah Schoff

Goals: The goal today was to fabricate the full slider design.

Content:

NOTES ON FABRICATION: Micah and I were able to fabricate pretty close to what the team was originally thinking in terms of the slider design. Now moving forward, the team will have to decide how to assemble this section of the device which will likely require another procedure. (Note: Refer to Procedure for Fabrication of Slider Portion of Design)

IMAGES: Attached Below

Conclusions/action items:

As a result of this, the team now has a headstart in the fabrication portion of the project, and can now set goals on how best to accomplish the other portions of this project.

Ethan Rao - Apr 09, 2024, 6:07 PM CDT

Download

IMG_2928.HEIC (2.38 MB)

Ethan Rao - Apr 09, 2024, 6:08 PM CDT

Download

IMG_9895.HEIC (1.98 MB)

Ethan Rao - Apr 09, 2024, 6:08 PM CDT

Download

IMG_9897.HEIC (2.8 MB)

2024/04/22 - Procedure for Fabrication of Side Posts

Ethan Rao - Apr 23, 2024, 4:02 PM CDT

Title: Procedure for Fabrication of Side Posts

Date: 04/22/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of this procedure was to ensure the fabrication of the side posts went smoothly and to plan with a limited time table.

Content:

Name of fabrication step/portion of prototype: Side Posts/Supports
Date to be completed: 04/19/2024
Team member(s) fabricating: Micah Schoff, Nikhil Chandra, Ethan Rao, Caelen Nickel

List of Materials Needed:

- Material 1: Sheet of High Density Polyethylene (HDPE)
    - Quantity: 2
    - Dimensions: 48 in. long by 12 in. wide
    - Manufacturer/Part Number: Zoro (PN:1ZAX7)
    - Purpose: The purpose of this material in the protocol is to provide the material with which the team will work on to create the side posts/supports for the pulley system
- Material 2: Drill Press
    - Quantity: 1
    - Dimensions: Not applicable
    - Manufacturer/Part Number: Grainger (PN: 36VE10) or any found in TEAM Lab
    - Purpose: The purpose of this drill press is to attach to the hole saw in order to cut the holes necessary for the rod in the pulley system to pass through
- Material 3: Hole Saw
    - Quantity: 1
    - Dimensions: 1 and 5/8' diameter
    - Manufacturer/Part Number: Zoro (PN: 49-56-9119)
    - Purpose: To drill the hole through which the rod will pass

- Material 4: 3D Printed Pieces
    - Quantity: 2
    - Dimensions: As specified within the SolidWorks File
    - Manufacturer/Part Number: N/A
    - Purpose: To ensure a compressive fit for the bearings to be inserted within the holes created using the hole saw
- Material 5: Bearings
    - Quantity: 2
    - Dimensions: 1 and 5/8 " outer diameter and 5/8 " inner diameter
    - Manufacturer/Part Number: McMaster Carr (PN: 5951N129)
    - Purpose: To give the rod and pulley rotation within the system
- Material 6: Plastic Screws
    - Quantity: 8
    - Dimensions 1" long and 3/8" diameter
    - Manufacturer/Part Number: TEAM Lab
    - Purpose: To fasten the 3D printed pieces to the side posts

Detailed bulleted steps of fabrication:

1. Acquire the appropriate materials utilizing the stated websites
2. Measure out the correct dimensions (5.1875 inches from the side of the post and 2 inches from the top of the post)
3. Use a marker in order to trace the bearing at the location specified by the measurements in Step 2
4. Attach the hole saw to the drill press
5. Set the speed on the drill press to between 250-350 RPM (relatively slow speed)
6. Place sheet of HDPE on the drill press and clamp down, using the provided clamps in the TEAM Lab
7. Turn the drill press on
8. Bring the drill press down slowly using the peck drilling technique to reasonably slowly to remove the material necessary
9. Place the 3D printed material on top of the post and align hole with the hole made using the hole saw
10. Use the drill press to make 4 identical holes in the four corners of both 3-D printed pieces
11. Use tools found in the team lab to countersink and tap the holes in order to insert screws
12. Insert bearing
13. Insert 3-D printed pieces and screws through the holes that have been drilled in all three materials
14. Tighten all screws
15. Repeat for Post 2
16. Add to Final Assembly

Conclusions/action items:

As a result of this procedure, the team has a solid plan in place in order to fabricate all portions of the side posts. This will bring the team one step closer to completing the final assembly of the prototype.

2024/04/22- Fabrication of Side Posts

Ethan Rao - Apr 22, 2024, 10:56 PM CDT

Title: Fabrication of Side Posts

Date: 04/22/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of this was to finish fabrication of the side posts, an important portion of the design

Content:

Refer to the Procedure for Fabrication of Side Posts for any Other Information

Image of Nikhil Measuring the Side Post:

Comments: The fabrication process went really well. Not too many hiccups. The only thing that was a little difficult was achieving the compressive fit for the bearings, but that was solved using the 3D printed pieces.

Conclusions/action items:

Based on the successful fabrication of the side posts, the team is now one step closer to a final prototype that will be satisfactory for the poster session as well as our client.

2024/04/23- Procedure for Fabricating Base

Ethan Rao - Apr 23, 2024, 4:21 PM CDT

Title: Procedure for Fabrication of Base

Date: 04/23/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of this procedure was to lay out the plan with which the team would use to fabricate the base of the device. This includes the triangle supports to be attached by screws

Content:

Name of fabrication step/portion of prototype: Base
Date to be completed: 04/23/2024
Team member(s) fabricating: Micah Schoff, Nikhil Chandra, Ethan Rao, Caelen Nickel

List of Materials Needed:

- Material 1: Sheet of High Density Polyethylene (HDPE)
    - Quantity: 1
    - Dimensions: 24 in. long by 24 in. wide
    - Manufacturer/Part Number: Grainger (PN: 1ZAN3)
    - Purpose: The purpose of this material in the protocol is to provide the base for the overall project
- Material 2: Hand Drill
    - Quantity: 1
    - Dimensions: 1/4 20 Drill Bit
    - Manufacturer/Part Number: TEAM Lab
    - Purpose: The purpose of the hand drill is to drill the holes through which the screws will secure the triangle supports to the base
- Material 3: Jig Saw
    - Quantity: 1
    - Dimensions: N/A
    - Manufacturer/Part Number: TEAM Lab
    - Purpose: The purpose of the jig saw is to cut the holes through the base that are necessary in order to place the side posts in position
- Material 4: Plastic Screws

    - Quantity: 10
    - Dimensions: 3/8 inch screws
    - Manufacturer/Part Number: TEAM Lab
    - Purpose: The purpose of the plastic screws is to properly attach the triangular supports to the base
- Material 5: HDPE Sheet
    - Quantity: 1
    - Dimensions:
    - Manufacturer/Part Number: 18 inches long by 9 inches wide by 2 inches thick
    - Purpose: To provide support for the side posts

Detailed bulleted steps of fabrication:

1. Acquire the appropriate materials utilizing the stated websites and the TEAM Lab
2. Measure out two 12 inch long 1 inch wide holes approximately 6 inches from one side and 3 inches from the other on the 24 X 24 sheet of HDPE
3. Choose an appropriate blade size for the jig saw as consulted by the TEAM Lab
4. Turn the jig saw on
5. Follow the marks made with the jig saw as best as possible and remove the material from the 24 X 24 sheet
6. Measure out as many 2.5 inch wide and 8 inch tall triangles from the thick sheet of HDPE as possible to provide ample support
7. Use the jig saw (or alternatively the band saw) to follow each line in order to cut out the triangle supports
8. Place the triangles at appropriate positions (at user discretion) in order to best support the side posts
9. Trace the form of the triangles with a marker in order to prepare for drilling
10. Measure approximately the center of each tracing of the triangle support on the base
11. Attach the appropriate drill bit (reference materials) to the hand drill
12. Utilize the hand drill to make all holes through the base and triangle supports
13. For all drilled holes, countersink and thread appropriately using tools found within the TEAM Lab
    1. NOTE: When threading, make sure to go slowly and use the 3 turns clockwise, 1 turn counterclockwise rule
14. Attach all screws, securing the triangle supports to the base plate

Conclusions/action items:

As a result of this procedure, the team should have a pretty effective and efficient time fabricating the base in the TEAM Lab.

2024/04/23- Fabrication of the Base Plate

Ethan Rao - Apr 23, 2024, 4:32 PM CDT

Title: Fabrication of the Base Plate

Date: 04/23/2024

Content by: Ethan Rao

Present: Everyone

Goals: The goal of this meeting was to fabricate the base plate in its entiriety.

Content:

REFER TO PROCEDURE FOR FABRICATION OF THE BASE PLATE FOR MORE DETAILS

Image of Micah Fabricating the Base Plate:

Comments: Overall, the process went really well. It took about 3 hours to completely fabricate the base plate and attach the triangle supports. There were a few design issues as with each portion of the project which will be referenced in separate entries

Conclusions/action items:

As a result of fabricating the base plate, the team is now really close to being able to assemble and finish up some of the total product testing. Finishing these things up will allow the team to shift focus to some of the documentation necessary for the Poster Session and the Final Report.

2024/04/23- Design Challenge 1: Bearing Fit

NIKHIL CHANDRA - May 02, 2024, 3:23 PM CDT

Title: Design Challenge 1: Bearing Fit

Date: 04/23/2024

Content by: Ethan Rao

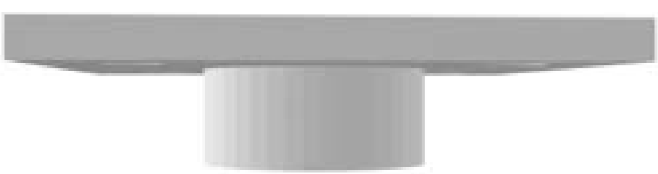
Present: Everyone

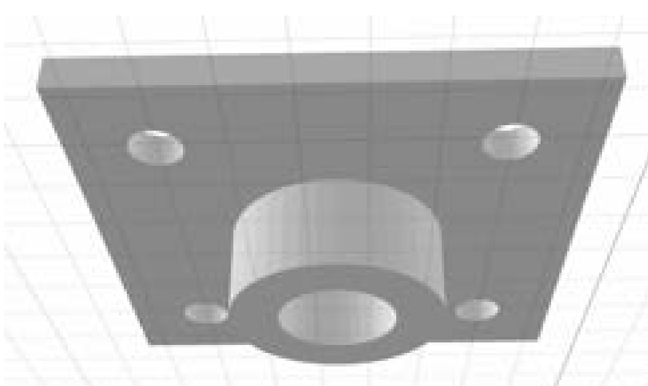
Goals: The goal of this entry is to highlight a design challenge that the team faced while working through the fabrication aspects of the project/

Content:

Comments: One of the major design challenges with fabrication that the team faced was ensuring a compressive fit for the bearing. The hole saw used to fabricate the side posts did not cut out perfectly to dimension holes which ultimately led to a loose fit for the bearing that would allow it to fall out. Therefore, the team needed to come up with a solution that would keep the bearing secure. The solution was two 3D printed pieces as shown below that are attached by plastic screws. This allowed for a more secure fit for both the bearing and the rod that the pulley is attached to.

In one meeting, Nikhil quickly designed a part to create a compressive fit for the bearing and both the design and 3D printed piece are shown below. The design file is also attached to view exact dimensions.





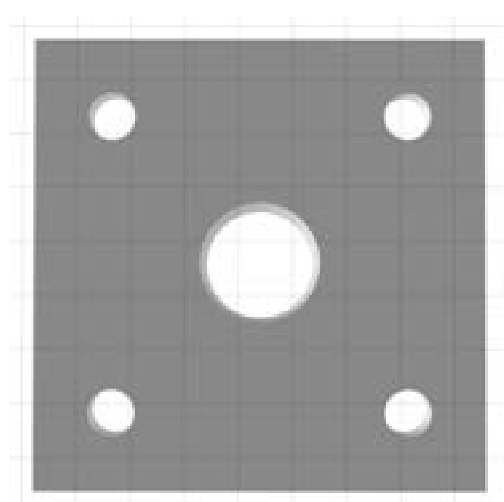


Image of the 3D Printed Piece:

Conclusions/action items:

As a result of this solution the team was able to relatively securely fasten the bearing in the overall device. This led to a more successful fabrication experience and left some time for the team to do some important testing and documentation.

NIKHIL CHANDRA - May 02, 2024, 3:25 PM CDT

Download

CompressiveBearing.STL (47.8 kB)

2024/04/23- Design Challenge 2: Shearing of the Support Screws

Ethan Rao - Apr 23, 2024, 4:53 PM CDT

Title: Shearing of the Support Screws

Date: 04/23/2024

Content by: Ethan Rao

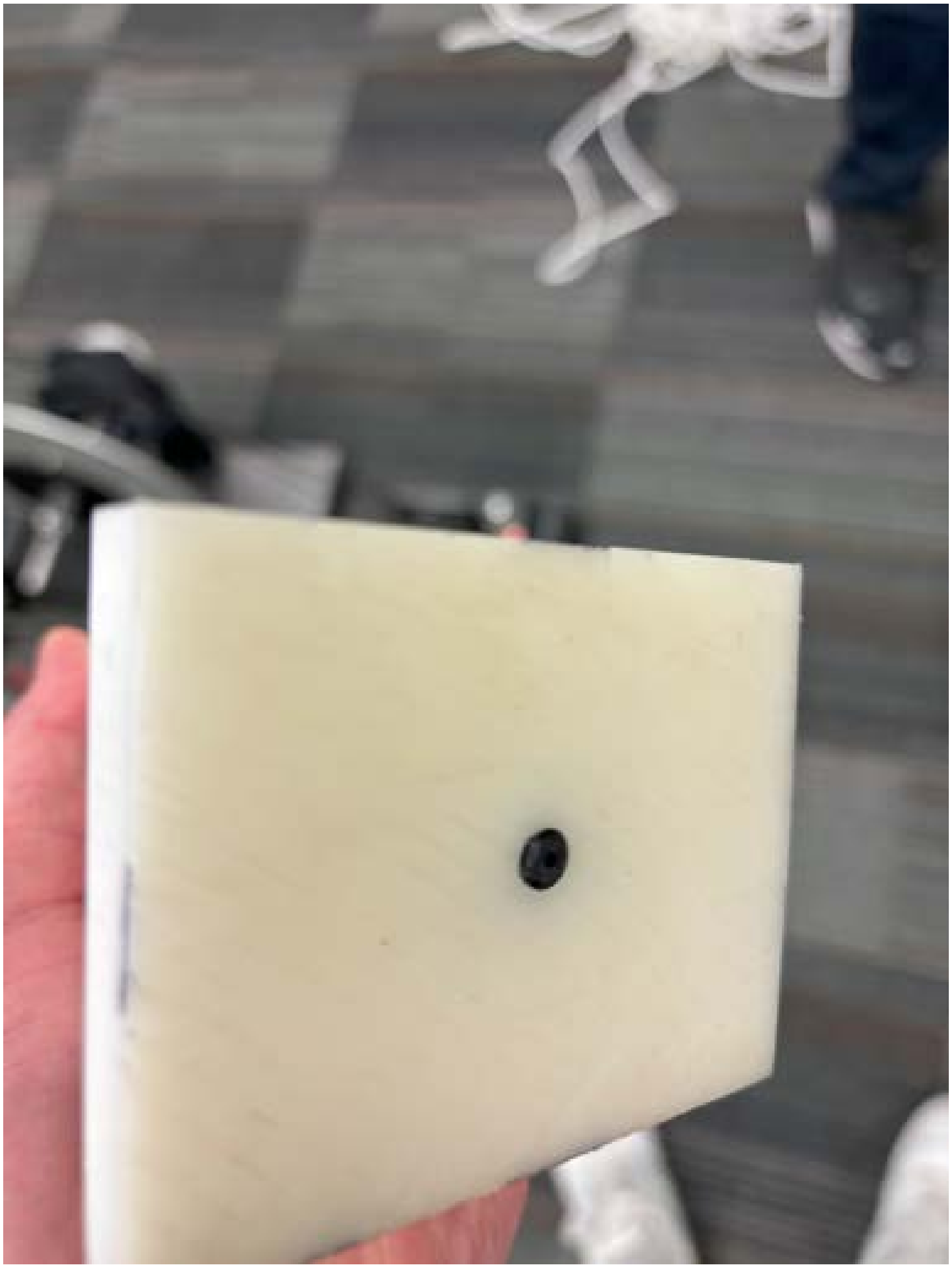
Present: Everyone

Goals: The goal of this entry is to highlight one of the design problems that the team faced during fabrication.

Content:

Comments: Another major issue that the team is actually currently working through is the lightweight, and relatively weak nature of plastic screws. To this point, the team has experience two shear failures due to sort of random events. Therefore, we are going to have to find a way to more securely fasten some of the supports so that this shearing does not happen. Whether that means more plastic screws at critical points, or some other material of screws in order to provide more strength/resistance to shear.

Image of Sheared Screw:



Conclusions/action items:

This issue has cause a lot of problems up until this point. This is something to think about as the team discusses future work and improvements for the device, so it is able to withstand a large amount of weight. Therefore, brainstorming and potentially design matrices may have to be used once this project moves forward in order to solve the problem.

2024/04/23- Assembly of Final Device

Ethan Rao - Apr 23, 2024, 5:12 PM CDT

Title: Assembly of Final Device

Date: 04/23/2024

Content by: Ethan Rao

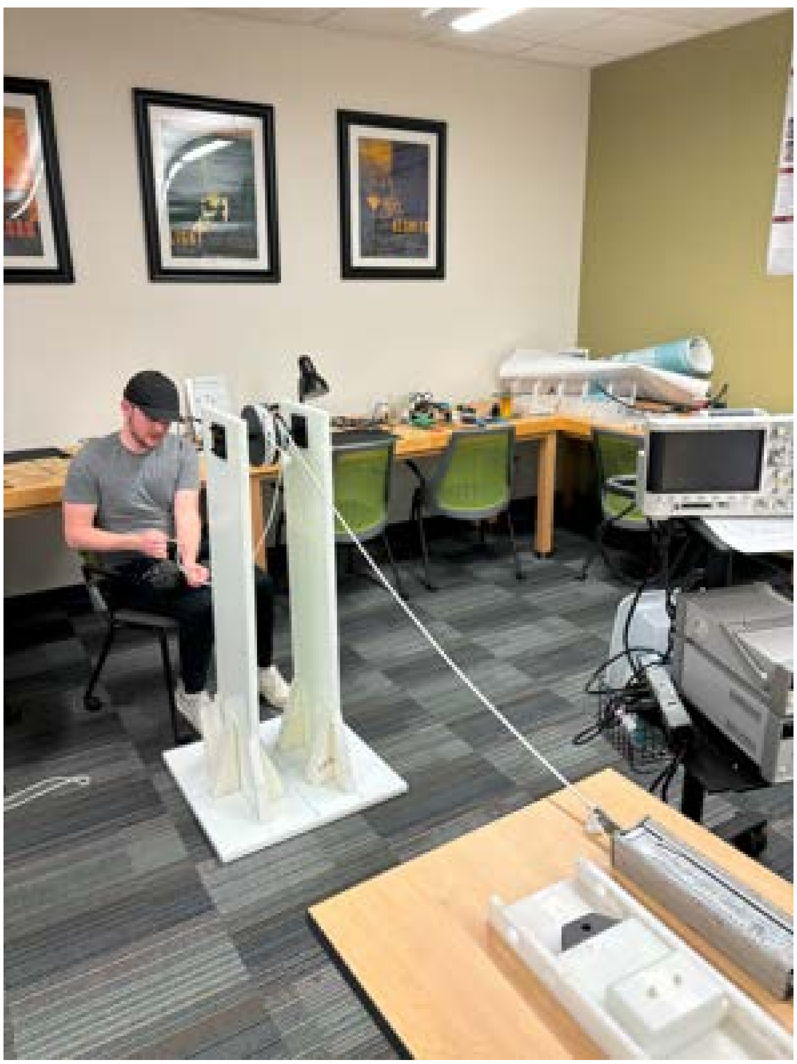
Present: Everyone

Goals: The goal of this entry is to give an idea of what the team was able to come up with as the final device for the semester of work.

Content:

Comments: There is some things that need to be worked on in relation to the final design. However, overall the design turned out much to plan. It was able to maintain constant tension which will be discussed in the testing portion of the notebook. The proof of concept of the pulley was also proven when doing constant tension testing as the weight was consistently amplified by 2.

Image of Final Product:



Conclusions/action items:

Overall, the semester of fabrication was very successful for the team. We were able to innovate based on previous designs and come up with a solution that provides constant tension and amplifies the weight appropriately as well. There is some future work to look into, such as strengthening the overall design but again as stated previously this was overall a successful semester.

2024/05/02 Procedure for General Mechanical Testing

Caelen Nickel - May 03, 2024, 5:28 PM CDT

Title: Procedure for General Mechanical Testing

Date: 05/02/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to ensure that we have included our testing protocol for our major test that was conducted for this project

Content:

Name of Test: Testing of the Pulley/Constant Tension
Date to be completed: 04/24/2024
Team member(s) testing: Micah Schoff, Nikhil Chandra, Ethan Rao, Caelen Nickel

List of Materials Needed:

- Material 1: Prototype
  - Quantity: 1
  - Dimensions: Refer to the dimensions for each part in Solidworks
  - Manufacturer/Part Number: MR Leg Loader Team
  - Purpose: The purpose of this material is for it to be tested in order for the team to be able to judge its efficacy in two major categories
- Material 2: Spring Gauge
  - Quantity: 1
  - Dimensions: N/A
  - Manufacturer/Part Number: Grainger (45AE70) or any that are readily available
  - Purpose: The purpose of the spring gauge is to be able to assess the weight at different points in the hamstring activation to ensure both constant tension and that the weight is being amplified
- Material 3: Weight
  - Quantity: 1
  - Dimensions: N/A
  - Manufacturer/Part Number: Any that are readily available (can use dumbbells or plates for testing)

- Purpose: The purpose of the weight is to provide the tension that will be acting upon the device

Detailed bulleted steps of fabrication:

1. Acquire the appropriate materials utilizing the stated websites
2. Set up the prototype as referenced in assembly
3. Tie the weight onto the end of the pulley
4. Attach the other end to the spring gauge
5. Complete Testing
    1. One person support the weight stack portion of the device and prevent damage and any unforeseen issues with the device during testing
    2. One person pull on the spring gauge
        1. Stop at 3 distinct positions in the slider portion of the design (We chose beginning, middle and end but these can be variable)
6. Take a video of the spring gauge as it moves in order to retrieve close to analog data
    1. Pictures are an alternative at the three points if necessary
7. Slowly allow the weight to move back towards the ground
8. Release the spring gauge once the weight has moved fully back to the ground
9. Utilize said data for graphs as well as statistical analysis of the device

Conclusions/action items:

Based on this protocol, the team was able to complete successful testing of the device and determined that it did meet two of the major criteria by which it would be judged. Therefore, it presents a viable solution for our client once the supports are stabilized somewhat.

2024/05/02 Constant Tension Testing Procedure

Caelen Nickel - May 03, 2024, 5:28 PM CDT

Title: Constant Tension Testing Procedure

Date: 05/02/2024

Content by: Ethan Rao, Caelen Nickel

Goals: The goal of this entry is to ensure that we have included our testing protocol for our major test that was conducted for this project

Content:

Name of Test: Constant Tension Test

Date to be completed: 04/24/2024

Team member(s) testing: Micah Schoff, Nikhil Chandra, Ethan Rao, Caelen Nickel

List of Materials Needed:

- Material 1: Prototype
  - Quantity: 1
  - Dimensions: Refer to the dimensions for each part in Solidworks
  - Manufacturer/Part Number: MR Leg Loader Team
  - Purpose: The purpose of this material is for it to be tested to judge its efficacy in two major categories
- Material 2: Spring Gauge
  - Quantity: 1
  - Dimensions: N/A
  - Manufacturer/Part Number: Grainger (45AE70) or any that are readily available
  - Purpose: The purpose of the spring gauge is to be able to assess the weight at different points in the hamstring activation to ensure both constant tension and that the weight is being amplified
- Material 3: Weight
  - Quantity: 3
  - Dimensions: N/A
  - Manufacturer/Part Number: Any that are readily available (can use dumbbells or plates for testing)
  - Purpose: The purpose of the weight is to provide the tension that will be acting upon the device

Detailed bulleted steps of fabrication:

1. Acquire the appropriate materials utilizing the stated websites
2. Set up the prototype as referenced in assembly
3. Tie the weight, starting with 5 lbs onto the end of the pulley
4. Attach the other end to the spring gauge
5. Complete testing
   a. One person support the weight stack portion of the device and prevent damage and any unforeseen issues with the device during testing
   b. One person pull on the spring gauge
      i. Hold the spring gauge at position 1, which is the beginning of the slider and standardized to be 0 inches.
      ii. Collect a force reading from the spring force gauge
      iii. Move the spring gauge to position 2, which is the middle of the slider and standardized to be 15 inches, and hold.
      iv. Collect a force reading from the spring force gauge
      v. Move the spring gauge to position 3, which is the end of the slider and standardized to be 30 inches, and hold.
      vi. Collect a force reading from the spring force gauge
      vii. Slowly allow the weight to move back towards the ground
      viii. Release the spring gauge once the weight has moved fully back to the ground
      ix. Repeat this testing 3 times to construct a sample data with multiple trials
6. Untie and remove the weight from the end of the pulley
7. Tie the 10 lbs weight now onto the end of the pulley

8. Repeat testing as described in step 5
9. Repeat steps 6 and 7, this time tying the 15 lbs weight
10. Repeat testing as described in step 5
11. Using the 3 trials for each of the 3 standard weights, complete data analysis and visualization to determine whether there is statistically significant constant tension

Conclusions/action items:

Based on this protocol, the team was able to complete successful testing of the device and determined that it did have statistically significant constant tension (see Experimentation folder). Therefore, it presents a viable solution for our client in this manner once the supports are stabilized somewhat.

2024/05/02 Pulley Verification Testing Procedure

Caelen Nickel - May 03, 2024, 5:31 PM CDT

Title: Pulley Verification Testing Procedure

Date: 05/02/2024

Content by: Ethan Rao, Caelen Nickel

Goals: The goal of this entry is to ensure that we have included our testing protocol for our major test that was conducted for this project

Content:

Name of Test: Pulley Verification Test

Date to be completed: 04/24/2024

Team member(s) testing: Micah Schoff, Nikhil Chandra, Ethan Rao, Caelen Nickel

List of Materials Needed:

- Material 1: Prototype
  - Quantity: 1
  - Dimensions: Refer to the dimensions for each part in Solidworks
  - Manufacturer/Part Number: MR Leg Loader Team
  - Purpose: The purpose of this material is for it to be tested to judge its efficacy in two major categories
- Material 2: Spring Gauge
  - Quantity: 1
  - Dimensions: N/A
  - Manufacturer/Part Number: Grainger (45AE70) or any that are readily available
  - Purpose: The purpose of the spring gauge is to be able to assess the weight at different points in the hamstring activation to ensure both constant tension and that the weight is being amplified
- Material 3: Weight
  - Quantity: 3
  - Dimensions: N/A
  - Manufacturer/Part Number: Any that are readily available (can use dumbbells or plates for testing)
  - Purpose: The purpose of the weight is to provide the tension that will be acting upon the device

Detailed bulleted steps of fabrication:

1. Acquire the appropriate materials utilizing the stated websites
2. Set up the prototype as referenced in assembly
3. Tie the weight onto the end of the pulley
4. Attach the other end to the spring gauge
5. Complete testing
   a. One person support the weight stack portion of the device and prevent damage and any unforeseen issues with the device during testing
   b. One person pull on the spring gauge
      i. Hold the spring gauge at a constant position
      ii. Collect a force reading from the spring force gauge
      iii. Slowly allow the weight to move back towards the ground
      iv. Release the spring gauge once the weight has moved fully back to the ground
      v. Repeat this testing 3 times to construct a sample data with multiple trials
6. Untie and remove the weight from the end of the pulley
7. Tie the 10 lbs weight now onto the end of the pulley
8. Repeat testing as described in step 5
9. Repeat steps 6 and 7, this time tying the 15 lbs weight
10. Repeat testing as described in step 5

11. Using the 3 trials for each of the 3 standard weights, complete data analysis and visualization to determine whether there is proper pulley amplification.

Conclusions/action items:

Based on this protocol, the team was able to complete successful testing of the device and determined that it did have satisfactory pulley amplification (see Experimentation folder). Therefore, it presents a viable solution for our client in this manner once the supports are stabilized somewhat.

2023/04/23 MATLAB Testing

Caelen Nickel - May 03, 2024, 5:35 PM CDT

Title: 2024/04/23 MATLAB Testing

Date: 04/23/2024

Content by: Caelen Nickel

Goals: Perform statistical calculations on the data obtained in testing.

Content:

See the attached MATLAB code and comments below which was run in order to obtain a p-value. A short description of the code is the following:

The collected data was passed into three data variables. 3 samples were taken for 3 different weights at 3 different positions, yielding a sample size of 9. Then, a bootstrap was performed. A bootstrap is any resampling method which uses random sampling with replacement. Bootstrapping uses this to expand on sample sizes, ensuring that all additional points which were generated follow the sample distributions and key aspects of the original data set. Using these additional samples, the sample size is adequate to support various statistical calculations. For my purpose, the bootstrap was necessary to ensure the efficacy of a student t-test, which usually requires a sample size of 30 which is often unattainable in the time period provided in this class. Analog data can be helpful in increasing this sample size and allows for more accurate models. However, we did not have access to any analog spring gauges which could be connected to MATLAB or similar program.

The accuracy of performing statistical calculations on a bootstrapped sample size is a fair concern. However, bootstrapping is known to be effective and accurate at even small sample sizes since it maintains sample distribution and all significant statistical identifiers of the group.

In the bootstrap code below, see comments for line specific operation. Each data group of 3 was expanded to 100 using MATLABs bootstrap function with replacement.

With this expanded sample size, a high quality statistical calculation could be performed. Due to the multiple group nature of the data (3 groups for each of the 3 positions), the most practical and direct analysis was an ANOVA test. ANOVA, simply put, compares multiple groups to find if any difference between any of the sample groups exists. In MATLAB, the built in ANOVA function returns an ANOVA table with many of the same statistics as a two sided t-test.

Conclusions/action items:

Performing quantitative testing is very important for communicating the performance of our device and will be important for our final presentation and report. As a result of this code in MATLAB and the overall testing which was performed, a p-value could be calculated and thus hypothesis could be upheld/rejected. More discussion on this will be in the MATLAB Results entry.

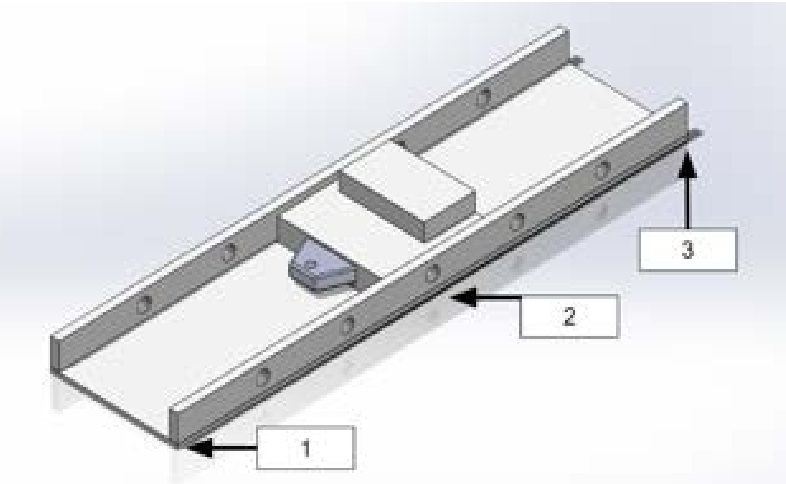
Caelen Nickel - Apr 28, 2024, 4:15 PM CDT

```
data1 = [8, 20, 30];

data2 = [9, 20, 29];

data3 = [9, 21, 30];


% Number of values to generate using bootstrap

numValues = 100;


% Perform bootstrap resampling

bootstrapData1 = zeros(1, numValues);  % Initialize array to store bootstrap samples


for i = 1:numValues

    % Resample with replacement from the original dataset

    bootstrapSample1 = datasample(data1, 3, 'Replace', true);


    % Calculate statistic of interest (e.g., mean, median, etc.)

    % Here, we'll just use the first value of the bootstrap sample

    bootstrapData1(i) = bootstrapSample1(1);

end


bootstrapData2 = zeros(1, numValues);  % Initialize array to store bootstrap samples


for i = 1:numValues

    % Resample with replacement from the original dataset

    bootstrapSample2 = datasample(data2, 3, 'Replace', true);


    % Calculate statistic of interest (e.g., mean, median, etc.)

    % Here, we'll just use the first value of the bootstrap sample

    = bootstrapSample2(1);
```

```
end

bootstrapData3 = zeros(1, numValues);  % Initialize array to store bootstrap samples

for i = 1:numValues
    % Resample with replacement from the original dataset
    bootstrapSample3 = datasample(data3, 3, 'Replace', true);

    % Calculate statistic of interest (e.g., mean, median, etc.)
    % Here, we'll just use the first value of the bootstrap sample
    bootstrapData3(i) = bootstrapSample3(1);
end


% Combine data into a single vector
data = [bootstrapData1, bootstrapData2, bootstrapData3];

% Create grouping variable
groups = [ones(1, numel(bootstrapData1)), 2*ones(1, numel(bootstrapData2)), 3*ones(1, numel(bootstrapData3))];

% Perform one-way ANOVA
[p, tbl, stats] = anova1(data, groups);

% Display ANOVA table
disp(tbl);

% Check significance
if p < 0.05
    disp('ANOVA result: There is a significant difference between groups.');
```

```
else
    disp('ANOVA result: There is no significant difference between groups.');
    disp(p)
end
```

Caelen Nickel - May 03, 2024, 5:43 PM CDT



SOLIDWORKS sketch illustrating the slider, labeled with each of the three positions where force readings were taken in the constant tension testing. The three positions were equally spaced along the slider at 0 inches, 15 inches, and 30 inches, indicated as 1, 2, and 3 respectively.

Loading [MathJax]/extensions/Safe.js

2023/04/23 MATLAB Results

Caelen Nickel - May 03, 2024, 5:10 PM CDT

Title: 2024/04/23 MATLAB Results

Date: 04/25/2024

Content by: Caelen Nickel

Goals: Perform statistical calculations on the data obtained in testing and analyze results.

Content:

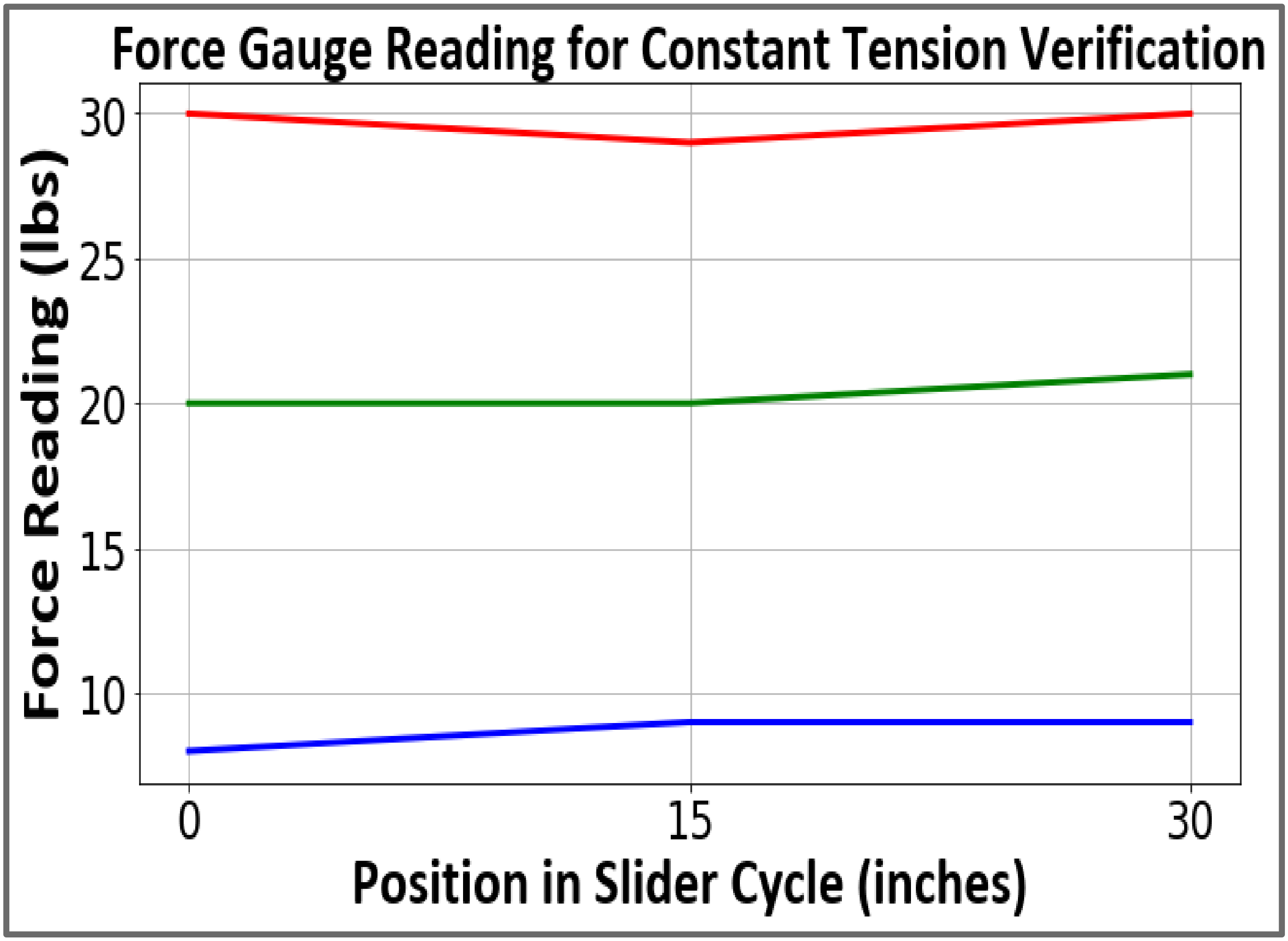
- Python's matplot library was used for graphing this data due to its flexibility in handling multiple groups of data, such as the three different weight values. For the purpose of statistical analysis, however, the position on the slider was considered the independent variable. In MATLAB, the data was processed and statistical analysis was performed.

- The optimal statistical analysis for the constant tension testing is ANOVA, which is similar to a two sided t-test in that it compares groups for statistically significant differences, but for multiple groups. Like a t-test, ANOVA produces a p-value. For the constant tension testing, the ɑ value is 0.05 and the null hypothesis is that there is no significant difference between any of the three position groups, indicating that there is constant tension throughout the heel slide motion. The alternative hypothesis would then be that there is a significant difference in two or all of the groups. Using MATLAB code for an ANOVA test (see Appendix D), the p-value was determined to be 0.966. This p-value is high and much greater than the ɑ value is 0.05. Therefore, the null hypothesis is upheld, indicating that the constant tension testing conclusively demonstrates that the device is capable of providing a constant resistance throughout the heel slide motion.

Conclusions/action items:

This statistical analysis and the corresponding data visualization and calculations are important to include in the final presentation and final report, as well as indicating to the client that the device can accurately and successfully induce constant resistance. The graph will be a highlight of the final presentation testing section, and mentioning the p-value from ANOVA is necessary. Explaining what this p-value as done above must be the focus of all claims made as a result of testing in addition to the pulley verification and MRI compatibility.

Caelen Nickel - May 03, 2024, 5:10 PM CDT



2024/04/23 Google Sheets Testing and Results

Caelen Nickel - May 03, 2024, 5:23 PM CDT

Title: 2024/04/23 Google Sheets Testing and Results

Date: 4/24/2024

Content by: Caelen Nickel

Goals: Obtain a numerical statistical relationship between the weight before and after the pulley as a method of pulley amplification verification.

Content:

See the below attachment for a pdf of the Google sheet and figure which was generated.

The testing data as described in the MATLAB Testing entry as well as outlined in general testing protocols was used for this Google Sheet as well (see attachment). The weight before and after the pulley was recorded for three different weights which we had avalible to us. This was meant to verify that the pulley amplified the weight by the factor of 2.0 as intended and calculated. The weight at the subject/slider end of the pulley divided by the standard weight specification should ideally equal 0. As the data table shows, all calculations were within a pound if they did not satisfy this expectation.

A statistical method was used to determine a quantifiable answer to this test. In Google Sheets, the a trendline was graphed on a graph of the two weight values in comparison. In Google Sheets, the trendline function uses linear least squares regression, which is a common modeling test which I have used in Python and data science courses to find linear relationships, so this is appropriate. This trendline produces a coefficient, or slope, which describes the nature of the linear relationship as well as an R^2 value indicating accuracy of the model. The R^2 was reported as 0.993 by Google Sheets, indicating an excellent model appropriate for making claims on the data.

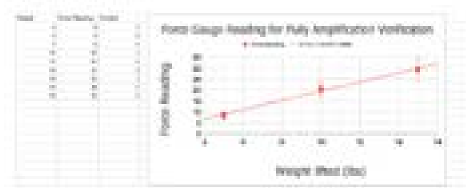
The slope of this trendline is the quantifiable value which represents the relationship between the force on one end of the pulley and the weight on the other end, or the force reading : weight lifted ratio. This slope value was calculated to be 2.1.

There is no available statistical method capable of comparing 2.1 to the intended 2.0, however a pulley amplification of 2.1 is satisfactory and very close to 2.0. The client can account for any slight discrepancy with their calculations, determining the resistance by multiplying the weight by 2.1. This is the case as long as the resistance value is constant.

Conclusions/action items:

This testing will be essential in both calculating the pulley amplification factor and comparing it to the intended value. While no statistical analysis can be done to compare how the slope compares to the intended value of 2.0, visual inspection and reasoning can be used and discussed. This graph as well as the data within it and provided by the trendline will be essential to the final presentation and report. Knowledge of the pulley amplification factor will also be necessary in calculations made by the client. With the slope of 2.1, the pulley amplification factor is 2.1 and compared to the intended value of 2.0, this is very close. The client can account for this so long as tension is constant, which was verified in the MATLAB Testing/Results entries.

Caelen Nickel - Apr 28, 2024, 4:17 PM CDT



Download

BME301_Testing_-_Sheet1.pdf (65.2 kB)

2024/04/23- Solidworks Files

MICAH SCHOFF - May 03, 2024, 1:41 PM CDT

Title: Final Solidworks Files

Date: 5/3/2024

Content by: Micah Schoff

Present: Everyone

Goals: Provide solid works assemblies for all parts.

Content:

Attached below are the assemblies of the slider, weight stack design, and pulley.

Conclusions/action items: This provides all required assemblies for this project.

MICAH SCHOFF - May 03, 2024, 1:48 PM CDT

Download

Final_Pulley_Design.SLDPRT (594 kB)

MICAH SCHOFF - May 03, 2024, 1:47 PM CDT

Download

Weight_Stand.SLDASM (451 kB)

MICAH SCHOFF - May 03, 2024, 1:42 PM CDT

Download

Slider_Assembly.SLDASM (181 kB)

2/8 - ASTM International F2503 Research

NIKHIL CHANDRA - Feb 08, 2024, 11:45 AM CST

Title: ASTM International F2503 Research

Date: 2/8

Content by: Nikhil Chandra

Goals: To conduct research on ASTM International F2503 that may be relevant to developing an MRI-compatible loading device

Content:

Search Term: "Standards related to medical devices that are MRI compatible" ChatGPT

Link: https://www.astm.org/f2503-20.html

Citation: Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment. https://www.astm.org/f2503-20.html. Accessed 8 Feb. 2024.

The standard titled, "Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment" details a set of guidelines for assessing the risk and safety of devices that will be operated within a magnetic resonance environment. It discusses specifications on MRi marking and icons to indicate the specialized use of a device, and the standard sorts devices into MR Safe, MR Conditional, MR Unsafe. Utilizing the described process of categorization, we can ensure that our prototype does interfere negatively with an MRI machine or a patient's safety.

Conclusions/action items:

With knowledge of ASTM International F2503 which is highly relevant to our project as we build an MRI compatible medical device, I plan on conducting further research on related standards and specifications and competing designs.

2/8 - ISO 10993 Research on Biocompatibility

NIKHIL CHANDRA - Feb 08, 2024, 5:52 PM CST

Title: ISO 10993 Research on Biocompatibility

Date: 2/8

Content by: Nikhil Chandra

Goals: To conduct research on ISO 10993 which may be relevant to our project as we aim to build an external loading device that is safe for patients with hamstring strain injuries

Search Term: “Standards related to medical devices that are MRI compatible” ChatGPT

Link: https://www.iso.org/standard/68936.html

Citation:

14:00-17:00. “ISO 10993-1:2018.” ISO, https://www.iso.org/standard/68936.html.

Accessed 8 Feb. 2024.

Content:

ISO 10993 refers to a series of standards titled “Biological Evaluation of Medical Devices” that are useful for evaluating the biocompatibility of medical devices. These standards cover tests for cytotoxicity, sensitization, irritation, and systemic toxicity, which not only apply for implants but may be relevant to our project which will have external direct contact for patients with hamstring strain injuries. The standard also provides guidelines on risk management for medical devices which may be useful in determine how to optimize our design to minimize harm to the patient given the sensitivity of the hamstring strain recovery process. This may include minimizing the use of straps of the patient to the loading device ensuring the patient can easily release the load at any point in time. We also will need to ensure the loading device does not interfere or obstruct the patient’s positioning within the MRI machine. These are examples of risks to consider and by following the risk assessment procedure in the standard series we can work towards minimizing these risks.

Conclusions/action items:

With an understanding of the different guidelines and risk management procedures ISO 10993 offers for assessing the biocompatibility and safety of medical devices, I can now continue with further research into other relevant standards and competing designs.

IRB Review Research - 5/3

NIKHIL CHANDRA - May 03, 2024, 1:31 PM CDT

Title: IRB Review Research - 5/3

Date: 5/3

Content by: Nikhil Chandra

Present: Nikhi**l**

Goals: After our client meeting, Dr.Scott Crawford discussed the potential for IRB testing prior to using this in the context of his research study. I want to conduct some individual research on what the IRB testing process is like.

Search Term: "IRB Testing for Medical Devices"

Link: https://www.fda.gov/medical-devices/investigational-device-exemption-ide/ide-institutional-review-boards-irb

Citation: IDE Institutional Review Boards (IRB)," U.S. Food and Drug Administration, [Online]. Available: https://www.fda.gov/medical-devices/investigational-device-exemption-ide/ide-institutional-review-boards-ir. [Accessed May 3, 2024].

Content:

- The IRB protects the rights and safety of people in research studies. They can approve, modify, or reject research plans.
- The IRB looks over the study's plan, risks, benefits, consent forms, and data methods to make sure everything is ethical and follows the law.
- It's vital that all participants understand the study and agree to join willingly.
- The IRB keeps an eye on the study, reviewing it periodically to handle any new risks or problems.
- Any unexpected or serious problems during the study must be reported to the IRB quickly.
- The IRB checks that the study meets all FDA rules, especially for new medical devices not yet approved.
- Depending on the type of study (like commercial, investigator-led, or emergency use), the IRB adjusts its review to fit the specific needs and rules.

Conclusion:

With a further understanding of IRB, in the summer and fall as we potentially get this device approved for use in the research study, this background knowledge may become useful.

1/30 - Initial Project Understanding

NIKHIL CHANDRA - Jan 30, 2024, 1:03 PM CST

Title: Initial Project Understanding

Date: 1/30

Content by: Nikhil Chandra

Present: Nikhil Chandra

Goals: To deepen my initial understanding of the project and what the client is requesting, by taking individual notes on important takeaways from the client meeting.

Content:

The overall purpose of this project is to develop a device that can load the hamstrings of an individual as they undergo a brain MRI scan, which fits into a broader research project investigating differences in brain activity between individuals with and without previous hamstring strain injuries.

Some additional important details mentioned during the client meeting include that the loading has to sit on the table of the MRI machine, it has to be compatible and not interfere with the machine(non ferrous), and the individual is laying in the supine position. In the supine position, loading the hamstrings can be more challenging as knee flexion is required and in turn elevating the heels and leg overall will be most likely necessary in some way to allow the individual to perform isometric, concentric and eccentric movements that target the hamstring. In addition to this, we also need to be able to keep track of various metric including the knee flexion angle and rate of flexion, and motion capture may be an optimal approach to achieve this.

Conclusions/action items:

With notes on the broader purpose and main constraints of the project, I can now move forward with more specific research into biology and physiology along with competing designs, before we then develop the PDS as a team.

1/31 - Client Research Articles

NIKHIL CHANDRA - Feb 02, 2024, 12:09 AM CST

Date: 1/31

Content by: Nikhil Chandra

Present: Nikhil Chandra

Goals: To read over the articles and write down major points from the research the client had sent to us after the client meeting.

Search Term: Google Scholar: Continuous pressure loading devices

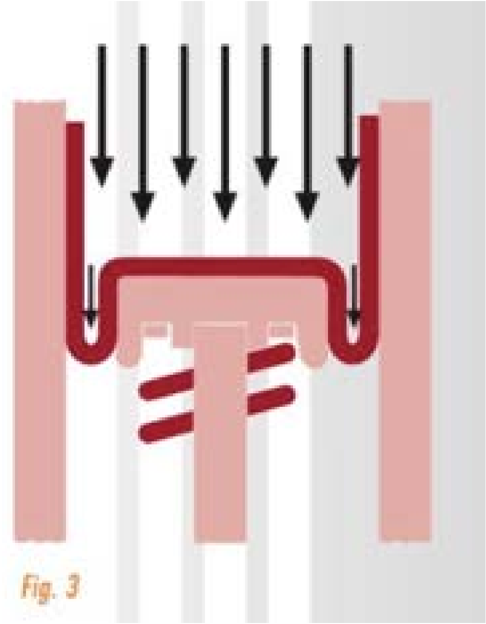
Citation: "Catalogs." *Marsh Bellofram - Bellofram Rolling Diaphragm Design Manual - Marsh Bellofram - Page - PDF Catalogs* | *Technical Documentation* | *Brochure*, pdf.directindustry.com/pdf/marsh-bellofram/marsh-bellofram-bellofram-rolling-diaphragm-design-manual/11788-27709-_5.html. Accessed 1 Feb. 2024.

Link: https://pdf.directindustry.com/pdf/marsh-bellofram/marsh-bellofram-bellofram-rolling-diaphragm-design-manual/11788-27709-_5.html

Content:

The article discusses a device called the Rolling Diaphragm where as a downwards force is applied it moves a frictionless slider against a pressure vessel which generates a backwards force/load. The larger the applied force, the pressure continues to increase and in turn notably the load is not constant which is a requirement by our client. In turn, we will have to consider a different approach that can apply a constant tension, and in turn elastic bands nor pressure vessels would be the optimal option, we may consider using weights.

The rolling diaphragm itself is a unique seal that allows for near frictionless piston strokes in the context of this pressure vessel, and the material is a woven fabric. The rolling diaphragm concept is used frequently in a number of industry applications from pumps to actuators. In our context, if we can find a way to customize it to drain out air to maintain a consistent pressure then the frictionless pressure vessel may be useful as a loading device.



Conclusions/action items:

With notes on the client research articles sent over, I aim to now conduct more research into competing designs specifically what examples exist for hamstring loading in general outside of the context of MRIs, and how these machines operate.

2/1 - Hamstring Muscle Kinematics during Sprinting

NIKHIL CHANDRA - Feb 01, 2024, 8:58 PM CST

Title: 2/1 - Hamstring Muscle Kinematics during Sprinting

Date: 2/1

Content by: Nikhil Chandra

Goals: To take relevant notes on the article, "Hamstring muscle kinematics and activation during overground sprinting"

Content:

Search Term: ChatGPT Prompt “find me some research articles that discuss the physiology and biology of hamstring strain injuries”

Citation: Yu, B., Queen, R., Abbey, A., Liu, Y., Moorman, C., & Garrett, W. (2008). Hamstring muscle kinematics and activation during overground sprinting.. *Journal of biomechanics*, 41 15, 3121-6 . https://doi.org/10.1016/j.jbiomech.2008.09.005.

Link: https://doi.org/10.1016/j.jbiomech.2008.09.005

Content:

The article discusses how hamstring strain injuries are highly prevalent among many sports including track, football, soccer, … And in the article, they analyzed 20 male runners, soccer or lacrosse players as they performed sprinting to their maximum capability on ground. Interestingly, eccentric contractions of the hamstring happened during the late stance and swing phase of running, and the contraction speed in the swing phase was notably high, thereby showing the main phases of running where injury of the hamstrings is most likely.

Conclusions/action items:

I now have a deeper understanding as to how hamstring muscle strain injuries occur in running especially during high speed springing in sports such as track, soccer, and football. I want to further investigate different constraints we should look into to ensure the device we develop is not only MRI compatible but also is safe for the patient given the biology of hamstring muscle strain injuries.

NIKHIL CHANDRA - Feb 01, 2024, 8:57 PM CST

Journal of Biomechanics

Hamstring muscle kinematics and activation during overground sprinting

Abstract

Introduction

Download

Hamstring_muscle_kinematics_and_activation_during_overground_sprinting_-_ScienceDirect.pdf (204 kB)

2/1 - Hamstring Razor Curl and Prone Curl Comparison

NIKHIL CHANDRA - Feb 01, 2024, 11:35 PM CST

NIKHIL CHANDRA - Apr 28, 2024, 5:01 PM CDT

Title: 2/1 - Hamstring Razor Curl and Prone Curl Comparison

Date: 2/1

Content by: Nikhil Chandra

Goals: To take relevant notes on the article, "Comparison of Hamstring and Gluteus Muscles Electromyographic Activity while Performing the Razor Curl vs. the Traditional Prone Hamstring Curl."

Content:

Search Term: ChatGPT Prompt "Find me research articles comparing the biomechanics of various hamstring activation exercises"

Citation: Oliver, G., & Dougherty, C. (2009). Comparison of Hamstring and Gluteus Muscles Electromyographic Activity while Performing the Razor Curl vs. the Traditional Prone Hamstring Curl. *Journal of Strength and Conditioning Research*, 23, 2250-2255. https://doi.org/10.1519/JSC.0b013e3181b8d34b.

Link: https://doi.org/10.1519/JSC.0b013e3181b8d34b

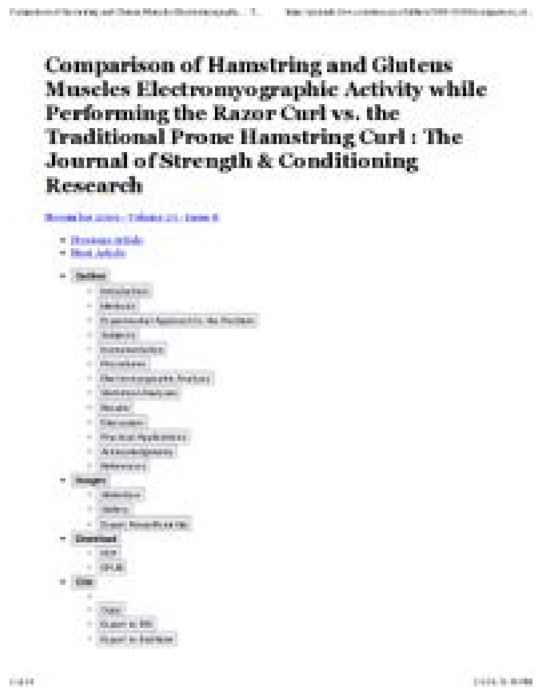
Content:

- **The article compares the effectiveness of two major hamstring muscle exercises including the razor curl vs. the traditional prone hamstring curl which may give us insight into optimal exercises that can target the hamstring muscles**
- **In the razor curl an individual starts full extended then flexes their knees and hip to 90 degrees and crunches their whole body while in the traditional hamstring curl, the individual essentially stays fully extended and only their ankle moves to flex their knee 90 degrees.**
- **Electromyographic (EMG) data was collected on eight female athletes on the biceps femoris, gluteus medius, and gluteus maximus.**
- **Importantly, they found no major differences in overall lower extremity muscle activation between the two exercises. However they did note that razor curl was better at targeting the hamstrings particularly because the flexion of the hips allowed for better flexion of the hamstrings**

Conclusions/action items:

Through this article, I was able to have a better understanding of the kinds of exercises that can optimize hamstring muscle activation and notably found that in activating the hamstrings, the flexion of both the hip and knee together could better target the biceps femorus. Moving forward I want to continue research on hamstring weight exercises.

NIKHIL CHANDRA - Feb 01, 2024, 11:54 PM CST



Comparison of Hamstring and Gluteus Muscles Electromyographic Activity while Performing the Razor Curl vs. the Traditional Prone Hamstring Curl : The Journal of Strength & Conditioning Research

Download

Comparison_of_Hamstring_and_Gluteus_Muscles_Electromyographi..._The_Journal_of_Strength_Conditioning_Research.pdf (1.8 MB)

NIKHIL CHANDRA - Feb 01, 2024, 11:53 PM CST

2/17 - General Non-ferrous Plastic Materials Research

NIKHIL CHANDRA - May 02, 2024, 4:03 PM CDT

Title: 2/17 - General Non-ferrous Plastic Materials Research

Date: 2/17

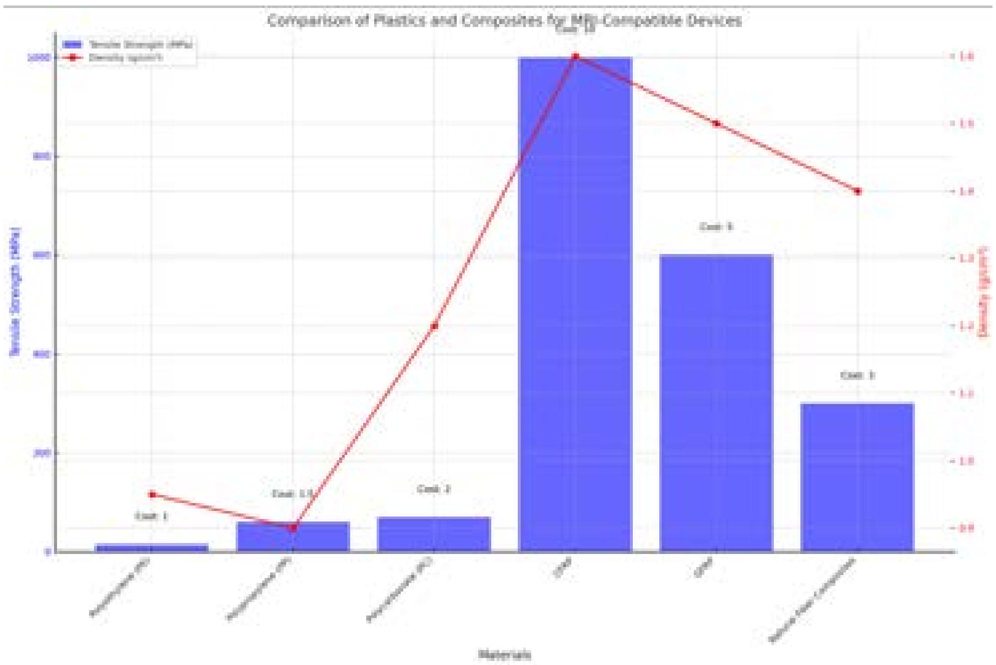
Content by: Nikhil Chandra

Present: Nikhil

Goals: To develop a simple graph comparing relevant properties including strength, cost, and density for a number of different plastics.

Content:

- The below graph compares some notable plastics and composites including:
  - **Polymethyl methacrylate (PMMA)**
  - **Polyether ether ketone (PEEK)**
  - **Polyethylene (PE)**
  - **Carbon fiber reinforced polymer (CFRP)**
  - **Glass fiber reinforced polymer (GFRP)**



- Notably polyethylene which is the most likely choice of material we will pursue due to its accessibility at the teamlab and makerspace offers a lower tensile strength compared to many other materials however it also has a much lower density, and this strength to weight ratio may overall be preferable in our specific application where we aim to minimize weight.
- Carbon fiber reinforced polymer is significantly stronger than many of the other relevant plastic and composite materials, however its density is higher. We may use carbon fiber for more critical load components.

References:

[1] R. Direct, “Medical Grade Plastics: Types of Plastics Used in Medical Products,” rapiddirect.com. Available: https://www.rapiddirect.com/knowledge-base/article/medical-grade-plastics. [Accessed: May 2, 2024].

[2] MatWeb, “Tensile Property Testing of Plastics,” matweb.com. Available: http://www.matweb.com/search/GetMatlsByProperty.aspx. [Accessed: May 2, 2024].

[3] IntechOpen, “Improving the Mechanical Properties of Natural Fiber Composites for Structural and Biomedical Applications,” intechopen.com. Available: https://www.intechopen.com/chapters/67289. [Accessed: May 2, 2024].

Conclusions/action items:

With a deeper understanding of some of the primary non ferrous plastics, when we have a discussion as a team further on in materials choices, I can bring forth some of these materials and the graph to the team to guide us in the right direction.

2/25 - General Non-ferrous Composites, Ceramics Research

NIKHIL CHANDRA - May 02, 2024, 4:12 PM CDT

Title: 2/17 - General Non-ferrous Composites, Ceramics Research

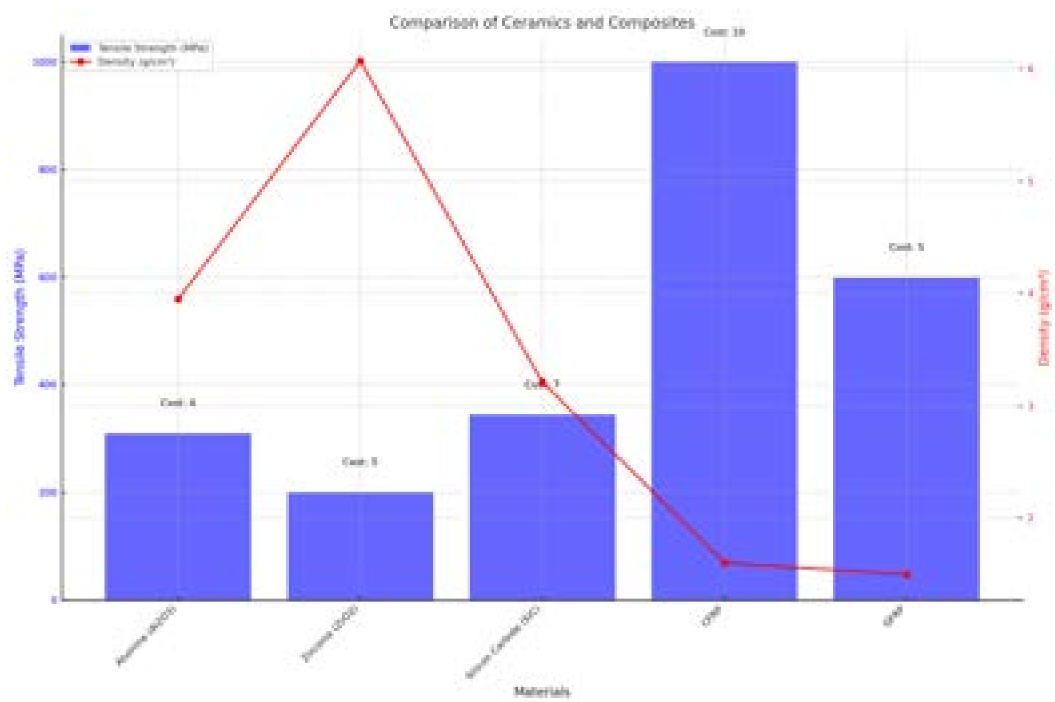
Date: 2/17

Content by: Nikhil Chandra

Present: Nikhil

Goals: To develop a simple graph comparing relevant properties including strength, cost, and density for a number of different composites and ceramics.

Content:

- Having completed research on some notable plastics and composites, I wanted to further develop a graph of some potentially relevant ceramics and composites.
- The below graph compares some notable composites and glass including:
  - **Alumina (Aluminum Oxide, Al2O3)**
  - **Zirconia (Zirconium Dioxide, ZrO2)**
  - **Silicon Carbide (SiC)**
  - **Carbon Fiber Reinforced Polymer (CFRP)**
  - **Glass Fiber Reinforced Polymer (GFRP)**
- 

- Notably in the comparison as we bring in some notable ceramics including alumina and silicon carbide, carbon fiber reinforced polymer continues to be prominent with both a higher absolute tensile strength and a low absolute density, and in turn a much higher strength to weight ratio.
- We ought to keep CFRP and GFRP in mind as we develop critical components including the system that will support the weight or load for hamstring activation.

References:

[1] Precision Ceramics, "Density," precision-ceramics.com. Available: https://www.precision-ceramics.com. [Accessed: May 2, 2024].

[2] IntechOpen, “Improving the Mechanical Properties of Natural Fiber Composites for Structural and Biomedical Applications,” intechopen.com. Available: https://www.intechopen.com/chapters/67289. [Accessed: May 2, 2024].

Conclusions/action items:

With a deeper understanding of some of the primary non ferrous ceramics and composites, the research and easy to understand graph in this entry will aid in our materials selection process.

3/17 - Hamstring Angle of Insertion Research

NIKHIL CHANDRA - Apr 28, 2024, 5:12 PM CDT

Title: Hamstring Angle of Insertion Research - 3/17

Date: 3/17

Content by: Nikhil Chandra

Present: Nikhil Chandra

Goals: In order to draw a free body diagram for the lower leg in the context of the slider design, I want to conduct some research on the angle of insertion of the hamstring muscles into the lower leg.

Search Term:

Consensus Prompt: Angle of Insertion Hamstring Biceps Femorus Lower Leg

Citation:

Grassi, C. A., Fruheling, V. M., Abdo, J. C., de Moura, M. F. A., Namba, M., da Silva, J. L. V., da Cunha, L. A. M., de Oliveira Franco, A. P. G., Costa, I. Z., & Filho, E. S. (2013). Hamstring tendons insertion - an anatomical study. Revista brasileira de ortopedia, 48(5), 417–420. https://doi.org/10.1016/j.rboe.2012.07.012

Link:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6565974/

Content:

Purpose: The study aimed to clearly identify where the hamstring tendons attach in the lower leg to improve the safety and effectiveness of tendon graft procedures used in knee surgeries.

- **Methods: The researchers examined ten knee specimens from cadavers, carefully measuring the distances and angles at which the hamstring tendons attach.**
- **Main Findings:**
  - **The distance from the top of the shin bone (tibial plateau) to where the tendons attach averaged about 41 mm, and the distance from the front bump of the shin bone (tibial tuberosity) was about 6.88 mm.**
  - **The angle at which the tendons attach to the shin bone was about 20.3 degrees, showing they attach at a slight angle.**
- **Implications for Surgery:**
  - **Knowing exactly where the tendons attach can help avoid nerve damage and make the procedure of removing a tendon for grafting more precise.**
  - **Using the measured distance of 40 mm from the top of the shin as a guide can help surgeons make cuts in the right place.**
- **Conclusion: The study provides essential measurements that are crucial for performing surgeries involving the hamstring tendons, especially in knee ligament reconstruction, like ACL (anterior cruciate ligament) surgeries.**

Conclusions/action items:

With an understanding of the angle of insertion of the hamstring muscles into the lower leeg and the distance of insertion relative to the knee, I have the necessary information to construct a simple 2d free body diagram of the lower leg in the context of the slider design.

NIKHIL CHANDRA - Apr 28, 2024, 5:14 PM CDT

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Hamstring_tendons_insertion_an_anatomical_study_-_PMC.pdf (468 kB)

4/5 - Anthropometry Data Research

NIKHIL CHANDRA - May 02, 2024, 4:31 PM CDT

Title: 4/5 - Anthropometry Data Research

Date: 4/5

Content by: Nikhil Chandra

Present: Nikhil

Goals: As we move into developing the final design, I wanted to conduct some research on human anthropometry data to potentially guide our dimensions estimation process along with the free body diagrams we will draw to evaluate our design theoretically and how it induces hamstring activation.

Search Term: "Anthropometry Human Body Standards" Bings

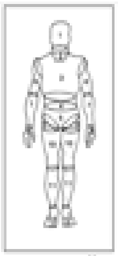
Link: https://msis.jsc.nasa.gov/sections/section03.htm

Citation: "Anthropometry and Biomechanics," in NASA Man-Systems Integration Standards (MSIS), sec. 3. Available: https://msis.jsc.nasa.gov/sections/section03.htm. [Accessed: May 2, 2024].

Content:

The article by NASA on anthropometric data shows the human body from various angles and under different conditions including microgravity situations where anatomical values may change. The article in turns offers a robust and technically detailed description of different lengths of various human body parts and sections.

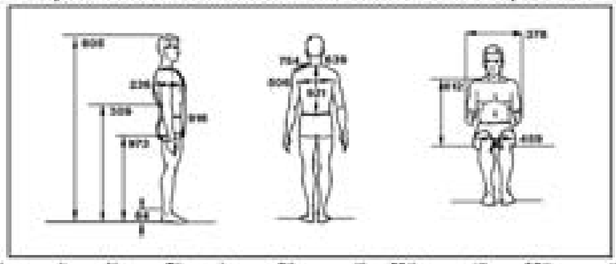
Notably for our context we will want to understand lengths of the lower leg including the length of the lower leg and heel and foot lengths.



Segment	Mass, gm (oz, weight) 5th percentile	50th percentile	95th percentile
1 Head	4260 (150)	440 (160)	4550 (160)
2 Neck	930 (30)	1100 (40)	1270 (40)
3 Thorax	20420 (720)	26110 (920)	31780 (1120)
4 Abdomen	2030 (70)	2500 (90)	2960 (100)
5 Pelvis	9420 (330)	12300 (430)	15150 (530)
6 Upper arm *	1600 (60)	2000 (70)	2500 (90)
7 Forearm *	1180 (40)	1450 (50)	1720 (60)
8 Hand	460 (20)	530 (20)	610 (20)
9 Hip flap *	2890 (100)	3640 (130)	4380 (150)
10 Thigh minus flap *	5480 (190)	6700 (240)	7920 (280)
11 Calf *	3320 (120)	4040 (140)	4760 (170)
12 Foot *	840 (30)	1010 (40)	1180 (40)
5 + 4 + 3 Torso	31870 (1120)	40910 (1440)	49870 (1760)
9 + 10 Thigh *	8360 (290)	10340 (360)	12300 (430)
7 + 8 Forearm plus hand *	1640 (60)	1980 (70)	2320 (80)

Figure 3.3.1.3-1 (2 of 12) Anthropometric Dimensional Data for American Male

Body Size of the 40-Year-Old American Male for Year 2000 in One Gravity Conditions



Microgravity notes	No.	Dimension	5th percentile	50th percentile	95th percentile
1	805	Stature	169.7 (66.8)	179.9 (70.8)	190.1 (74.8)
1	973	Wrist height			
	64	Ankle height	12.0 (4.7)	13.9 (5.5)	15.8 (6.2)
1	309	Elbow height			
	236	Bust depth	21.8 (8.6)	25.0 (9.8)	28.2 (11.1)
1	916	Vertical trunk circumference	158.7 (62.5)	170.7 (67.2)	182.6 (71.9)
2 1	612	Midshoulder height, sitting	60.8 (23.9)	65.4 (25.7)	70.0 (27.5)
	459	Hip breadth, sitting	34.6 (13.6)	38.4 (15.1)	42.3 (16.6)
1	921	Waist back	43.7 (17.2)	47.6 (18.8)	51.6 (20.3)
	506	Interscye	32.9 (13.0)	39.2 (15.4)	45.4 (17.9)
	639	Neck circumference	35.5 (14.0)	38.7 (15.2)	41.9 (16.5)
	754	Shoulder length	14.8 (5.8)	16.9 (6.7)	19.0 (7.5)
	378	Forearm-forearm breadth	48.8 (19.2)	55.1 (21.7)	61.5 (24.2)

Joint motion data for the knee is also neatly provided with specific ranges. The knee joint flexion ranges from 118.4 degrees to 145.6 degrees for the 5th to 95th percentile in males and 125.2 to 145.2 degrees for females (MSIS NASA). This data helps in designing spacesuits and spacecraft interiors to accommodate natural human movement.

Conclusions/action items:

With anatomical references values for knee flexion and lower leg lengths and masses, when drawing FBDs in the context of our final design for theoretical validation of hamstring activation, we can refer back to these data points.

2/1 - MRI Hamstring Compatible Loading Device Study

NIKHIL CHANDRA - Feb 01, 2024, 8:28 PM CST

Title: MRI Hamstring Compatible Loading Device Study

Date: 2/1/

Content by: Nikhil Chandra

Goals: To take relevant notes on the article, "A Magnetic Resonance-Compatible Loading Device for Dynamically Imaging Shortening and Lengthening Muscle Contraction Mechanics."

Content:

Search Term: ChatGPT Prompt “Find me some research articles related to the topic of Hamstring Loading In MRI machines”

Citation: Silder, A., Westphal, C. J., and Thelen, D. G. (September 3, 2009). "A Magnetic Resonance-Compatible Loading Device for Dynamically Imaging Shortening and Lengthening Muscle Contraction Mechanics." ASME. *J. Med. Devices*. September 2009; 3(3): 034504. https://doi.org/10.1115/1.3212559

Link: https://doi.org/10.1115/1.3212559

Content:

First, interestingly the article was written by a professor at UW Madison in the department of mechanical engineering, Christopher Westphal, whom we should definitely meet with.

The article is closely related to our BME project, where the author develops a device that can allow a user to perform contractions or eccentric movements for their hamstrings in the context of an MRI machine, where in the device ten subjects tested had about 30 degrees of knee joint motion on average. In this device, the MR imaging was done of the lower extremity region itself as opposed to being a brain MRI, and the purpose of the study was to develop a device that can further allow us to understand the biomechanical properties of the lower extremities during various concentric or eccentric exercises.

Conclusions/action items:

Moving forward, I want to continue to do research on competing designs for hamstring loading devices including both patent and literature studies.

NIKHIL CHANDRA - Feb 01, 2024, 9:43 PM CST


ASME DIGITAL COLLECTION

Journal of Medical Devices

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A_Magnetic_Resonance-Compatible_Loading_Device_for_Dynamically_Imaging_Shortening_and_Lengthening_Muscle_Contraction_Mechanics_J._Med._Devices_ASME_Digital_Collection.pdf (430 kB)

2/8 - Common Hamstring Weight Machines Research

NIKHIL CHANDRA - Feb 08, 2024, 11:28 AM CST

Title: Common Hamstring Weight Machines Research

Date: 2/8

Content by: Nikhil Chandra

Goals: To conduct research and take notes on some of the common hamstring gym weight machines which may provide design inspiration for an MRI compatible hamstring loading device.

Content:

Search Term: "Common gym machines that target hamstring muscles" Google search

Link: https://www.sportskeeda.com/health-and-fitness/6-best-gym-machine-exercises-for-stronger-hamstrings

Citation: Bajaj, Aryan. 6 Best Gym Machine Exercises For Hamstrings. 28 Aug. 2022, https://www.s portskeeda.com/health-and-fitness/6-best-gym-machine-exercises-for-stronger-hamstrings.

The article iterates some of the popular and common gym machines that target the hamstrings including The Lying Leg Curl, Seated Leg Curl, Standing Leg Curl, Smith Machine Stiff-leg Deadlift, Smith Machine Romanian Deadlift, and the Leg Press machines.

None of these machines include an individual lying in a supine position which is reasonable as it is not the most optimal position to activate the hamstrings through knee flexion. Most of these machines and exercises allow an individual to work their hamstrings by activating their hamstrings for knee flexion, however notably in the leg press machine, an individual must work to extend their knee, yet their hamstrings are still activated as they extend their hip. Importantly, when building a hamstring loading device, given the insertion points of the three major hamstring muscles, it will be useful for us to remember that in addition to knee flexion, hip abduction, adduction, and extension will also target the hamstring muscles.

Conclusions/action items:

With a deeper understanding of some of the common gym machines that target the hamstring muscles and what biomechanical movements an individual performs in these machines, we now have further inspiration for how to construct a loading device that can effectively target the hamstrings. I will continue to look into competing designs.

Initial Individual Brainstorming - 2/9

NIKHIL CHANDRA - Mar 15, 2024, 12:49 PM CDT

Title: Initial Individual Brainstorming

Date: 2/9

Content by: Nikhil Chandra

Goals: To write down a number of ideas that I can bring to the group brainstorming session specifically for the mechanical system by which we will load the hamstrings in an MRI machine.

Content:

- One idea is to develop a stand that can support the upper leg and essentially lock them in place allowing only the knees to move
    - Maybe this can be achieved by having one single stand with a connected ankle roller that directly connects to a pulley on the stand
    - We could also have one stand just for supporting the legs, then a separate stand that has the pulley with foot plates for which the individual can place their foot, flex their knee and pull the cable
- Another idea is to have a stand at the end of the MRI table with a cable and pulley connected to a foot plate on one end and the weight on the other end. Since their legs are not knocked in place, once their foot gets strapped in the foot plate they will essentially have full freedom to move the foot plate however they like including performing knee flexion and hip extension
- Another idea is the slider design similar to what the client proposed where we have a slider with a cable applying an outwards force and as they flex their knee and pull the slider inwards their hamstrings become activated
- Some weirder ideas include potentially a system that lies off the table where the individual's leg will have to hang off the end of one side of the table where they can then perform knee flexion with a connected pulley weight system
    - There could also be a system on the table that allows the individual to perform only hip extension which will passively activate the hamstrings but there being overall a lot less movement may be an advantage.

Conclusions/action items:

With some solid ideas for the mechanical system by which we can load an individual's hamstrings through an MR compatible device, moving forward in the upcoming group brainstorming session I aim to present my ideas to the group and build upon the other group member's ideas.

Slider Design Scratch Work - 3/14

NIKHIL CHANDRA - Apr 27, 2024, 5:21 PM CDT

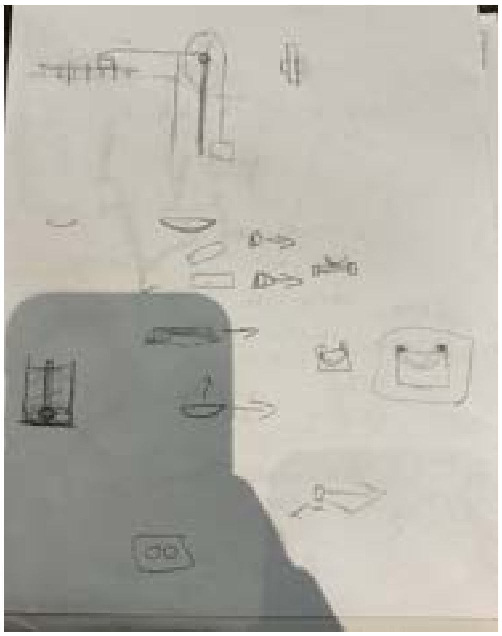
Title: Slider Design Scratch Work

Date: 3/14

Content by: Nikhil Chandra

Goals: To show some of the scratch work for the slider design including the pulley system and cylindrical slider that I created when discussing the design with the group.

Content:



Specifically I was envisioning an idea for a slider that was a half cylinder as opposed to block, since with less contact surface area we can minimize friction and stress concentrations that may appear at the corners. And for the pulley system I was thinking of having two parallel connected pulleys that rotate with one another and by altering the radii of the pulleys we can change the force that gets amplified.

Conclusions/action items:

With a more solid understanding of the design of the slider system, and with measurements from the MRI table that we recently obtained we are now equipped to move forward with designing the system in solidworks including the slider and the pulley system.

Initial Slider Design Brainstorming - 3/17

NIKHIL CHANDRA - Apr 27, 2024, 4:59 PM CDT

Title: Initial Slider Design Brainstorming

Date: 3/17

Content by: Nikhil Chandra

Present: Nikhil, Micah

Goals: To bring together our final vision for the slider design after some discussion and potentially more brainstorming before we move into the designing the slider.

Content:

- Micah and I explored several design options for the slider, beginning with my initial idea of a cylindrical slider and slide.
- We agreed that this cylindrical approach could potentially reduce friction. However, we also recognized that fabricating it with the necessary precision could be quite challenging.
- Considering that any slight inaccuracies in manufacturing could undermine the low-friction benefit, we decided to pivot to a more practical solution.
- We settled on a rectangular design for both the slider and the slide, which would allow us to construct the assembly from stacked sheets of HDPE, requiring only basic cuts with a band saw.
- To fine-tune the friction in this rectangular design, we planned to integrate layers of felt between the HDPE sheets, giving us more control over the sliding smoothness.

Conclusions/action items:

With an idea in our minds for what the frictionless slider design is going to look like we can now move into creating more detailing drawings and CAD models.

Lower Leg Free Body Diagram - 3/17

NIKHIL CHANDRA - Apr 28, 2024, 3:08 PM CDT

Title: Lower Leg Free Body Diagram - 3/17

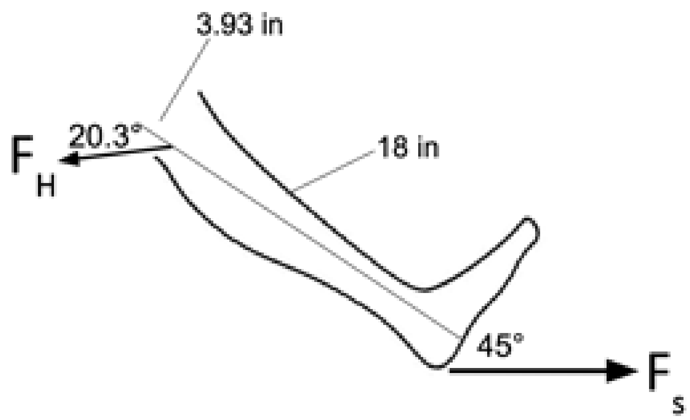
Date: 3/17

Content by: Nikhil Chandra

Present: Nikhil Chandra

Goals: In the process of creating the slider design, I want to develop a FBD for the lower leg given to assess the hamstring force production in the context of this design.

Content:



This is an FBD of the lower leg assuming an anatomical length of 18 inches and an insertion angle of the hamstrings being 60 degrees along with a 45 degree heel angle.

In this case:

F_H*sin(20.3)*(3.94 in) = F_s*sin(45)*(18 in)

When solving for F_H, we see that it is about 9.3 times that of the cable force, which is a significant amplification and even for a small cable force will require notable hamstring activation, which allows us to minimize the amount of weight attached to the pulley.

Anatomical Reference Values:

Grassi, C. A., Fruheling, V. M., Abdo, J. C., de Moura, M. F. A., Namba, M., da Silva, J. L. V., da Cunha, L. A. M., de Oliveira Franco, A. P. G., Costa, I. Z., & Filho, E. S. (2013). Hamstring tendons insertion - an anatomical study. *Revista brasileira de ortopedia*, *48*(5), 417–420. https://doi.org/10.1016/j.rboe.2012.07.01

Conclusions/action items:

With an FBD of the lower leg, we now have a more thorough understanding of the necessary hamstring force production for a given cable force in the context of the slider design.

Slider Design Materials Research - 3/18

NIKHIL CHANDRA - Apr 27, 2024, 5:16 PM CDT

Title: Slider Design Materials Research - 3/18

Date: 3/18

Content by: Nikhil Chandra

Present: Nikhil

Goals: To conduct some research on potential materials choices for the frictionless slider

Content:

- In selecting materials for our frictionless slider, we faced the constraint that the material must be non-ferrous to avoid magnetic interference, which is crucial for making sure our design does not create fragmentation
- The material also needs to be sufficiently strong to support a distributed load equivalent to the weight of a human leg. This requirement ensures that the slider remains functional and durable under regular use.
- Beyond HDPE, we considered UHMW (Ultra High Molecular Weight Polyethylene) as an alternative due to its higher strength and durability, while still being non-ferrous and capable of supporting significant weight without deformation.
- We also evaluated composite materials, such as fiberglass or carbon fiber reinforced polymers, which are non-ferrous and offer high strength-to-weight ratios. These materials could provide the necessary support while also contributing to a low-friction interface.
- However, carbon fiber was ultimately deemed too expensive for our budget constraints to construct the entire slider, and HDPE was a more commonly accessible and suitably strong material that we could find at the TeamLab as scrap or makerspace along with easily ordering online to be delivered in a short time frame.

Conclusions/action items:

With a materials choice of HDPE for the slider based on the primary reason that it is very accessible, is non-ferrous and would be sufficiently strong for only a small load of less than 30 pounds distributed over a larger area, we are now a step closer towards fabrication of the frictionless slider.

Pulley System Brainstorming and Discussion - 3/29

NIKHIL CHANDRA - Apr 27, 2024, 5:37 PM CDT

Title: Pulley System Brainstorming and Discussion - 3/29

Date: 3/29

Content by: Nikhil Chandra

Present: Nikhil, Micah

Goals: To have a discussion with Micah on some of the ideas we have for the design of the pulley and weight stack system before we proceed with designing it in solidworks.

Content:

- In the design of our pulley weight system, we set a clear objective to find a robust and practical solution for supporting a shaft. This shaft needs to handle both the pulley and its associated load effectively.
- A key decision in our design process was choosing between integrating bearings directly into the pulley or opting for a design where the shaft fits snugly with bearings. We considered using two bearings to allow the shaft to rotate freely, enhancing the system's functionality.
- Our design includes two vertical posts connected to a base, which supports the shaft at the top. We plan to cut two parallel holes on either side of the base to secure the shaft in place.
- To reinforce the stability of the vertical supports on the base, we're considering the use of L brackets. Additionally, we thought about cutting holes in the base sheet for a secure fit of the vertical posts.
- Given the setup's proximity to an MRI table, we anticipate the need for the vertical posts to be longer along the length of the table to prevent tipping. We are also aiming for a vertical post width of about 0.5 to 1 inch to ensure adequate support and stability.

Conclusions/action items:

With a simple yet effective idea on how to support the pulley and shaft, we now need to have a discussion on materials choices and solidify dimensions for this idea before we then create a CAD for the pulley weight system.

Pulley Weight Stack System Individual Component Design - 3/29

NIKHIL CHANDRA - Apr 28, 2024, 2:15 PM CDT

Title: Pulley Weight Stack System Individual Component Design - 4/5

Date: 4/5

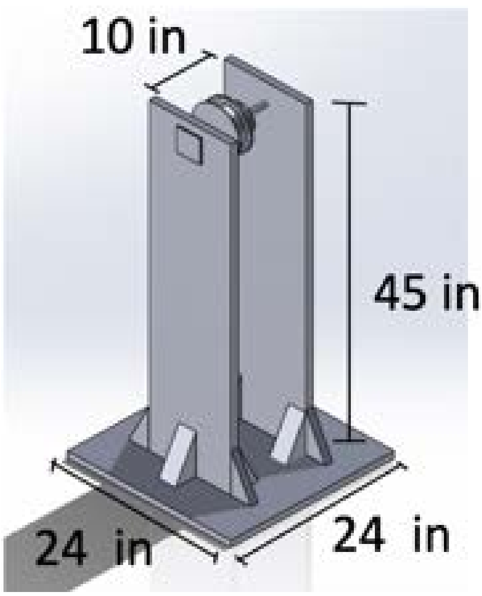
Content by: Nikhil Chandra

Present: Nikhil, Micah

Goals: To show the pulley and weight stack system that Micah and I initially designed.

Content:

This is the pulley weight stack system that we designed that we will show and discuss with the rest of the team. The components include the base sheet, the pulley, and the vertical posts. As the pulley rotates, press fit bearings on either side of the vertical posts will allow frictionless rotation.



Conclusions/action items:

With the initial pulley weight stack iteration discussed and decided upon we can now proceed forward with showing the design to the rest of the team and having a more thorough discussion of the materials we will use for the shaft, the posts, and the pulley.

Materials Research for Shaft Design- 4/5

NIKHIL CHANDRA - Apr 28, 2024, 2:33 PM CDT

Title: Materials Research for Shaft Design- 4/5

Date: 4/5

Content by: Nikhil Chandra

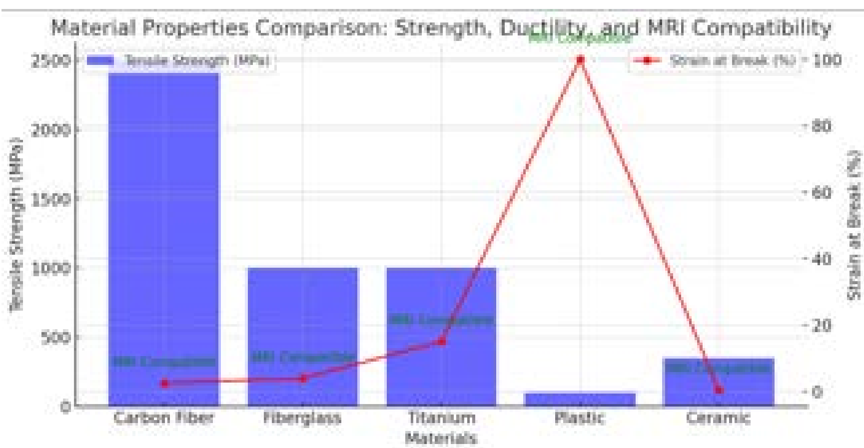
Present: Nikhil Chandra

Goals: To conduct some individual research on potential materials choices for the pulley weight stack system.

Content:

- Specifically I want to look into conducting research for the shaft that will support the pulley since that is the critical component that has the highest potential to break.
- Due to the primary reasons of ease of accessibility, ease of fabrication, and non ferrous properties, HDPE was chosen as the material for the base support, the vertical supports. And as essentially the only alternative to metal bearings, plastic glass ball bearings were chosen and will be ordered through McMaster Carr. This is discussed more in the team design process folder where we further elaborate on this decision for HDPE and bearings.
- Here I want to conduct individual research showing a comparison of potential materials for the pulley shaft

Our first major constraint is the material has to be non ferrous, and in turn I will mainly be comparing ceramics, composites, and polymers based on their tensile strength, ductility. Preferably, we want to choose a material that has a high tensile strength and can withstand an amplifier force of above 120 lbs, as per a general estimate from a client meeting. Here is a graph I produced comparing some notable materials:



Each of the materials above are MRI compatible, and the graph shows the fracture strain and the ultimate tensile strength for each of the materials. Notably carbon fiber has the highest tensile strength significantly greater than that of the others, but it also has the lowest ductility. Preferably we woul like a material that can plastically deform near failure as a warning as opposed to a brittle fracture. Currently although carbon fiber does not offer the benefit of plastic deformation, its tensile strength is highly preferable. In addition, we cannot machine titanium at the teamlab requiring us to get a perfect rod that we would not have to machine.

Reference:

"Material Property Data," MatWeb. [Online]. Available: https://www.matweb.com/search/PropertySearch.aspx.

[Accessed: 28-Apr-2024].

Conclusions/action items:

With a comparison of the tensile strength and ductility of some major non ferrous materials, I am going to further discuss my material preferences for the shaft with the team. Assuming carbon fiber as the material, I am going to proceed with producing an FBD of the shaft and calculating a safety factor given the critical bending stress.

Pulley Free Body Diagram - 4/8

NIKHIL CHANDRA - Apr 28, 2024, 4:24 PM CDT

Title: Pulley Free Body Diagram - 4/8

Date: 4/8

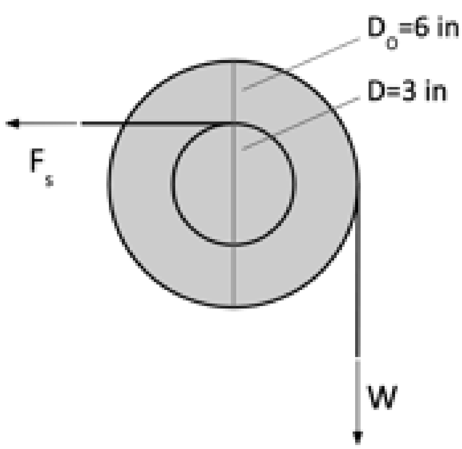
Content by: Nikhil Chandra

Present: Nikhil Chandra

Goals: After 3D printing the pulley and discussing the need for a redesign, I want to create a simply FBD of the pulley radii to provide evidence of validation of the pulley amplification for our new design

Content:

The full design of the pulley is discussed further in our team activities folder, however here is a simple FBD diagram of the pulley from the side to show how in torque equilibrium the force is amplified:



F_s*(3 in) = W*(6 in)

Fs = 2*W

Given an outer diameter of 6 inches and an inner diameter of 3 in, we are able to see that the amplified force is 2 times that of the weight force.

Conclusions/action items:

With evidence through a free body diagram and torque equilibrium we show that the amplified force is two times that of the weight given a radii ratio of 2, and we can now further proceed with the design and fabrication of the new pulley.

Carbon Fiber Shaft Free Body Diagram - 4/10

NIKHIL CHANDRA - Apr 28, 2024, 2:49 PM CDT

Title: Carbon Fiber Shaft Free Body Diagram - 4/10

Date: 4/10

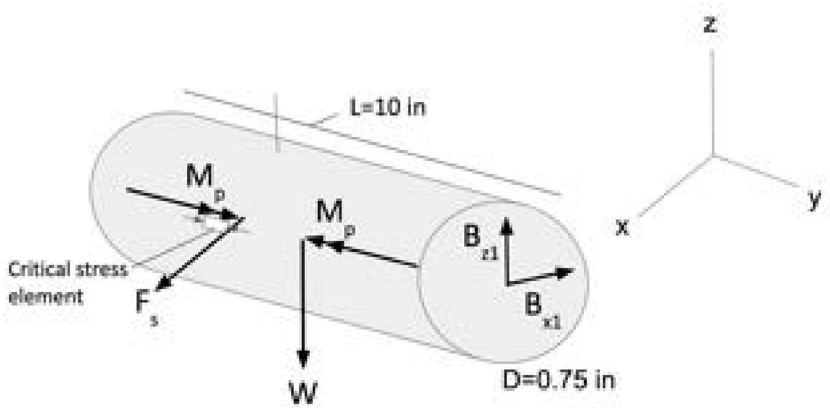
Content by: Nikhil Chandra

Present: Nikhil Chandra

Goals: To show a FBD of the carbon fiber shaft supporting the pulley and subject to the attached weight and amplified force.

Content:

Below is a free body diagram showing the amplified force and the weight along with the reaction forces from the bearings on either side for the shaft. This is assuming a 10 inch length and a ¾ inch diameter for the shaft, which are dimensions that work well with the pulley weight stack system design and is of a length that will require no machining from the vendor we will purchase the shaft from. This purchase is further discussed in the team activities section.



This FBD assumes static equilibrium in turn causing the torques due to the weight and amplified force to cancel out.

Conclusions/action items:

With a FBD of the carbon fiber shaft, we can now proceed with calculating the safety factor which was delegated to Ethan and is detailed more in his individual notebook.

New Pulley Design Rope Calculations - 4/13

NIKHIL CHANDRA - Apr 28, 2024, 4:59 PM CDT

Title: New Pulley Design Rope Calculations - 4/13

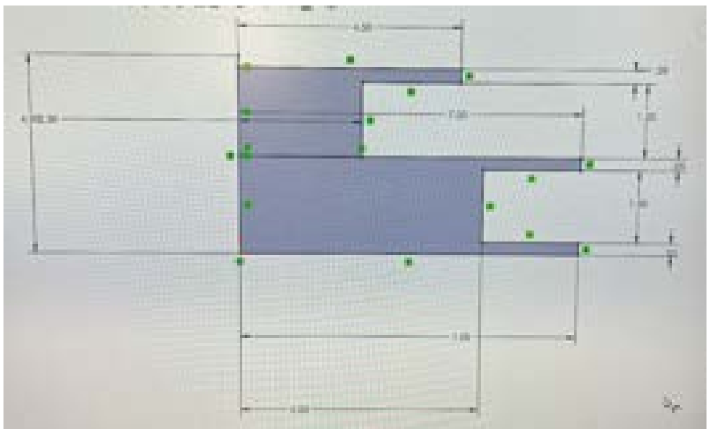
Date: 4/13

Content by: Nikhil Chandra

Present: Nikhil Chandra

Goals: To calculate the inner widths of the new pulley design in order to allow for enough cable to wrap around without protruding from the pulley.

Content:



Given a ¼ inch cable, and given that we want the cable to extend 6 ft as a conservative estimate. For a pulley width, w, and the smaller radii of the pulley being 2.5 inches.

((Rope length/(circumference of pulley)))/(width of pulley/width of rope)

((6*12 in)/(2*pi*(2.5 in)))/(1.5 in/0.25 in) = number of wrap around

Given a pulley width of 1.5 in, a 6ft cable would wrap around 0.76 times which is a sufficient value such that the cable does not protrude from the pulley

Conclusions/action items:

With evidence that the cable will not have to wrap around the pulley too many times, we have validated both the pulley width and the pulley radii and can further proceed with fabrication of our pulley design.

1/31/2024 - Neural activity for hip-knee control

MICAH SCHOFF - Feb 02, 2024, 1:28 PM CST

Title: Neural Activity for hip-knee control

Date: 1/31/2024

Content by: Micah Schoff

Goals: Learn about similar studies in the field to grasp a better understanding of the scope of this project.

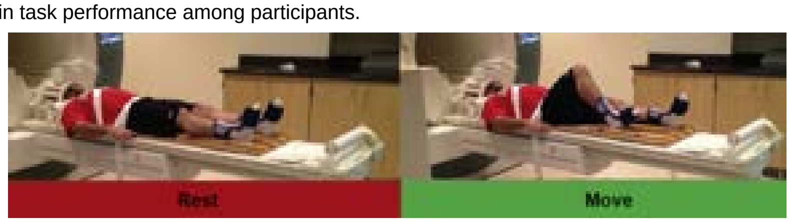
Search Terms: PubMed article provided by our client Dr. Crawford

Citation:

C. R. Criss, J. A. Onate, and D. R. Grooms, "Neural activity for hip-knee control in those with anterior cruciate ligament reconstruction: A task-based functional connectivity analysis," *Neuroscience Letters*, vol. 730, p. 134985, Jun. 2020, doi: 10.1016/j.neulet.2020.134985.

Link: https://www.sciencedirect.com/science/article/abs/pii/S030439402030255X?via%3Dihub

Content:

a. Increased Activation in Specific Brain Regions: ACLr individuals showed increased activation in several brain regions compared to healthy controls. These regions include the intracalcarine cortex, lingual gyrus, occipital fusiform gyrus, lateral occipital cortex, angular gyrus, and superior parietal lobule. These areas are associated with visual-spatial cognition, orientation, and attention.
b. Functional Connectivity Differences: Task-based functional connectivity analyses revealed connectivity patterns among fronto-insular-temporal and sensorimotor regions within the ACLr participants. This suggests that there are alterations in the communication between these brain regions in individuals who have undergone ACL reconstruction.
c. Increased Cognitive Demands for Motor Control: The observed increased activity and connectivity in areas responsible for visual-spatial cognition, orientation, and attention suggest that ACLr individuals may require enhanced neural resources for effective motor control of the hip and knee. This implies that the injury and reconstruction may influence not only local motor control but also the cognitive aspects of movement.
d. Methodological Approach: The study addressed prior limitations by employing a multi-joint motor paradigm, allowing for a more comprehensive understanding of the effects of ACL injury on neural control. The use of a metronome to control spatial-temporal parameters ensured consistency in task performance among participants.
e. 

f. Th above image represents similar movements to which we will be implementing into the project. This not only give a good idea for what the movement looks like, but also spatial awareness of what the MRI table looks like.

Conclusion: This article provided good insight into a similar study. Not only did this help to learn more about the scope of the project, but also provided me with good knowledge of what space we have to work with. I think once we met with the client more and learn about the types of FMRI measurements are being made it would be nice to have a better understanding of that.

MICAH SCHOFF - Feb 01, 2024, 5:19 PM CST

Download

Neural_activity_for_hip-knee_control_in_those_with_anterior_cruciate_ligament_reconstruction__A_task-based_functional_connectivity_analysis.pdf (2.86 MB)

1/31/2024 - EMG-angle relationship with hamstrings

MICAH SCHOFF - Feb 01, 2024, 5:38 PM CST

Title: 1/31/2024

Date: 1/31/2024

Content by: Micah Schoff

Goals: Learn more about specific movement in knee and hamstrings and their effect on the anatomy.

Search Terms: Hamstring and Knee Flexion and EMG

Citation:

Hideaki Onishi, Ryo Yagi, Mineo Oyama, Kiyokazu Akasaka, Kouji Ihashi, Yasunobu Handa, EMG-angle relationship of the hamstring muscles during maximum knee flexion, Journal of Electromyography and Kinesiology, Volume 12, Issue 5, 2002, Pages 399-406, ISSN 1050-6411.

Link: **EMG-angle relationship of the hamstring muscles during maximum knee flexion - ScienceDirect**

Content:

a. Isometric Testing: The knee flexion torque was greater at 60 degrees compared to 90 degrees. The EMG activity of hamstring muscles varied with the change in knee flexion angle, except for the short head of the biceps femoris.
b. Isokinetic Testing: The mean peak isokinetic torque occurred between 15 and 30 degrees of knee flexion, decreasing as the knee angle increased. Integrated EMG activity of certain hamstring muscles increased significantly as the knee angle increased from 0 to 105 degrees during isokinetic contraction.
c. Muscle-Specific Differences: The integrated EMG activity of the long head of the biceps femoris muscle showed distinct patterns. For example, during isometric testing, its activity was greater at a knee angle of 60 degrees compared to 90 degrees.
d. Variability with Muscle Length or Joint Angle: The study demonstrated that EMG activity during maximal knee flexion varies with changes in muscle length or joint angle. The long head of the biceps femoris muscle exhibited notably different activity compared to the other hamstring muscles.
e. The image below represents how knee flexion was measured during hamstring activation. This provides more insight on possible ways to activate hamstring movement.

Conclusion: this article helps to represent and show how isometric and isokinetic movements affect hamstring activation and a possible was in how to activate the hamstrings. On top of this I learned more about knee flexion and its relationship to hamstring movement.

MICAH SCHOFF - Feb 01, 2024, 5:35 PM CST

EMG-angle relationship of the hamstring muscles during maximum knee flexion

Download

PII__S1050-6411_02_00033-0.pdf (208 kB)

1/31/2024 - Hamstring Strain and ultrasound

MICAH SCHOFF - Feb 01, 2024, 5:52 PM CST

Title: Ultrasound shear wave seeds reduced following hamstring strain injury but not after returning to sport.

Date: 1/31/2024

Content by: Micah Schoff

Goals: Learn more about ultrasound and shear waves as the device we build will be used for this purpose as well.

Search Terms: Hamstring and injury and strain and ultrasound or waves

Citation:

Crawford, S.K., Wille, C.M., Joachim, M.R. *et al.* Ultrasound shear wave seeds reduced following hamstring strain injury but not after returning to sport. *Insights Imaging* **15**, 7 (2024). https://doi.org/10.1186/s13244-023-01571-x.

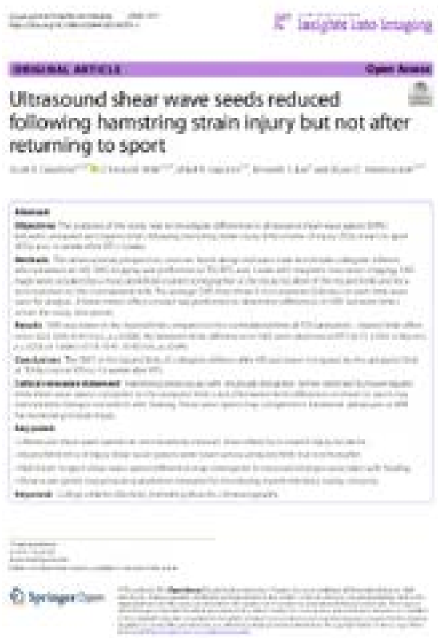
Link: Ultrasound shear wave seeds reduced following hamstring strain injury but not after returning to sport | Insights into Imaging (springer.com)

Content:

a. The study followed an observational, prospective, cross-sectional design and involved male and female collegiate athletes who experienced HSI.
b. SWS imaging was conducted at TOI, RTS, and 12 weeks post-RTS using magnetic resonance imaging.
c. A musculoskeletal-trained sonographer performed SWS mapping at the injury location on the injured limb and matched locations on the contralateral limb.
d. Analysis used the average SWS from three 5 mm diameter Q-boxes on each limb, and a linear mixed effects model determined differences in SWS between limbs across the study time points.
e. Ultrasound shear wave speed can non-invasively measure tissue elasticity in muscle injury locations.
f. Injured limb shear wave speeds were lower than uninjured limb at TOI but not thereafter.
g. Lack of shear wave speed differences at RTS may correspond to structural changes associated with healing.
h. Shear wave speed could provide quantitative measures for monitoring muscle elasticity during recovery.

Conclusion: The study suggests that ultrasound shear wave speed is a good way to address and learn about post injury tissue healing. The space it requires can vary so it is important to get more accurate information when looking to build something that capable for both MR table and ultrasound.

MICAH SCHOFF - Feb 01, 2024, 6:02 PM CST


Insights into Imaging

ORIGINAL ARTICLE Open Access

Ultrasound shear wave seeds reduced following hamstring strain injury but not after returning to sport

SpringerOpen

Download

s13244-023-01571-x.pdf (1.76 MB)

2/1/2024 - Adaptive Force of Hamstring

MICAH SCHOFF - Feb 01, 2024, 6:02 PM CST

Title: Adaptive Force of Hamstring Muscles is reduced ...

Date: 2/1/2024

Content by: Micah Schoff

Goals: Learn about similar products/devices that have been built to serve this purpose.

Search Terms: hamstring AND activation OR isometric OR kinematic AND device

Citation:

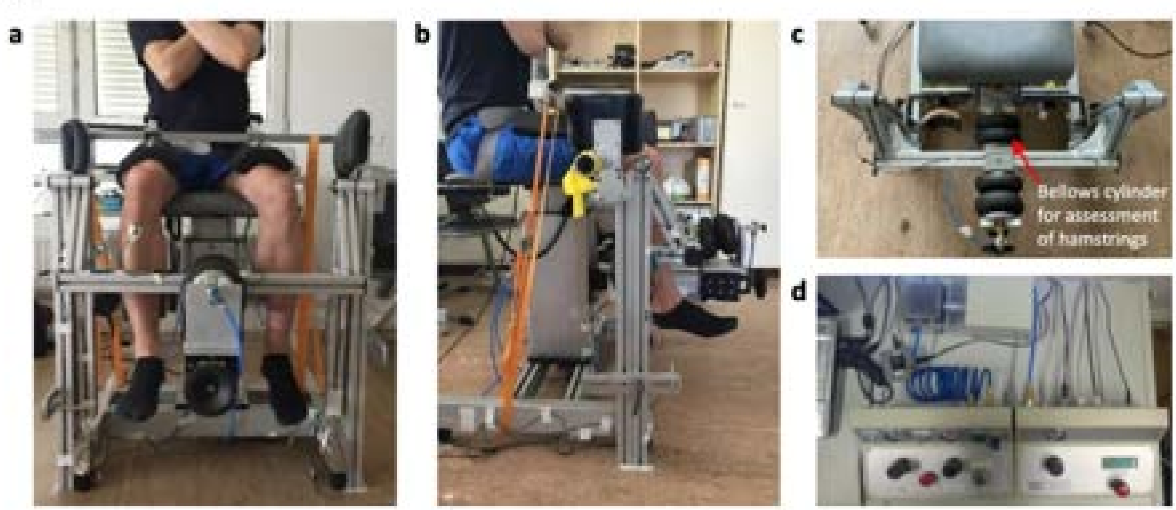
Schaefer, L.V., Dech, S., Carnarius, F. *et al.* Adaptive Force of hamstring muscles is reduced in patients with knee osteoarthritis compared to asymptomatic controls. *BMC Musculoskelet Disord* **25**, 34 (2024). https://doi.org/10.1186/s12891-023-07133-y.

Link: Scopus - Document details - Adaptive Force of hamstring muscles is reduced in patients with knee osteoarthritis compared to asymptomatic controls | Signed in

Content:

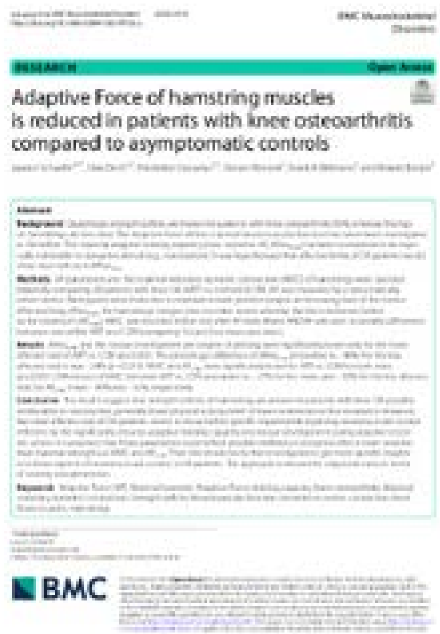
a. Pneumatically driven system designed for measuring the Active Force (AF) of hamstring muscles.
b. Adapted from a previously described principle used for elbow extensors.
c. Demonstrated reliability in detecting AF parameters (ICC = 0.896 – 0.966) with acceptable random errors.
d. Swing structure with two levers (left/right) providing a range of motion (ROM) from 82°-100° for extension-flexion (0° represents fully extended knee).
e. Connection to two bellows cylinders through a cross strut.
f. Pneumatic actuation of bellows cylinders, one opposing knee extension and the other opposing knee flexion.
g. Interface with strain gauges on each lever records force between the device and the lower leg.
h. Motor-controlled throttle to prevent abrupt pressure increases at the beginning.
i. Figure 1: Illustrates the entire system, showcasing the swing structure, bellows cylinders, and the overall design for measuring hamstring muscle AF.

Fig. 1



Conclusion: This study is not as important for what this study is based on, but more the device they built to study hamstring force. This gives good insight to how we can add resistance to our device as that is the main problem to solve.

MICAH SCHOFF - Feb 01, 2024, 6:02 PM CST


RESEARCH Open Access

Adaptive Force of hamstring muscles is reduced in patients with knee osteoarthritis compared to asymptomatic controls

BMC

[Download](#)

s12891-023-07133-y.pdf (1.75 MB)

2/8/2024 - Hamstring loading device for MRI

MICAH SCHOFF - Feb 09, 2024, 11:29 AM CST

Title: Hamstring loading device for MRI

Date: 2/8/2024

Content by: Micah Schoff

Goals: Learn about similar products/devices that have been built to serve this purpose.

Search Terms: hamstring and loading device and MRI or MR compatible

Citation:

Silder A, Westphal CJ, Thelen DG. A Magnetic Resonance-Compatible Loading Device for Dynamically Imaging Shortening and Lengthening Muscle Contraction Mechanics. J Med Device. 2009 Sep 1;3(3):10.1115/1.3212559. doi: 10.1115/1.3212559. PMID: 24353749; PMCID: PMC3864847.

Link: **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3864847/**

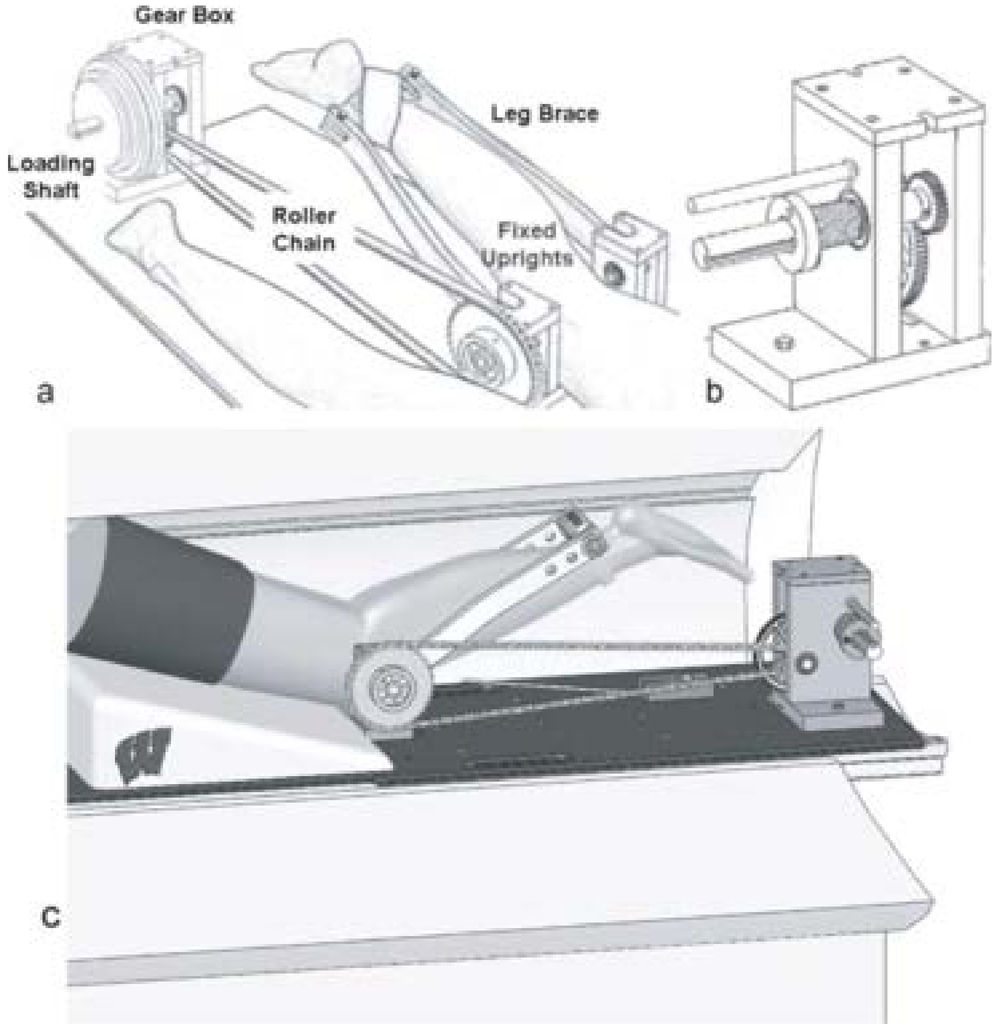
Content:

1. Purpose of the study: Design and test an MR-compatible device for inducing shortening or lengthening muscle contractions during dynamic MR imaging.
2. Device operation: Guides knee through cyclic flexion-extension, imposing elastic or inertial loads on hamstrings.
3. Subjects: Ten participants tested in a motion capture lab for limb motion and imposed load repeatability.
4. Data collection: Cine phase contrast imaging obtained image data for all subjects during knee motion cycles.
5. Results: Subjects achieved ~30 degrees of knee joint motion, with ~1 degree variation across 56 cycles.
6. Muscle activity: Max hamstring activity during shortening contraction (flexed knee) for elastic loading, and lengthening contraction (extended knee) for inertial loading.
7. MR imaging repeatability: Similar tissue velocities in repeat acquisitions under the same loading condition.
8. Spatial variations: Clear differences in velocity data between elastic and inertial loading conditions.
9. Potential applications: Device enables dynamic imaging of muscles under various loads, enhancing understanding of muscle mechanics, identifying causes of injury, and quantitatively assessing tissue-level injury effects.
10. Future possibilities: Device modifications could allow imaging of quadriceps or knee with slight adjustments in design or subject positioning.
11. Kinematic Data Collection:

    System Used: 8-camera passive motion capture system (Motion Analysis, Santa Rosa, CA).

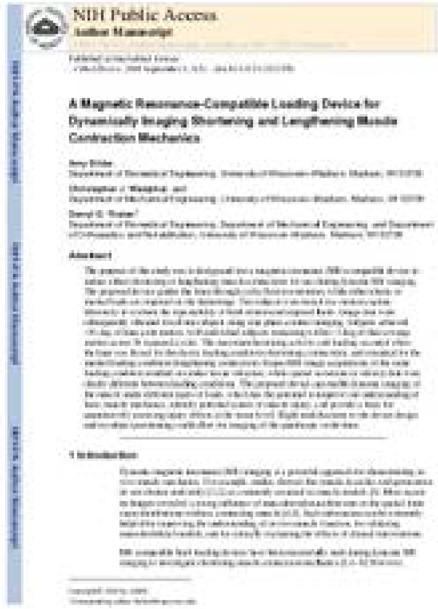
    Frequency: Data collected at 100Hz.

    Marker Placement: Markers on the knee's axis of rotation and support arms near the ankle to monitor knee flexion-extension angle.
12. Materials: The base was made from 15.9 mm thick high density polyethylene



Conclusion: This study is beneficial to our team as this device serves a similar purpose to what we are trying to build. On top of this it provides us with some material ideas as well as mechanical movement ideas for the device. This device is also important as it tells use how knee flexion is recorded as this is a reach goal for our client. I think further research into similar device like this will provide us with a good foundation on what we can use.

MICAH SCHOFF - Feb 09, 2024, 11:30 AM CST



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A Magnetic Resonance-Compatible Loading Device for Dynamically Imaging Shortening and Lengthening Muscle Contraction Mechanics

Abstract

1 Introduction

[Download](#)

nihms-484684.pdf (1.26 MB)

2/8/2024 - Hamstring loading device for MRI

MICAH SCHOFF - Feb 09, 2024, 11:52 AM CST

Title: Hamstring loading device for MRI

Date: 2/8/2024

Content by: Micah Schoff

Goals: Learn about similar products/devices that have been built to serve this purpose.

Search Terms: hamstring and loading device and MRI

Citation:

Westphal CJ, Schmitz A, Reeder SB, Thelen DG. Load-dependent variations in knee kinematics measured with dynamic MRI. J Biomech. 2013 Aug 9;46(12):2045-52. doi: 10.1016/j.jbiomech.2013.05.027. Epub 2013 Jun 24. PMID: 23806309; PMCID: PMC3759229.

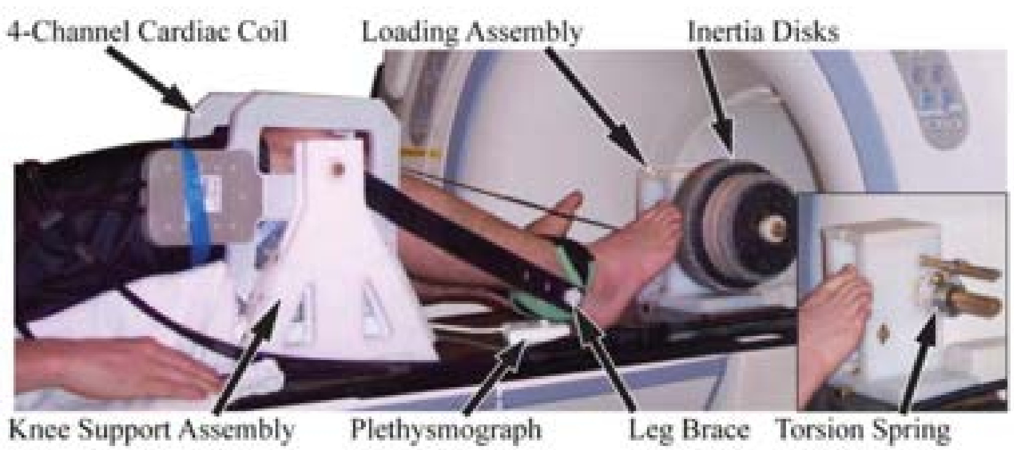
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3759229/

Content:

1. Purpose: Constructed an MRI-compatible device for knee flexion and extension against elastic or inertial loads in an MR scanner
   1. Subject Positioning: Subjects placed supine, right knee on a padded support assembly aligned with a rotating brace
   2. Device Components: Rotating brace coupled to a loading assembly via a flat belt, with gearing for precise motion control.
2. Movement Instructions: Subjects cycled knee flexion-extension synchronized with a metronome at 30 cycles per minute (frequency = 0.5Hz).
3. Loading Conditions:

   Elastic Loading: Used a stainless steel torsion spring (k=0.3Nm/rad) on the loading shaft.

   Inertial Loading: Implemented with high-density disks (I=348kg-cm2) on the shaft.



Conclusion: This is not a direct application as this is focused more on knee flexion, but this provides another way that we could provide resistance using MR compatible inertia disks to provide resistance. This device also uses MR safe materials so from this we can generate more material ideas/see common trends in devices. Our study will also include having to do movements in a specific frequency. This study provides how frequency was collected as well as possible ways we can use to test our device for frequency and make sure that it is possible.

MICAH SCHOFF - Feb 09, 2024, 11:50 AM CST


NIH Public Access

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Load-Dependent Variations in Knee Kinematics Measured with Dynamic MRI

Abstract

Keywords

[Download](#)

nihms500631.pdf (2.65 MB)

4/10/2024 - Knee Glide

MICAH SCHOFF - Apr 22, 2024, 10:52 PM CDT

Title: Knee Glide

Date: 4/10/2024

Content by: Micah Schoff

Goals: Learn about similar products/devices that have been built to serve this purpose.

Search Terms: Heel slide machiene

Citation:

"Knee Glide | Therapy Essentials | OPTP," *www.optp.com*. https://www.optp.com/Knee-Glide (accessed Apr. 23, 2024).

Link: Knee Glide | Therapy Essentials | OPTP

Content:

- Physical Therapy Tool: The Knee Glide aids in rehabilitation of both lower and upper extremities, developed by physical therapists Robert Schrupp and Bradley Heineck.

- Ease of Use: Simply place foot or hand on the plate and move smoothly along the track for low-impact exercise.

- Suitable for Various Conditions: Ideal for individuals recovering from knee, hip, or shoulder surgeries, stroke, arthritis, or those at risk of falling.

-*Benefits:

  - Increased range of motion.

  - Improved joint strength.

  - Promotion of synovial fluid to reduce friction.

  - Increased blood flow.

- Portability: Lightweight design (three pounds) with a convenient carrying handle for easy transport.

- Stability: Can be securely attached to the wall for added stability during use.

- Dimensions: Maximum dimensions (with handle unfolded): 32″ L x 5″ W x 5 ½″ H.

Conclusion: In reflecting on the design principles embodied by the Knee Glide, similarities emerge with our concept for a heel slider, both aimed at facilitating rehabilitative exercises effectively and conveniently. The Knee Glide's emphasis on simplicity, smooth movement along a track, and minimal effort requirement resonates with our vision for a user-friendly device. However, insights gleaned from the Knee Glide's features suggest avenues for improvement in our design. Enhancing portability, stabilizing the device for added confidence during use, and incorporating comprehensive exercise instructions stand out as potential areas for refinement. By drawing from the successes of the Knee Glide while addressing these considerations, our heel slider design can evolve to offer enhanced functionality and user satisfaction in rehabilitation settings.

2/8/2024 - Standards for non-surgical medical devices in MR environment

MICAH SCHOFF - Feb 09, 2024, 1:50 PM CST

Title: Standards for medical devices in MRI: Present and future

Date: 2/8/2024

Content by: Micah Schoff

Goals: Learn about standards and regulations in the frame of MRI and materials.

Search Terms: MRI standards and medical equipment or devices and materials

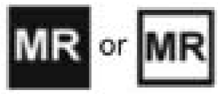
Citation: T. O. Woods, "Standards for medical devices in MRI: Present and future," Journal of Magnetic Resonance Imaging, vol. 26, no. 5, pp. 1186–1189, 2007, doi: https://doi.org/10.1002/jmri.21140.

Link: https://onlinelibrary.wiley.com/doi/10.1002/jmri.21140

Content:

1. ASTM F2503-05:
    1. MR Safe:
        - Definition: Poses no known hazards in all MR environments.
        - Example: Nonconducting, nonmagnetic items like a plastic Petri dish.
        - Determination: Can be established through a scientifically based rationale, not necessarily requiring test data
    2. MR Conditional:
        - Definition: Demonstrated to pose no known hazards in a specified MR environment under specific conditions.
        - Specified Conditions: Include field strength, spatial gradient, dB/dt, RF fields, and SAR.
        - Additional Requirements: May need specific configurations of the item.
    3. MR Unsafe:
        - Definition: Known to pose hazards in all MR environments.
        - Example: Magnetic items such as ferromagnetic scissors.
2.

A square — MR safe



An equilateral triangle with radiused outer corners — MR conditional

A circle with a diagonal bar — MR unsafe

Conclusion: This standard provides us guidance on how to navigate materials we can use as well as the labeling system used. This will be useful when identifying and classifying materials we use so we can ensure our device meets relative standards.

MICAH SCHOFF - Feb 09, 2024, 11:42 AM CST


Review Article

Standards for Medical Devices in MRI: Present and Future

Download

Magnetic_Resonance_Imaging_-_2007_-_Woods_-_Standards_for_medical_devices_in_MRI_Present_and_future.pdf (148 kB)

3/7/2024 - Dyneema

MICAH SCHOFF - Mar 08, 2024, 12:05 AM CST

Title: Dyneema (Cable material)

Date: 3/7/2024

Content by: Micah Schoff

Goals: Learn about possible cable materials

Search Terms: synthetic cable or rope

Citation: "The Science of Dyneema®," *www.dyneema.com*. https://www.dyneema.com/experience-more/the-science-of-dyneema

Link: https://www.dyneema.com/experience-more/the-science-of-dyneema

Content:

1. - Powder dissolved, heated, and subjected to proprietary gel-spinning process.

   - Resulting elongated molecules resemble high-strength Dyneema® fiber.

   - Draw cycle aligns molecules into strands during fiber production.

   - UD transformation involves laying parallel fibers, resin impregnation, and drying.

   - Cross-ply machine cuts dried layers into sheets, laminating for ultra-high strength.

   - Collaboration with manufacturers for weaving, knitting, or bonding in diverse applications.

   - Dyneema® Composite Fabric (DCF) sold as finished fabric for specialty uses.

   - Versatile layering of Dyneema® UD with different resins based on application needs.

   - Proprietary gel-spinning process is a crucial step in fiber production.

   - Application in protective gear, workwear, motorcycle gear, and more.

Conclusion: This material is a viable option for the cable that will connect the slider design to the resistance options. Overall this material also fits all requirements that we need to meet via the PDS (non-ferrous & capable of weight limit).

3/7/2024 - HDPE

MICAH SCHOFF - Mar 08, 2024, 12:18 AM CST

Title: HDPE

Date: 3/7/2024

Content by: Micah Schoff

Goals: Learn about possible structural materials

Search Terms: Non-Ferrous structural Materials

Citation: "HDPE Plastics - Grainger Industrial Supply," *Grainger.com*, 2023. https://www.grainger.com/category/raw-materials/plastics?attrs=Material%7CHDPE&filters=attrs (accessed Mar. 08, 2024).

Link: https://www.grainger.com/category/raw-materials/plastics?attrs=Material%7CHDPE&filters=attrs

Content:

Plastics, versatile polymers, find applications in packaging, parts fabrication, structural support, and wear strips.

Plastic angle stock supports building applications.

Full round, half round, channel stock, and tube stock guide conveyor systems and pathways in manufacturing.

Perforated plastic sheets function as strainers, guards, screens, and partitions.

Bar stock and rod stock are machined into high-precision mechanical parts.

Plastic sheets and films serve injection molding, machining, packaging, construction, and sign materials.

Plastic tubes act as electrical insulators and protective housings.

Plastic rods offer stiffness, straightness, and durability.

Plastic discs are cylindrical shapes used for high-precision part fabrication.

Conclusion: This material works very well in structural components. This will also with stand disinfection allowing for seamless use in the research function.

4/13/2024 - Nylon Screws

MICAH SCHOFF - Apr 22, 2024, 10:47 PM CDT

Title: Nylon Screws

Date: 4/13/2024

Content by: Micah Schoff

Goals: Learn about possible assembly screws

Search Terms: Nylon Screw information

Citation: "How to choose nylon screws," *www.essentracomponents.com*. https://www.essentracomponents.com/en-gb/news/solutions/fastening-components/how-to-choose-nylon-screws#:~:text=What%20are%20nylon%20screws%20and%20why%20are%20they (accessed Apr. 23, 2024).

Link: Nylon Screws: What are they and how to use them | Essentra Components UK

Content:

- Nylon screws, primarily nylon 6/6, offer alternatives to metal screws with distinct advantages.

- Benefits include electrical insulation, corrosion resistance, lightweight design, vibration damping, thermal insulation, and chemical endurance.

- However, nylon screws have limitations such as lower strength, temperature sensitivity, and hygroscopic tendencies.

- Types of nylon screws include machine screws, pan head screws, cheese head screws, knurled thumb screws, hex head cap screws, round head screws, and set screws (grub screws).

- Considerations when choosing nylon screws include the type of nylon, thread specifications, head design, drive type, load capacity, environmental factors, assembly process, long-term performance, and cost analysis.

- Consultation with experts is recommended for selecting the most suitable nylon screws for specific applications.

Conclusion: Overall, Nylon screws will be the best option to screw HDPE together while keeping the device MR compatible. These are also available at the team lab in many different types and sizes.

2/16/2024 Design Idea 1

MICAH SCHOFF - Feb 16, 2024, 1:10 PM CST

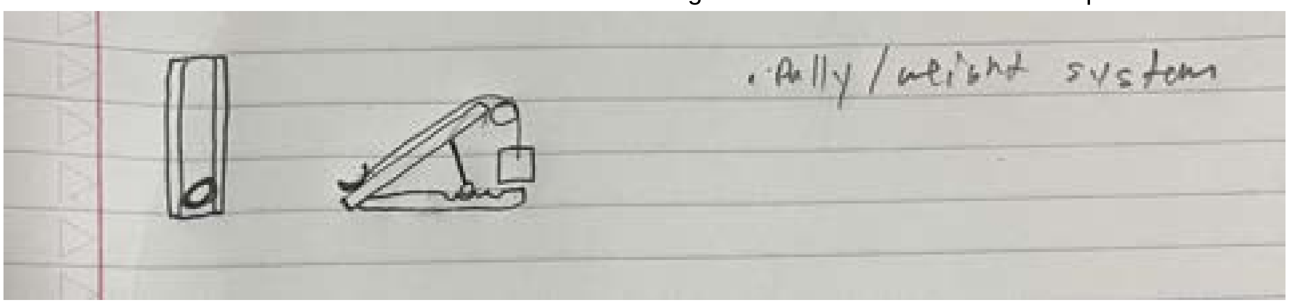
Title: Design 1: Slider

Date: 2/13/2024

Content by: Micah Schoff

Goals: Fully describe the design and its unique elements.

Content:

1. This design is the slider design. This device allows for extension and retraction through a single track sliding device. The device will keep constant resistance through. cable stack weight system similar to that which you'd see in a gym for a hamstring machine. A key feature of this device is that you can adjust the base angle allowing for adjustment to isolate the best knee flexion angle allowing for the hamstring isolation.
2. There is potential to change the resistance method within this design to elastic bands, but with the complicated to do all the calculations needed to find and adjust resistance.
3. The materials would be all NON-Ferrous materials allowing the entire device to be MR compatible.
4. 

2/16/2024 Design Idea 2

MICAH SCHOFF - Feb 16, 2024, 1:11 PM CST

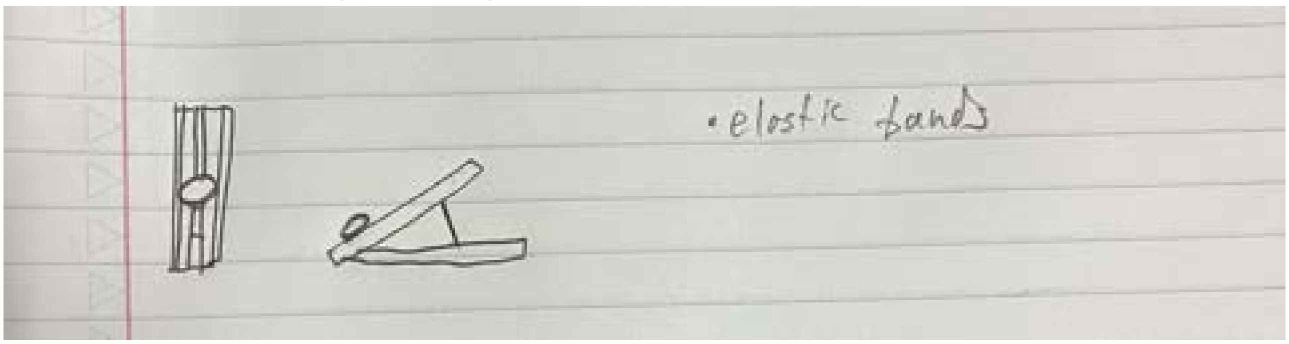
Title: Design 1: Slider II

Date: 2/16/2024

Content by: Micah Schoff

Goals: Fully describe the design and its unique elements.

Content:

1. This design is similar to the first design however the adjustment is less varied. This design used opposing elastic bands to provide a handoff of resistance between two opposing elastic bands. The subject would place their heel into a heel cup and push forward and back wards to get resistance in both directions.
2. This device consists of an adjustable base height allowing for change in knee flexion in the subject. This allows for us to adjust and figure out the best angles to isolate the hamstring.
3. This design is similar to the first design in terms of the actual base/frame of the device and would use the same materials and MR compatible is required.
4. 

2/29/2024 Silder Design SolidWorks

MICAH SCHOFF - Feb 29, 2024, 9:56 AM CST

Title: Design 1: Slider SolidWorks

Date: 2/29/2024

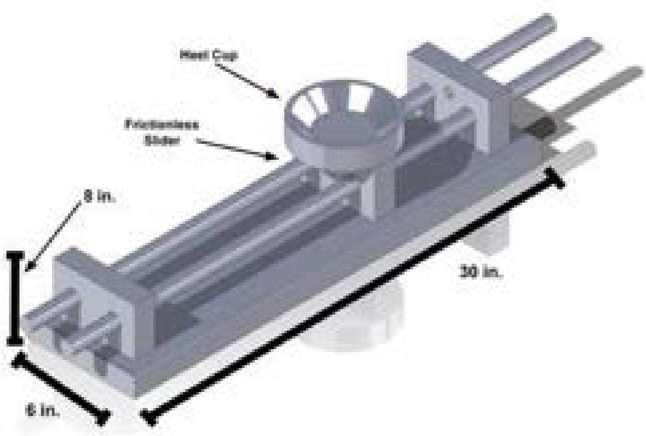
Content by: Micah Schoff

Goals: Show in CAD what the slider will look like with dimensions.

Content:

- This design is the slider design. This device allows for extension and retraction through a single track sliding device. The device will keep constant resistance through. cable stack weight system similar to that which you'd see in a gym for a hamstring machine. A key feature of this device is that you can adjust the base angle allowing for adjustment to isolate the best knee flexion angle allowing for the hamstring isolation.
- There is potential to change the resistance method within this design to elastic bands, but with the complicated to do all the calculations needed to find and adjust resistance.
- The materials would be all NON-Ferrous materials allowing the entire device to be MR compatible.

MICAH SCHOFF - Mar 01, 2024, 11:01 AM CST



Download

Slider_Design.jpg (48.5 kB)

3/8/2024 - Preliminary Slider and Cable stack

MICAH SCHOFF - Mar 08, 2024, 12:25 AM CST

Title: Slider and Cable Stack Design

Date: 3/8/2024

Content by: Micah Schoff

Goals: Explain how the two design will work together.

Content:

- The slider will provide the subject an easy way to extend and contract their leg with resistance
  - This allows for hamstring isolation
- This design will implement materials like HDPe and Dyneema which are both non-ferrous and will provide sufficient strength for the application
- The pulley system within the cable stack will either be 3D printed or ordered if we can find a MR-compatible option
  - Goal is to find a prefabricated option, but can fabricate if needed
- The slider design will have adjustable stops allowing for adjustment subject to subject

Conclusion: Overall this combination will be the easiest to fabricate. This also aligns well with our clients needs and PDS criteria. Further discussion and prototyping will allow us to iron out this design and make it work for our client.

3/15/2024 - Second iteration of Prototype

MICAH SCHOFF - Mar 15, 2024, 1:15 PM CDT

Title: Slider and Cable Stack Design

Date: 3/15/2024

Content by: Micah Schoff

Goals: Explain how the two design will work together.

Content:

- The slider will provide the subject an easy way to extend and contract their leg with resistance
    - This allows for hamstring isolation
- This design will implement materials like HDPe and Dyneema which are both non-ferrous and will provide sufficient strength for the application
- The pulley system within the cable stack will either be 3D printed or ordered if we can find a MR-compatible option
    - Goal is to find a prefabricated option, but can fabricate if needed

Post MRI dimension collecting:

- The design needs to have a minimal height profile
    - This will be most likely 2-3 in.
- The design will consist of a flat sheet in which a Frictionless slider will move back and fourth.
    - there will be adjustable limits to the range of the device allowing for us to standardize the movements subject to subject
    - There will also be limits to the vertical movement of the slider
- The heel cup will now be more supportive like a foot pedal with heel support
    -
- The device will be mounted via the mounting holes within the MR-table
- The weight stack will be off the end of the table to keep a low profile within the room
    - The weight will be on a stand allowing for the pulleys to be directly in line with the slider
- We will use a synthetic cable to connect the weight stack to the slider
-

Conclusion: Now with the correct dimensions and constraints addressed we will now re disign within solid works

4/5/2024 - Cable Weight Stand / Pulley

MICAH SCHOFF - Apr 05, 2024, 12:03 PM CDT

Title: Cable Stack and Pulley Design

Date: 4/5/2024

Content by: Micah Schoff

Goals: Explain how the two design will work together.

Content:

- The pulley / weight stand will be rectangular base with two vertical supports
- The pulley will connect on a central axel through a frictionless bearing
- The pulley will have two different radiuses
    - one to connect to weight stack
    - one to connect to foot slide
- The stand will be tall enough to reach above the MRI table
    - no adjustment needed as height of table doesn't change
- Materials:
    - HDPE or Wood
    - 3D printed PLA Pulley
    - Ceramic or Glass Bearing
    -

Conclusion: This is a rough idea of the cable stand and pulley. A full redesign will be coming soon, but will follow this idea.

4/5/2024 - Slider Design for Show and Tell

MICAH SCHOFF - Apr 05, 2024, 12:35 PM CDT

Title: Slider Design for Show and Tell

Date: 4/5/2024

Content by: Micah Schoff

Goals: Explain the prototype.

Content:

- Here is the the 3D printed model that we used for show and tell
    - It is made of PLA and assembled via super glue
- After printing this design we learned we needed to add more limiter holes for horizontal range
- This design dimension wise worked really well
    - we realized some of the tolerances might need to be adjusted

Conclusion: The show and tell didn't give us much in terms of feedback on our design, but making a small scale prototype allowed us to see some pivitol flaws in the design that need to be addressed.

MICAH SCHOFF - Apr 05, 2024, 12:35 PM CDT

Download

IMG_9842.HEIC (2.25 MB)

MICAH SCHOFF - Apr 05, 2024, 12:35 PM CDT

Download

IMG_9851.MOV (28.4 MB)

4/17/2024 - Slider Design Fabrication

MICAH SCHOFF - Apr 22, 2024, 10:42 PM CDT

Title: Slider Design fabrication

Date: 4/15/2024

Content by: Micah Schoff

Goals: Explain the fabrication/decision making process

Content:

- Initially we started with scrap materials we found which were HDPE for the slider and acrylic for the base and side walls
    - We ran into some issues using the acrylic so we opted to switch to HDPE for the entire thing.
- We also originally planned to epoxy the plastic however the epoxy was not strong enough for our application, so we switched to nylon screws.
    - The team lab had all the screws we needed as well as the tools for drilling and tapping the holes
- These were the major walls we ran into when fabricating this part of the project

Conclusion: Overall, the fabrication of the slider went well. This was the first part that we started fabricating and after climbing the walls we ran into this is a solid product. Once the rest of the project is built we will move into testing.

4/17/2024 - Final Solidworks Models

MICAH SCHOFF - May 02, 2024, 1:24 PM CDT

Title: Final Solidworks Designs for all parts

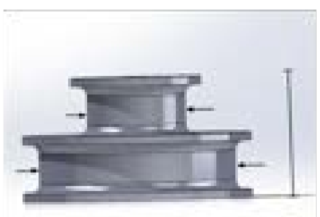
Date: 4/17/2024

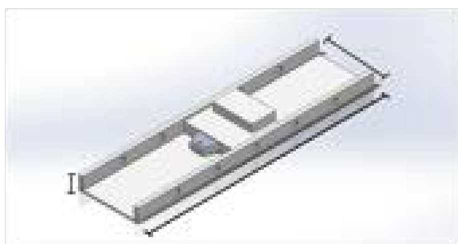
Content by: Micah Schoff

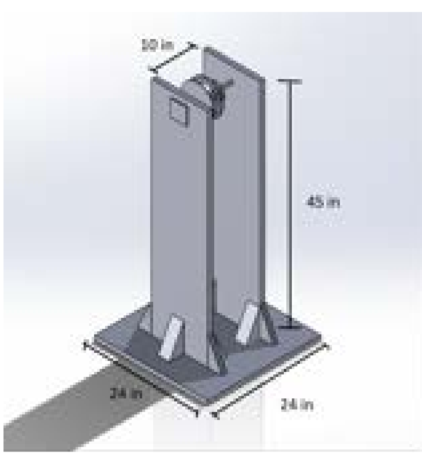
Goals: Show isometric views of all parts of project we developed within solidworks.

Content:

- Here we have models of the slider, weight stack, and custom design amplification pulley.
- For the slider it will consist of two parts the base and the slider itself. The holes on the edges are designed to have some limitation/control of the range of movement.
- The weight stack have 3 different major components the base, and two vertical posts. Between the vertical posts the pulley will lie on a carbon fiber rod allowing the weight to hang between the posts. The carbon fiber rod will be connected to 2 glass ball bearings allowing for frictionless movement of the pulley.
- The pulley itself amplifies the weight. This is because the radius that the subject will be pulling on is 1/2 the size of the weight pulley. This allows us to not hang as much weight saving space and time. It will be 3D printed at a high infill to give it strength.







Conclusion: Overall, these designs are well thought through and will be the easiest option for both our client and for fabrication.

4/17/2024 - Final Design

MICAH SCHOFF - May 02, 2024, 1:36 PM CDT

Title: Final fabricated design

Date: 4/26/2024

Content by: Micah Schoff

Goals: Show isometric views of all parts of project we developed within solidworks.

Content:

- Here is our final design after fabrication.
    - This is the slider, rope (authentic cable), amplification pulley, and weight stand
- After testing we found that the vertical support pieces (triangle supports) we not strong enough in combination with the nylon screws. This made it really easy to shear the screws off.
    - Future work: stronger fasteners like stainless steel screws as well as implementation of L brackets in order to strengthen this even more.

T

Conclusion: Overall, this design address all PDS criteria. We were able to maintain constant tension through eccentric, concentric, & isometric motion. There is some future work like stronger fasteners as well as stronger vertical support pieces. This would allow this project to be fully complete and allow for all research to be conducted using this device.

4/21/2024 MatLab Training

MICAH SCHOFF - Apr 22, 2024, 10:56 PM CDT

Title: MATLAB training

Date: 4/21/2024

Content by: Micah Schoff

Goals: This training will help me to run some statistic on our testing to ensure our project will be working well.

Content: Attached is the certificate of completion of the Matlab training allowing me to learn more about how to run statistics test.

MICAH SCHOFF - Apr 22, 2024, 10:56 PM CDT

Download

MatLab_Training.pdf (354 kB)

2/1/2024 EMG Simultaneous MRI

Caelen Nickel - Feb 01, 2024, 11:24 PM CST

Title: 2/1/2024 EMG Simultaneous MRI

Date: 2/1/2024

Content by: Caelen Nickel

Goals: Gain an understanding of how to incorporate an EMG in an MR room

Search Terms: PubMed MRI AND compatible AND EMG

Citation:

A.-F. van Rootselaar *et al.*, "Simultaneous EMG-functional MRI recordings can directly relate hyperkinetic movements to brain activity," *Hum Brain Mapp*, vol. 29, no. 12, pp. 1430–1441, Dec. 2008, doi: 10.1002/hbm.20477.

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6870914/

Content:

8 patients with familial cortical myoclonic tremor with epilepsy (FCMTE) suffered from involuntary muscular movements as a part of their pathology state. In order to observe and classify these movements and the neuromuscular electrophysiology for their occurrence, researchers observed head MRIs while taking an EMG.

Functional MRI (fMRI) is used for live imaging and is useful in observing brain activity over time similar to an EEG. This variation of MRI is said to be well established in the imaging of both involuntary and voluntary movements. The research article discusses a separate study which used this MRI technique for cyclic wrist flexion and extension between 1 Hz and 4 Hz, which is similar to what the client outlined. Paired with this, the study performed an EMG. While there is little detail on how the MRI and EMG interacted and what materials were necessary for the EMG, the simultaneous measurement and presence of both components worked. The majority of literature outlining the use of EMG and MRI together typically only describes using the EMG as a reference for determining the start and finish of muscle activation.

However, this research article, along with exploring FCMTE, sought to show that EMG data is reliable when taken during an fMRI. Using commercially avalible MR compatible EMG equipment, this study was able to use them together safely and effectively. The use of EMG is such a strong magnetic field produce significant noise, but the use of a 10 Hz high pass filter allowed for better visualization of EMG data. The article describes removing "artifacts" from the MRI to a satisfactory extent. This was based on EMG from the test subjects without MR interference.

Conclusions/action items:

This article details the use of EMG in the presence of MRI magnetic fields in the past and describes that it has been and can be done safely and effectively. However, for more in depth results, commercially avalible MRI compatible EMG equipment can be obtained. This is significant, as the client mentioned the desire for having EMG data in addition to kinematics and dynamics of the biomechanical movements. For the design project, such commercially avalible leads can be purchased and incorporated into the design. From this, additional research is necessary on this equipment to determine its functioning with other components and how to fit it into the overall design. Also, cost is a topic that must be considered with any designs featuring this component, especially in the preliminary design matrix.

Caelen Nickel - Feb 01, 2024, 10:42 PM CST

Simultaneous EMG-Functional MRI Recordings Can Directly Relate Hyperkinetic Movements to Brain Activity

Download

MRI-functional_EMG.pdf (405 kB)

2/24/2024 Non-ferrous metals

Caelen Nickel - Feb 25, 2024, 5:26 PM CST

Title: 2/24/2024 Non-ferrous metals

Date: 2/24/2024

Content by: Caelen Nickel

Goals: Establish metals that can be used in the device

Search Terms: PubMed "non-ferrous" AND "MRI" and "metal"

Citation:

N. C. Bhavaraju, V. Nagaraddi, S. R. Chetlapalli, and I. Osorio, “Electrical and thermal behavior of non-ferrous noble metal electrodes exposed to MRI fields,” *Magn Reson Imaging*, vol. 20, no. 4, pp. 351–357, May 2002, doi: 10.1016/s0730-725x(02)00506-4.

Link: https://pubmed.ncbi.nlm.nih.gov/12165354/

Content:

This research study explores the use of various metals in circuitry used in electrodes. This study is similar to our clients, where they wish to use MRI during brain activation (rather than brain activation to move a limb, they stimulate the brain directly).

In order to safely use electrodes and wires during an MRI, the study did extensive research on materials. The following metals were deemed safe for use in the electrodes and thus MRI compatible:

Titanium, Cobalt-Chromium, Copper, Stainless steel

Conclusions/action items:

This study concluded that the mentioned metals were MRI compatible. Copper being safe to use in the presence of MRI magnetic fields will be helpful in including EMG circuitry in the design. Simply put, however, the mentioned metals are options to fabricate the design with. As the design has been chosen and fabrication is the next step in the design process, these considerations will be made.

2/25/2024 MRI compatible concrete

Caelen Nickel - Feb 26, 2024, 11:12 AM CST

Title: 2/25/2024 MRI compatible concrete

Date: 2/25/2024

Content by: Caelen Nickel

Goals: Determine if concrete is MRI compatible for the fabrication of weights

Search Terms: Google search: "Is concrete MRI compatible"

Citation:

E. Marfisi and C. Burgoyne, “MAGNETIC RESONANCE IMAGING OF CONCRETE WITH FRP REINFORCEMENT,” 2007.

Link: http://www-civ.eng.cam.ac.uk/cjb/papers/cp73.pdf

Content:

In light of finding commercially avalible weights which are fabricated from concrete and rubber/plastic, ensuring that my initial hypothesis that these were MRI compatible is important since there are minimal ways to test this outside of an MR environment. There are no accessible magnets as strong as that in an MRI and this makes the only way of ensuring the weight is MR compatible is to use it in the presence of an MRI. Since the effects of ferrous materials in an MRI are severe and can damage the machine and anyone nearby, this is not a safe and logical route. Therefore, all of the materials to be used in the design must be known that there will be no unsafe affects from the MRI.

In order to accomplish this, I researched the mentioned search terms and found the listed source. This source acknowledges that concrete is generally non ferrous as a material and thus MRI compatible.

However, this source does explain that concrete often contains iron. Iron is a ferrous metal that would be unsafe and unfit for use in or near an MRI. Therefore, it cannot be confirmed that concrete is MRI compatible. Concrete as a material is variable between vendors and batches, and it is likely that some does not contain iron and some contains a lot.

Conclusions/action items:

From this research, a better understanding of what comprises concrete and how it affects our project has been achieved. Since concrete can and often does contain nonzero concentrations of iron, a highly ferrous metal that cannot be near an MRI machine, we can not safely and logically include it in the design. As a result, the design for the weights must pivot from commercially avalible concrete and rubber/plastic weights. This is the case unless the specific contents of the concrete in the weights we purchase and use is identified, or we can otherwise verify the weight is overall not ferrous and will have no adverse effects on imaging. Since this is not likely, fabricating weights ourself appears to now be the logical route.

3/7/2024 Research standards

Caelen Nickel - Mar 07, 2024, 11:45 PM CST

Title: 3/7/2024 Research standards

Date: 3/7/2024

Content by: Caelen Nickel

Goals: Determine what standards devices used in research are subjected to for the use in the preliminary report.

Search Terms:

Citation:

[] "1910.304 - Wiring design and protection. | Occupational Safety and Health Administration," www.osha.gov. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.304

Link: **www.osha.gov. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.304**

Content:

This device must comply with National Safety Standard IEC 61010-031 Ed. 20 b: 2015, which specifies specific safety standards that electrical devices must follow in order to be utilized. Under IEC 61010-031, the device should be able to be utilized without risk of general mechanical hazards and excessive temperature hazards. Certain materials have been observed to heat as a result of interaction with the magnetic and radiofrequency fields from the magnet used in MRI.

Conclusions/action items:

An understanding of how the device is required to perform and what safety measures must be taken in its design and operation is necessary for the development of the device. This content will be added to the preliminary report as well.

1/31/2024 Hamstring activation exercises

Title: 1/31/2024 Hamstring Activation Exercises

Date: 1/31/2024

Content by: Caelen Nickel

Goals: Assemble a set of movements and exercises which effectively isolate the hamstring in order to accurately perform the client's research

Search Terms: PubMed hamstring AND activation AND movement

Citation:

"Impact of exercise selection on hamstring muscle activation", Accessed: Jan. 31, 2024. [Online]. Available: https://core.ac.uk/reader/159507467?utm_source=linkout

Link: https://core.ac.uk/reader/159507467?utm_source=linkout

Content:

Hamstring strain injuries are cited to be the most common in numerous sports and physical activities. This article specifically examines the biceps femoris long head when it references the hamstring muscle s hamstring injuries commonly occur during the late swing phase of the gait cycle in running, and this is because at this point, the biceps femoris long head is at its maximum length and has its maximum interna including this phase/motion in testing would make sense. This article concurs with the client and other research, where past injury of this muscle causes neuromuscular alterations and shows that standard rel

Increased strength in knee flexor muscles other than the biceps femoris have been shown to decrease the risk for hamstring strain injury (HSI). As a result, testing could be done on these muscles to examine

Using surface EMG (sEMG) and MR imaging of the hamstring during different common hamstring-targeting exercises, the ability for each exercise to effectively activate the hamstring, specifically the biceps f

These exercises included bilateral and unilateral stiff-leg deadlift, hip hinge, lunge, unilateral bent and straight knee bridges, leg curl, 45° hip extension, and glute-ham-raises.

In order to be compatible with a head MRI, explosive activities (hip hinge) are not feasible due to full body movement. Many more exercise options for use in the project design are eliminated due to full bodyn

The unilateral stiff-leg deadlift eccentric phase had the largest activation of the hamstring BFlh at 99.3%, which is the notable result from this experiment.

Conclusions/action items:

The background information dictating the experimental design and methods in this research article shows that the biceps femoris long head is the crucial component of the hamstring muscle that must be exa product because inducing motion that replicates this leg position provides the most relevant data to understanding HSI reinjury risk and the electrophysiology behind why this occurs. As a result, a motion whic stiff-leg deadlift achieves a very effective BFlh activation and thus should be the implemented motion. To make this applicable in an MR environment, the motion can be altered to be completed in a prone or s device functioning.

Caelen Nickel - Jan 31, 2024, 8:14 PM CST


Abstract

Download

Hamstring_Activation_Exersices.pdf (29.5 kB)

2/1/2024 Hamstring activation exercises 2

Caelen Nickel - Feb 01, 2024, 4:57 PM CST

Title: 2/1/2024 Neural muscle control post ACL repair

Date: 2/1/2024

Content by: Caelen Nickel

Goals: Assemble a set of movements and exercises which effectively isolate the hamstring in order to accurately perform the client's research

Search Terms: PubMed hamstring AND activation AND movement

Citation:

L. Llurda-Almuzara *et al.*, "Biceps Femoris Activation during Hamstring Strength Exercises: A Systematic Review," *Int J Environ Res Public Health*, vol. 18, no. 16, p. 8733, Aug. 2021, doi: 10.3390/ijerph18168733.

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8393607/

Content:

This resource is an article outlining a study of how different physical exercises activate the hamstring biceps femoris long head (BFlh) and to what extent. This is very similar to the 1/31/24 Hamstring activation exercises entry in the Biology and Physiology folder. The general background information about hamstring injuries and the importance of the biceps femoris long head was consistent.

For this experiment, researches collected various hamstring exercises from literature, looking at over 3000 studies and filtering these to a specific 29 which detail different hamstring exercises. Different from the other previously mentioned hamstring activation research, this study did not testing of its own, but searched databases and evaluated other relevant experiments. Then, all of the data was accumulated, standardized, and compared.

This study concluded that isokinetic and Nordic hamstring exercises induced the greatest BFlh activation. Nordic exercises ankle dorsiflexion caused 128% of the maximum voluntary isometric contraction, and this was the highest value of all exercises evaluated.

Conclusions/action items:

The background information about the biceps femoris long head and its significance was consistent with other research and the client, further establishing that this is the muscle head to focus on. This study cast a wide net into the literature regarding exercise physiology of the hamstring, and processed high volumes of data. While this study did not mechanically perform these exercises, it analyzed research on them and compiled a large, more variable list of exercises which the design could use to induce hamstring activation. As a result of this evaluation, it was determined that Nordic exercises are optimal for hamstring activation. Further research is necessary in order to understand how these exercises are performed and how they can be applied in the clinical MR setting. With this understanding, the exercise can be implemented into the design in order to induce ample hamstring activation.

Caelen Nickel - Feb 01, 2024, 4:09 PM CST

Abstract

Download

Hamstring_Activation_Exersices.pdf (29.5 kB)

2/14/2024 Biceps femoris insertion

Caelen Nickel - Feb 15, 2024, 7:35 PM CST

Title: 2/14/2024 Biceps Femoris Insertion

Date: 2/14/2024

Content by: Caelen Nickel

Goals: Learn where the biceps femoris inserts in order to consider knee angles for hamstring activation and free body diagrams

Search Terms: Physiopedia "Biceps Femoris" and "Attach" or "Insert"

Citation:

“Biceps Femoris,” Physiopedia. Accessed: Feb. 15, 2024. [Online]. Available: https://www.physio-pedia.com/Biceps_Femoris

Link: https://www.physio-pedia.com/Biceps_Femoris

Content:

This article provided a plethora of information on the hamstring as a whole, specifically the long and short head of the biceps femoris. The applicable takeaways that I was pursuing had to do with its insertion point.

The biceps femoris long head joins the biceps femoris short head above the knee. The net direction of these muscles is from the base of the pelvis under the gluteus, distally down the leg and wrapping to the lateral side of the lower thigh. The biceps femoris tendon then passes posterior and lateral to the knee joint and inserts at the top of the fibula. From this description and images, I was able to find the tendon on myself.

This value is dependent on height, but the insertion point for the biceps femoris on the fibula is about 2 inches below the axis of rotation of the knee and slightly posterior to it in the sagittal plane.

Conclusions/action items:

Using this information, better visualization of the functioning of the biceps femoris is possible. I have gained an understanding of how it moves the leg mechanically, and knowing where the tendon is in my leg helps with determining what movements activate the muscle. Also, for moment calculations and free body diagrams, knowing its insertion relative to the axis of rotation in the knee is important. From this, these calculations will be performed and movements will be analyzed for activation of this muscle.

1/31/2024 Neural muscle control post ACL repair

Caelen Nickel - Feb 07, 2024, 8:23 PM CST

Title: 1/31/2024 Neural muscle control post ACL repair

Date: 1/31/2024

Content by: Caelen Nickel

Goals: Learn how a similar procedure as the one our client would like to perform (not a competing design) is done and why it is performed. Also, an understanding of the equipment (overall set-up, devices, and materials) that they use could be helpful to the design brainstorming for the project.

Search Terms: PubMed article referenced by the client during a client meeting

Citation:

C. R. Criss, J. A. Onate, and D. R. Grooms, “Neural activity for hip-knee control in those with anterior cruciate ligament reconstruction: A task-based functional connectivity analysis,” *Neuroscience Letters*, vol. 730, p. 134985, Jun. 2020, doi: 10.1016/j.neulet.2020.134985.

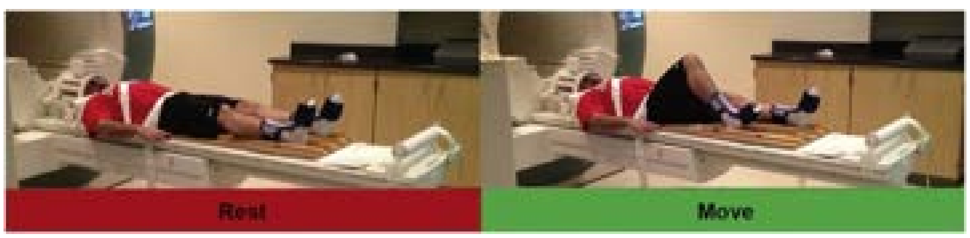
Link: https://www.sciencedirect.com/science/article/abs/pii/S030439402030255X?via%3Dihub

Content:

Muscle, tendon, and ligament injuries, especially full tears, have been shown to have complex rehabilitation timelines and cycles. A past injury of this nature increases the patient's risk of experiencing the same injury, both to the same leg/ligament and the opposite one. In determining why/how this occurs in a more detailed manner, recorded EEG data and brain MRIs shows how neural activation of the legs change following injury. The article discusses ACL injury causing neurophysiological changes in sensorimotor control, which is thought to contribute to reinjury risk due to altered movement patterns.

The article and the experiment which it outlines describes using 15 ACL reconstruction patients who have completed all rehab requirements and 15 matched healthy individuals, the control group. Similar to the client's description of his desired experiment(s), this one incorporates a supine heal slide that allows for the head to be inside the MRI machine, while the legs are moved and loaded outside. In order to control the effects of contraction speed on internal forces experiences by muscles, tendons, and ligaments, a metronome was used with a constant frequency among patients.

For the purpose of this experiment, an EMG was used to track the coactivation of muscles around the knee and in the leg. Our client has outlined this as a possibility, but is more focused on knee flexion angle and loading of the leg. However, if the project has progressed to where an EMG is being developed, this article and its methods has details for ways to address this in an MR room.



This photo from the article shows the overall experimental setup, and while the focus here is to test ACL reconstructions, it is likely that this setup will also work for hamstring activation for hamstring tear testing. The wood track on the table surface forces the heel slide to be perfectly in line with the leg and maintain knee flexion in the sagittal plane. A mechanism secures around the foot to serve as the interface between the body and the device, and this ensures the foot stays in the track during knee flexion and the heel slide. During knee flexion and leg muscle activation, the head is in the MRI machine for imaging.

This research paper cites single planar movement as a limitation of the experiment, which is necessary in order to keep the head still. While multiplanar movement would be beneficial when testing the ACL, for the testing our client wishes to perform, this will not be necessary. The hamstring activation mainly occurs only in the sagittal plane, so a setup similar to that of this experiment would suffice. However, the client desires that our design provide resistance against knee flexion (prompting increased hamstring activation), and this experimental setup does not appear to have this component.

Conclusions/action items:

This research article was highly useful in the client conveying what he and his lab would like to perform. While there are differences between some of the client's requirements and the goals of this experiment, the overall experimental design and equipment setup is similar and can be applied to aid our project design brainstorming. As a result of the client's project description and this visualization, the formulation of design ideas and product design specifications can begin. Therefore, from this research, the team should continue research in the functioning of such setups, other physiological data that would be useful to collect that is specific to the hamstring (rather than the ACL), and create preliminary design ideas from it. Also, the PDS deliverable should be amended with pertinent information regarding requirements specific to this setup should it be the basis of design ideas.

Caelen Nickel - Jan 31, 2024, 7:03 PM CST

Download

Neural_activity_for_hip-knee_control_article.pdf (2.91 MB)

2/13/2024 Constant tension elastic band

Caelen Nickel - Feb 15, 2024, 6:24 PM CST

Title: 2/13/2024 Constant tension elastic band

Date: 2/13/24

Content by: Caelen Nickel

Present: Caelen Nickel

Goals: Determine whether there is a commercially avalible or even theoretical elastic band which can provide constant tension

Content:

In corresponding with Randall Nickel, ProHealth Care physical therapist, Steven Platt, Department of Veterans Affairs Milwaukee Health Care physical therapist, as well as certified athletic trainers Abby Leisemann and Hannah Podbielski, it was determined that there are no known elastic bands capable of providing constant tension.

In the professionals' combined (approximately) 75 years of clinical experience, they have not seen or worked with any such product, and gave very firm answers that there is no such elastic band capable of providing constant tension.

Conclusions/action items:

For design implications, there is almost certainly no commercially available elastic band capable of constant tension. Based on the client requirements, this eliminates bands from their usability in the design and thus other methods, namely free weights, cables, and pullys will be used. However, the lack of such a product does open the door for solutions to this design being marketable if they address the void in current exercise bands.

2/13/2024 Design Ideas

Caelen Nickel - Feb 14, 2024, 6:24 PM CST

Title: 2/13/24 Design Ideas

Date: 2/13/2024

Content by: Caelen Nickel

Goals: Brainstorm design ideas or components that could be incorporated into the design

Content:

See the attachment for the entry

In summary, the attachment brainstorms ideas for preliminary designs and methods of constructing the device. Specifically, the force mechanism used to activate the hamstring was the focus. While it is obvious that cable stacks, free weights, pullys, etc. are a method of applying constant tension which is necessary per the client requirements, I presumed other team members would focus on these mechanisms. Concerned with the weight which these mechanisms and weights would posses to the device, as well as the space that cable stacks and pully could take up especially with non ferrous weights, I decided to pursue an alternative. There are many different methods of activating muscles as seen in the gym, but the defining issue is maintaining constant tension and only activating the hamstring.

I first went to friction as a method of providing constant, changeable tension. The friction force would be equal to the coefficient of kinetic friction (a constant material property) multiplied by the normal force between moving surfaces which can be modulated with weight. This has two flaws, as weight is still necessary to alter the force levels, and friction changes as the surface area between surfaces increases/decreases with sliding.

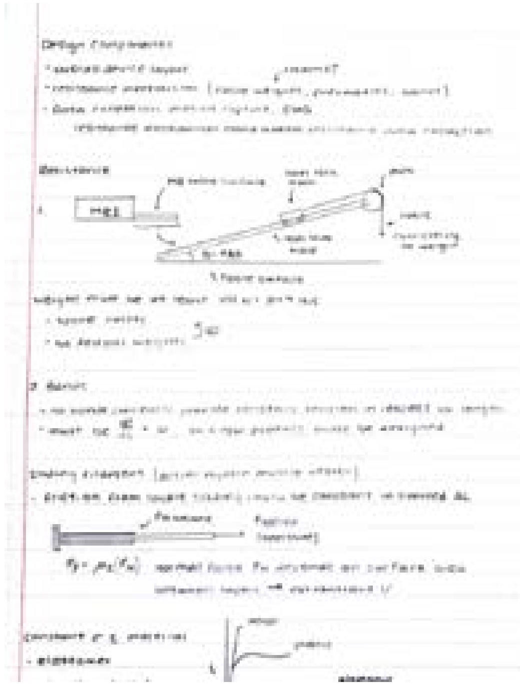
As a result, I looked in to materials which have constant internal forces or stress with changing strain. Since this doesn't to my knowledge exist, I looked for material which had very gentle and linear stress strain curves. I discovered elastomers, a class of chemical materials which fit the above description. More research is to be done into these materials, but the gradual, linear nature of their changing tension would make it feasible to counteract mechanically.

An example of this counteraction would be with a friction design as mentioned. As the sliding mechanism in the heel slide of the design moves, friction decreases gradually and linearly while tension increases gradually and linearly. Pending these calculations can be performed to match these changes, a constant tension mechanism can be achieved without cables/pullys and possibly weights. More work is to be done in this design thinking.

Conclusions/action items:

From this very preliminary design brainstorming, the idea of combined components to cancel out changes in tension without the use of weights is a possibility and can be refined. The ideas as are were mentioned to the design team in a meeting aimed to choose preliminary designs. While this ideas may not be suitable for a semester long design project and have more complex material needs and calculations, they are not heavily reflected in preliminary designs. However, the possibility of incorporating this design should the project continue, or using these ideas for a separate product are attractive.

Caelen Nickel - Feb 14, 2024, 6:25 PM CST



Download

BME_301_design_brainstorm.pdf (802 kB)

2/14/2024 Knee Moment Considerations

Caelen Nickel - Feb 15, 2024, 8:27 PM CST

Title: 2/14/2024 Knee Moment Considerations

Date: 2/14/2024

Content by: Caelen Nickel

Goals: Determine the optimal range of motion and knee angle for hamstring activation.

Content:

See the attachment for the entry

Using knowledge of where the attachment/insertion of the biceps femoris tendon is, I began to draw free body diagrams to determine where the optimal knee angle would be for hamstring activation when I encountered a difficult and interesting distinction:

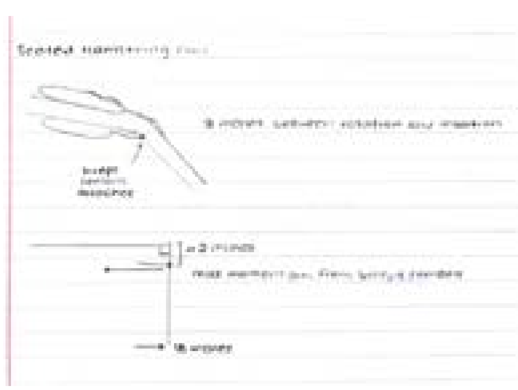
There are two ways of considering this and how the physics and physiology compete. In order to maximize the force required by the biceps femoris during a hamstring curl, the closer the knee angle is to straight (180 degrees or 0 degrees of clinical knee flexion), the more the force from the hamstring has to be in order to generate an equal moment as the weight. However, when the leg is straight and the hamstring is not efficiently able to do work with its force, it is thought that other muscles would activate and be more prominent. In the straight leg example, when the person is trying to flex the knee against resistance, the quads will activate and do more work than the hamstring. Coactivation is not desirable even though more hamstring force would be required to do work. While this is true, the body will use other muscles to do this work that are more optimal for the task.

Meanwhile, while the knee is approximately flexed to 90 degrees it is true based on physics that this requires the lowest force from the hamstring to generate an equal moment. However, in this position the hamstring is most activated compared to other muscles.

Conclusions/action items:

Using strictly a physics based approach is not sufficient for these considerations as optimal knee angle for maximum hamstring force causes other muscles to activate more than the hamstring. More research is required to find this sweet spot to optimize hamstring activation and force generation. From previous research, most hamstring injuries occur during eccentric contraction during the late swing phase of the run gait cycle. This could be a benchmark to aim for and this is where I'll turn my focus.

Caelen Nickel - Feb 15, 2024, 8:15 PM CST



Download

BME_301_hamstring.pdf (386 kB)

2/23/2024 MR compatible weight

Caelen Nickel - Feb 25, 2024, 5:12 PM CST

Title: 2/23/2024 MR compatible weight

Date: 2/23/24

Content by: Caelen Nickel

Goals: Outline a material or commercial product for fabricating/using as the weights.

Content:

There are numerous metals which are technically non ferrous. However, the use of such has been affiliated with interference in MRI. In order to circumnavigate this, avoiding metals entirely would be beneficia

Metals are traditionally used for weights as they are the most dense and can be fabricated into heavy weights that do not take up considerable space. Without using metals, such a property must be replicated in the chosen material. Heavy nonmetals mostly include ceramics and concrete.

Using both a Google search and Amazon store search, commercially avalible weights that are fabricated from concrete with a rubber or plastic covering exist. These weights are mostly in plate form, but can b bought as 10 lb plates, making the device adjustable and with a considerable degree of accuracy towards the 20% to 30% of maximum hamstring load.

Many of these products are cost effective, and links are provided below.

https://www.uline.com/Product/Detail/H-8015/Canopies-and-Tents/Canopy-Weight-Discs-Set-of-4?pricode=WC1251&gadtype=pla&id=H-8015&gad_source=1&gclid=CjwKCAiA_tuuBhAUEiwAvxkgTjduXXsgwkgw5IwZBMIKbvRLnBuYwSiNMnamvPNjAF6Exxfbjn1eWRoCg6wQAvD_BwE

https://www.walmart.com/ip/CAP-Barbell-Standard-Vinyl-Weight-Plate-Set-50-lb-25-lb-x-2/226011783?wmlspartner=wlpa&selectedSellerId=0&adid=22222222227226011783_144010511501_18632966377&wl0=&wl1=g&wl2=c&wl3=651736151482&wl4=pla-1878303098398&wl5=9018948&wl6=&wl7=&wl8=&wl9=pla&wl10=8175035&wl11=online&wl12=226011783&veh=sem&gad_source=1&gclid=Cj0KCQiAoeGuBhCBARIsAGfKY7y4NOMIPsgAWQgQF4TIDH0dWlQAlOo-V8dAGu19f2y22D2t-EF0QaAuKxEALw_wcB

Conclusions/action items:

Avoiding the use of metals can effectively eliminate MRI effects on the device or vice versa. Ceramics and cements are dense and majorily non-ferrous, which upholds safety and size criteria in the product design specifications. Pending further research and testing to ensure these weights are safe for use, the purchase and use of such commercial products would be productive in the fabrication of the device.

2/23/2024 Email: MR compatible weight

Caelen Nickel - Feb 27, 2024, 12:15 PM CST

Title: 2/23/2024 Email: MR compatible weight

Date: 2/23/24

Content by: Caelen Nickel

Goals: Receive confirmation that the desired concrete weight design will be MR compatible

Content:

Below is the email correspondence I sent to Dr. Block of the UW-Madison BME department in order to understand the MR effects on cement:

Hi Dr. Block,

I'm working on a BME academic design project that requires exercise weights to be present within an MR room. I've found some rubber and concrete weights and hypothesize that they are non-ferrous, but I know that cement can contain iron. In your experience, would these weights likely be MR compatible before I purchase them?

Thank you,

Caelen Nickel

Conclusions/action items:

The conclusion as a result of this email is pending the response from Dr. Block and will be updated at that time. This knowledge will be imperative in the purchase and use of weights for the design, however.

Following a response from Dr. Block, new information has been acquired that is important for the project. First, in response to my initial question, Dr. Block has no experience with cement affecting MRIs in any way, since iron concentration is trace and cement is used in the MR room. As a result, the commercial weights that I've been considering are an option again. In addition, Dr. Block offering the ability to use a test magnet to test the design is very helpful towards testing and ensuring the device is safe to use with an MRI. In fact, for something to be used with an MRI, it has to be tested with the magnet. Moving forward, this will be instituted as a testing protocol pending Dr. Block facilitating its use.

Caelen Nickel - Feb 27, 2024, 11:40 AM CST

Dr. Block,

I understand that the composition of cement is variable between vendors, but it sounds like this should not be a concern for out project then!

The opportunity to test out our design with a test magnet would be much appreciated and fast-track our design process. Once we purchase materials and begin fabrication, would I be able to coordinate some testing with you?

Thank you,

Caelen

From: Wally Block <wfblock@wisc.edu>

Sent: Monday, February 26, 2024 3:32 PM

To: Caelen R Nickel <crnickel@wisc.edu>

Subject: Re: MR compatible cement

Hi Caelen,

Interesting, I wasn't aware of iron being in cement. I see it could be about ½ a percent.

That most probably won't be enough iron to create a force that would pull the weights, but we could easily test that with a test magnet. (Before anything goes into the MR room, it must be tested with a test magnet to see if there is a force.)

Cement is used in flooring under MR magnets

Let me know if I could help you with the test,

Wally

From: Caelen R Nickel <crnickel@wisc.edu>

Date: Friday, February 23, 2024 at 11:32 AM

To: Wally Block <wfblock@wisc.edu>

Subject: MR compatible cement

Hi Dr. Block,

I'm working on a BME academic design project that requires exercise weights to be present within an MR room. I've found some rubber and concrete weights and hypothesize that they are non-ferrous, but I know that cement can contain iron. In your experience, would these weights likely be MR compatible before I purchase them?

Thank you,

Caelen Nickel

Caelen Nickel - Feb 27, 2024, 11:17 PM CST

Sure,

We have a very strong hand magnet. I just put it by your object and see if I experience a pull.

Quite simple,

Wally

From: Caelen R Nickel <crnickel@wisc.edu>

Date: Tuesday, February 27, 2024 at 11:35 AM

To: Wally Block <wfblock@wisc.edu>

Subject: RE: MR compatible cement

Dr. Block,

I understand that the composition of cement is variable between vendors, but it sounds like this should not be a concern for out project then!

The opportunity to test out our design with a test magnet would be much appreciated and fast-track our design process. Once we purchase materials and begin fabrication, would I be able to coordinate some testing with you?

Thank you,

Caelen

2024/01/29- Understanding Injuries of the Hamstring Muscle Complex

Ethan Rao - Jan 31, 2024, 8:32 PM CST

Title: Understanding Injuries of the Hamstring Muscle Complex

Date: 01/29/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to better understand the functionality of the hamstring muscle complex in the body and its potential for injuries.

Content:

Search Location/Search Term: UW Library (Hamstring)

Link: https://link-springer-com.ezproxy.library.wisc.edu/article/10.1007/s00167-013-2744-0

Citation: van der Made, A. D., et al. “The Hamstring Muscle Complex.” *Knee Surgery, Sports Traumatology, Arthroscopy*, vol. 23, no. 7, July 2015, pp. 2115–22, https://doi.org/10.1007/s00167-013-2744-0.

Notes:

- Injuries of the hamstring muscle are fairly common in sports like soccer and basketball
  - THOUGHT: Shows how this project is applicable can be applicable to daily life; understanding what goes through someone's brain after a hamstring injury may allow them to return to play earlier
- The most frequently injured muscle in the complex is the biceps femoris and the second most injured is the semimembranosus
- The most vulnerable part is the musculotendinous junction
- Most hamstring strains or tears can be treated conservatively but, in some severe tears, surgery can be required
- In the study that this article covers general lengths of the origins of the muscles in the complex that were studied were listed
  - SM - 1.3 +/- 0.3 cm medial to lateral and 1.1 +/- 0.5 cm anterior to posterior
  - Mean length of the BFlh 15.8 cm
  - Based on the lengths of the tendons origins (also found in the study) they were able to determine that the muscles mentioned above had connections to both tendons
- FOR MY UNDERSTANDING: ST stands for semitendinosus
- Raphe = tendinous inscription; is found on a lot of the ST muscles in the study
- Hamstring injuries at high speed running generally affected the BFlh
  - Injury located at the musculotendinous junction
- Injury sustained during stretching was located at the ST
- The muscle configuration of the hamstring could be the reasoning for these injuries
  - THOUGHT: Could be interesting to see if any research was done on this
- Studying the muscle-tendon-bone complex could be helpful in determining cause of injuries
- The raphe on the ST could also be a cause
- No definite hypothesis was able to be made based on this study

Conclusions/action items:

This article gave me better insight on what causes the hamstring injuries to occur within the muscle. However, in reading this I realized that I have some gaps on the overall anatomy of the hamstring, so it would be a good idea to do a little research into that as well.

Ethan Rao - Jan 31, 2024, 8:26 PM CST


The hamstring muscle complex

Download

s00167-013-2744-0.pdf (2.47 MB)

2024/01/29- Anatomy of the Hamstring

Ethan Rao - Jan 31, 2024, 2:09 PM CST

Title: Anatomy of the Hamstring

Date: 01/29/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to fill the gaps in my knowledge of the anatomy of the hamstring.

Content:

Search Location/Search Term: UW Library (Anatomy of the Hamstring)

Link: https://link-springer-com.ezproxy.library.wisc.edu/chapter/10.1007/978-3-030-31638-9_1

Citation: Timmins, Ryan, et al. "Anatomy of the Hamstrings." *Prevention and Rehabilitation of Hamstring Injuries*, edited by Kristian Thorborg et al., Springer International Publishing, 2020, pp. 1–30, https://doi.org/10.1007/978-3-030-31638-9_1.

Notes:

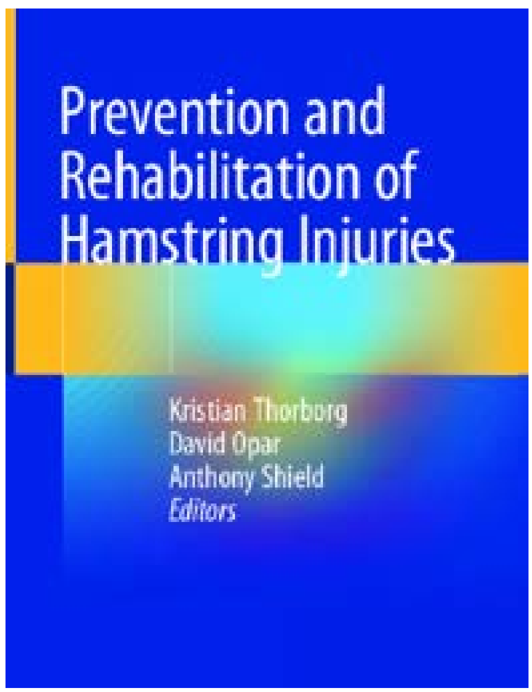
- Introduction
  - The muscles of the hamstring include semimembranosus (SM), semitendinosus (ST), biceps femoris (BF, LH- long head, SH- short head)
  - Long hamstring group- SM, ST, BF long head
    - Involved in hip extension, knee extension, etc.
  - Anatomy is unique to the hamstring which could be why injuries are common
  - There are several theories as to why the injuries are common, but none have been decided on as of yet
- Proximal Insertions
  - SM
    - Origin is separate of the origin of the tendon
    - A common tendon comprised of the SM and the BF long head and ST is an anatomical variant
    - Has an accessory tendon that works to alleviate some of the force from the main tendon
  - ST and BF Long Head
    - The tendons of each form a conjoined tendon
    - Important when looking at the transfer of forces within the tendons
    - Provides another soft tissue anchor
    - These factors work to prevent hamstring rupture
    - THOUGHT: The complexity of this structure may make it difficult to isolate different areas of the muscle if we need to do so with our design
    - Appears to be the large part of the hamstring
  - BF Short Head
    - THOUGHT: May be worth looking into a little more; only thing mentioned was size/measurements of the muscle
- Tendons and MTJ
  - Two components: "free" tendon and MTJ

    - Based on the reading the tendons of the hamstring are fairly intricate in the way that they are arranged
        - THOUGHT: Definitely could play a role in hamstring injury
    - A small or narrow MTJ increases the risk of injury which would make sense, as this could make the tendon a bit weaker
- Size of the Muscle
    - The ACSA, PCSA, Volume and Fasicle Orientation and Length Measures are different components that are looked into when measuring the muscles
- Neural and Vascular Support of the Muscle
    - Tibial division of the sciatic nerve is what supports the muscle neurally
    - Femoral artery supports the bloodflow to the muscle

Conclusions/action items:

Based on this research, I feel I better understand the hamstring and its anatomy. Additionally, it could be useful to understand some of the measurements provided This will allow me to provide better insight as we work on the PDS and begin to think about designs.

Ethan Rao - Jan 31, 2024, 8:28 PM CST



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978-3-030-31638-9.pdf (13 MB)

2024/01/31- Impact of Hamstring Injury on Flexion

Title: Impact of Hamstring Injury on Flexion

Date: 01/31/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to better understand, using a primary source, the impact on flexion that a hamstring injury has. This research will be par

Content:

Search Location/Search Term: Web of Science (Hamstring Injury)

Link: https://pdf.sciencedirectassets.com/273554/1-s2.0-S0141542500X00489/1-s2.0-0141542589901477/main.pdf?X-Amz-Security-Token=IQoJb3JpZ2luX2VjEHIaCXVzLWVhc3QtMSJIMEYCIQDuWmKJRNIHQp3O2IFtQWStucdeZ%2Bg0tbbtFRF11KLeagIhAL54PKm4ekDjtVyKmLxowh

Citation: "Biomechanical Assessment of the Effects of Significant Hamstring Injury: An Isokinetic Study." *Journal of Biomedical Engineering*, vol. 11, no. 3,

Notes:

- Commonly these injuries will occur as a result of poor warmup, fatigue, or low strength in the muscle complex
- Was done on a Cybex Isometric Machine
    - THOUGHT: Assuming that at this point this machine is outdated, but I am curious to see how it was used, because it could provide potential ide
- Adjustable velocity of 300 degrees per second (WAY faster then the team is looking for)
- This study looked more at the extension of the knee, and included looking at quadriceps strength to compare with the hamstring strength
- The speeds that the study looked at were 30, 60 and 90 degrees per second which is more in line with the speed the team will be looking at
- The machine measuring was linked to a computer that showed the joint torques
- All of the subjects in the study were professional athletes and young, which definitely could affect the residual affects of a hamstring injury
- It was very difficult to compare individuals but the groups were able to be compared
- There was no significant difference found between the two in this particular study
- Based on the definitions provided of levels of hamstring injury, the subjects in the study had Level 2 strains
    - THOUGHT: The level of strain definitely can have some impact on the residual impacts of the injury

Conclusions/action items:

This was a good first look into some of the previous studies that have been done in relation to knee flexion for those who have had a hamstring injury and t

Ethan Rao - Jan 31, 2024, 8:31 PM CST


Biomechanical assessment of the effects of significant hamstring injury: an isokinetic study

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1-s2.0-0141542589901477-main.pdf (251 kB)

2024/02/22- Attachment of the Hamstring (For FBD)

Ethan Rao - Feb 22, 2024, 8:56 PM CST

Title: Attachment of the Biceps Femoris (For FBD)

Date: 02/22/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to better understand the attachment of the biceps femoris longheads for the purposes of drawing a FBD that will help inform the team on some of the calculations needed for this project.

Content:

Search Term/Search Location: Caelen did some research on this article and I wanted to get a better understanding as well.

Citation: “Biceps Femoris,” Physiopedia. Accessed: Feb. 15, 2024. [Online]. Available: https://www.physio-pedia.com/Biceps_Femoris

Link: https://www.physio-pedia.com/Biceps_Femoris

Notes:

- Arises proximally from two heads (long head and short head)
    - Found at the back of the leg (hamstring)
- THOUGHT: They both appear to be attached to the back of the knee which will allow for the team to draw an effective FBD
    - Actually attached to fibula
- Gets blood supply from blood vessels branching off from the main arteries of the legs
- Long Head: flexes the knee and extends the hip
- Short Head: flexes the knee; rotates lower leg when the knee is flexed
- The major functions of both of these muscles is stability of the different aspects of the leg
- A major injury to this tendon would be snapping the tendon, however it appears that this is a very rare occurrence so there is not too much known
- When sprinting is a major time when injuries to the hamstring can occur due to overstretching of the muscle
- The article went into some of the techniques that PT's could use to help stretch the hamstring tendon but this won't be as relevant to the project

Conclusions/action items:

Based off of the article, I feel that I will be able to make a better attempt at drawing a FBD of the hamstring as a result of this research. This will allow the team to make more accurate calculations as it relates to the forces within the system.

2024/01/31- Bellofram Pneumatic

Ethan Rao - Jan 31, 2024, 9:44 PM CST

Title: Bellofram Rolling Diaphragm

Date: 01/31/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to understand the bellofram rolling diaphragm. The client mentioned this during the meeting as a potential means by which to control the tension and provided an article.

Content:

Search Location/Search Term: Client Provided Research Article

Link: https://pdf.directindustry.com/pdf/marsh-bellofram/marsh-bellofram-bellofram-rolling-diaphragm-design-manual/11788-27709-_5.html

Citation: *Marsh Bellofram - Bellofram Rolling Diaphragm Design Manual - Marsh Bellofram - Page - PDF Catalogs* | *Technical Documentation* | *Brochure*. https://pdf.directindustry.com/pdf/marsh-bellofram/marsh-bellofram-bellofram-rolling-diaphragm-design-manual/11788-27709-_5.html. Accessed 1 Feb. 2024.

Notes:

- The basic idea is that they are pressure vessels that have a changeable volume and moving sidewalls
- Strength has to be considered when looking at safety factors
- Most of the time this does not have to be a major concern when in use as they are generally made with a large factor of safety, meaning failure is very unlikely
- A lot of the pressure load is supported by the piston head; only a small amount of this is supported by the rolling diaphragm
    - QUESTION: Does this allow it to more effectively function?
- There are applications for this in several industries, which most likely means it is extremely versatile and could be potentially applied to this situation
- Benefits of the design
    - Friction Free
    - No breakaway friction
    - No spring rate
    - High sensitivity
    - Long life
    - Leak Proof
    - Versatile
    - Low hysteresis
- THOUGHT: I'm wondering if the design would just be based on this or actually using one in the design would be useful. This could be a potential question to pose at a meeting if this is something that the client wants to move forward with

Conclusions/action items:

This research has broadened my understanding of this product. I can understand how this was brought up when looking at maintaining a constant tension based on its features but now have questions regarding how it would be applied. It will be important to get these questions answered in a future meeting to determine if this is a feasible part of a design.

Ethan Rao - Jan 31, 2024, 9:46 PM CST

Download

Marsh_Bellofram_-_Bellofram_Rolling_Diaphragm_Design_Manual_-_Marsh_Bellofram_-_Page_-_PDF_Catalogs___Technical_Documentation___Brochure.html (593 kB)

2024/02/01- A Study on the Influence of Hamstring Injury on Muscle Tissue Mechanics

Title: A Study on the Influence of Hamstring Injury on Muscle Tissue Mechanics

Date: 02/01/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to understand a study that may use similar techniques to achieve the goals they were looking for. This could provide ins

Content:

Search Location/Search Term: Scopus (Hamstring AND Loading AND Device)

Link: https://pdf.sciencedirectassets.com/271132/1-s2.0-S0021929010X00124/1-s2.0-S0021929010002460/main.pdf?X-Amz-Security-Token=IQoJb3JpZ2luX2VjEIL%2F%2F%2F%2F%2F%2F%2F%2F%2F%2FwEaCXVzLWVhc3QtMSJGMEQCICpj6svIM61vvk2aMvT3fxIpBEF9ZSrNPv5P\

Citation: "The Influence of Prior Hamstring Injury on Lengthening Muscle Tissue Mechanics." *Journal of Biomechanics*, vol. 43, no. 12, Aug. 2010, pp. 2254

Notes:

- Introduction
  - Muscle is most susceptible to the injury during active lengthening contractions
  - Most injuries of the hamstring are thought to happen when sprinting which involves both these lengthening contractions and large amount s of ir
  - Commonly involve the MTJ of the biceps femoris
  - Following injury of the muscle, fibrous tissue can develop creating a scar
  - This scar tissue could change the deformation patterns of the tissue
    - This scar tissue would be a concern for future injuries
    - QUESTION: Does the amount of scar tissue depend on the injury? And how long on average is this scar tissue present?
- Methods (How this fits into competing designs tab)
  - 11 healthy subjects, 8 who had been injured
  - Conducted post injury modeling using IDEAL
    - THOUGHT: Is this program something that applies to the project? Or is it too complicated or not what the project requires?
  - Tests were carried out with the patients laying on their stomach and flexing the knee against resistance bringing the leg towards the body using t
    - Done by aligning a fixed rotation shaft to the leg and securing the ankle to two leg braces that ran adjacent
    - 30 degrees of motion
    - The resistance was kept low to prevent fatigue
    - Stress and strain calculations were done using Matlab
    - Made 3-D images of the muscle while in usage
- Results
  - There appeared to be the least amount of displacement of tissue around the MTJ and the larger strains
  - Injured subjects showed a lower level of motion in the MTJ due to the scar tissue
  - There was discussion of how this lower level of motion could result in injury to the surrounding muscle

Conclusions/action items:

It was definitely enlightening to see how a different research study looking to induce some similar contractions in the hamstring went about doing it. The stu

Ethan Rao - Feb 01, 2024, 12:22 PM CST


Journal of Biomechanics

Download

1-s2.0-S0021929010002460-main.pdf (878 kB)

2024/02/08 - Emory Design (MR Compatible)

Ethan Rao - Feb 08, 2024, 10:56 AM CST

Title: Emory Design (MR Compatible)

Date: 02/06/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to understand one of the competing designs that was created at the Emory School of Medicine.

Content:

Search Location/Search Term:

Link: https://med.emory.edu/departments/orthopaedics/research/sparc/imaging-research.html

Citation: *Neuroscience Research* | *Emory School of Medicine*. https://med.emory.edu/departments/orthopaedics/research/sparc/imaging-research.html. Accessed 6 Feb. 2024.

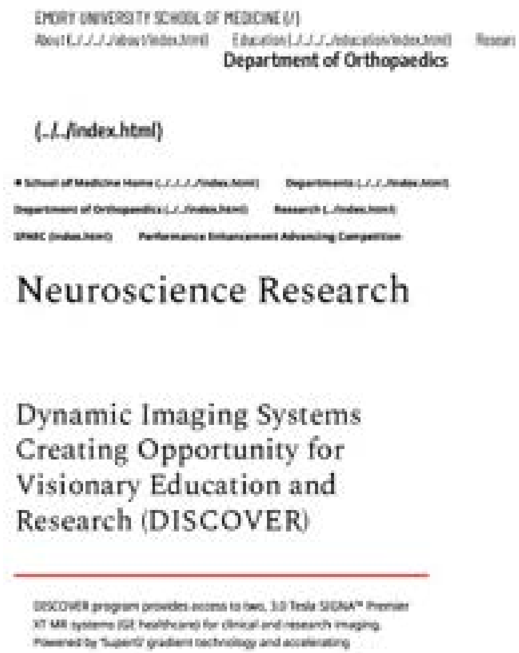
Notes:

- Conducted through the Discover Program at Emory
- Used 3 Tesla SIGNA Premier XT MR Systems (GE Healthcare)
  - THOUGHT: These are probably slightly different from the MAGNUS GE MRI the team will be designing the device for
- Used the IMAGINE Program to integrate 3-D motion analysis of the kinematics while the MRI was working on doing analysis of the brain
  - THOUGHT: The actual technology used to do this seems very impressive but may be out of the scope of this project
  - THOUGHT: Could be better to use a simpler method of determining the kinematic data necessary for the project (May have to research a bit more)
- 12 3-D motion analysis cameras are set up strategically to allow for this motion capture to happen
  - QUESTION: What went into making these cameras MR compatible?
- Have dots attached to the subject that allow the cameras to track movement
- Have designed a device (similar to what the team would be looking to do) that is MR compatible, and allows lower extremity movement during an fMRI scan
- The device appears to be around 45 degrees angled upwards to account for height
- The device is also outside of the MRI machine (as the team's is intended to be
- Appears to have two different sliding components that will allow for sliding of one or both of the heels which would activate the corresponding hamstring
- Wondering how the device is supported or how much support is needed as it is really hard to tell based on the image

Conclusions/action items:

Based on this research, I now have a better understanding of what went into a very similar device. There were some aspects of this project that will most likely be out of scope for the course but it displays a good example for how the device should function/activate the hamstring.

Ethan Rao - Feb 08, 2024, 10:56 AM CST



EMORY UNIVERSITY SCHOOL OF MEDICINE (/)

Department of Orthopaedics

(../../index.html)

Neuroscience Research

Dynamic Imaging Systems Creating Opportunity for Visionary Education and Research (DISCOVER)

DISCOVER program provides access to two, 3.0 Tesla SIGNA™ Premier XT MR systems (GE healthcare) for clinical and research imaging. Powered by 'SuperG' gradient technology and accelerating

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Neuroscience_Research___Emory_School_of_Medicine.pdf (369 kB)

2024/02/08 - Study on Transducer Compatibility to MRI

Ethan Rao - Feb 08, 2024, 11:59 AM CST

Title: Study on Transducer Compatibility to MRI

Date: 02/08/24

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research understand the role of a ultrasound transducer as well as what materials are compatible with an MRI, as an ultrasound transducer to track some data when conducting testing with the device.

Content:

Search Location/Search Term: Scopus (MRI Compatible Materials)

Link: https://pdf.sciencedirectassets.com/274158/1-s2.0-S1120179723X00143/1-s2.0-S112017972301222X/main.pdf?X-Amz-Security-

Citation: "MRI Compatibility Testing of Commercial High Intensity Focused Ultrasound Transducers." *Physica Medica*, vol. 117, Jan. 2024, p. 103194, https://doi.org/10.1016/j.ejmp.2023.103194.

Notes:

- The main issue researchers and clinicians have run into with transducers is the strong magnetic fields that MRI machines will make and the effect they have on the transducers
    - MRI generates strong fields which interfere with any electromagnetic devices
- MR compatibility is looked at by taking images with the transducer in varied activation states
- Metals with magnetic susceptibility but are comparable to human tissue could be used to help solve the problem
    - Copper, alumina powder
- Any conductive components of the transducer must also be covered
- 6 different companies transducers were tested in the study
- Utilized an MRI phantom to do the testing
    - QUESTION: What is an MRI phantom? How does it work? Could this be used to test our device?
    - Article provided previous literature that explains this better
- Metal loaded epoxy served as a material for one of transducers
    - Others were non-metal
- Imaged without the transducer and then with each transducer to determine the quality of the images
    - NOTE: Upon further research, it appears the use of a transducer would allow the researchers to recreate images of the hamstring while in use
- Transducer number 1 was affected pretty heavily by the MRI because of the ferromagnetic material present
- The others were much better but between them there didn't seem to be too much of a difference
- Study indicates the overall importance of using MR compatible materials both with transducers and overall objects in contact with an MR machine as it can become a danger to people as well as affect results

Conclusions/action items:

Based on this research, I was able to learn a little bit more about transducers and what they would be used for in relation to the study we are working with. The transducer will be provided so I don't think it will be too much of an issue the team will have to tackle, but this study still does a good job of stressing the importance of MR compatible material (non-ferrous metals) when creating a device that will be used in the same setting as an MR machine.

2024/02/05 - Magnetic Resonance Safety

Ethan Rao - Feb 05, 2024, 9:13 PM CST

Title: Magnetic Resonance Safety

Date: 02/05/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to better understand the levels of MR safety. This will allow for sufficient information to consider when formulating designs with regard to these standards.

Content:

Search Location/Search Term: Google (General Conditions Needed in an MR Room)

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4848040/

Citation: Sammet, Steffen. “Magnetic Resonance Safety.” *Abdominal Radiology (New York)*, vol. 41, no. 3, Mar. 2016, pp. 444–51, https://doi.org/10.1007/s00261-016-0680-4.

Notes:

- Magnetic Fields in a Magnetic Suite:
  - Static Magnetic Field (0.2 T - 0.3 T)
  - Radiofrequency Fields
  - Magnetic Field Gradients
  - THOUGHT: The device must be unaffected by all of these fields in order for it to be a viable option for this project
- MRI Zones
  - Zone I: All areas freely accessible to the general public where the magnet field poses no hazard
  - Zone II: Patients are under general supervision from the MR staff
  - Zone III: Access restricted by physical barriers such as doors; only approved MR staff and patients that have undergone MR screening are allowed
  - Zone IV: Room where the magnet is located
- The attractive forces generated by the magnet will make metals potentially dangerous projectiles; important that none are in the room
- Larger objects will not necessarily resist the pull of the field
- There are potential thermal concerns based on the radiofrequency fields that are generated by the machine
- Proper preparation is necessary to prevent burns
- NOTE: The rest of the article may not be applicable to the team's device as it goes more into direct things the patient and operators must do to remain safe but would be good to review and understand

Conclusions/action items:

After completing this research, I have a more in depth understanding of the safety procedures and regulations required in an MR facility. This will allow for the team to take these into proper consideration when working on formulating designs and constructing a prototype.

Ethan Rao - Feb 05, 2024, 9:14 PM CST

HHS Public Access

Magnetic Resonance Safety

Download

Magnetic_Resonance_Safety_-_PMC.pdf (1.18 MB)

2024/02/05 - Force Length Relationships in the Hamstring

Ethan Rao - Feb 05, 2024, 10:01 PM CST

Title: Force Length Relationships in the Hamstring

Date: 02/05/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to better understand the ergonomic considerations that the team will have to take into account when beginning to work on the device.

Content:

Search Location/Search Term: Google (Average Force Exerted by the Hamstring)

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9446565/

Citation: Kellis, Eleftherios, and Anthony J. Blazevich. “Hamstrings Force-Length Relationships and Their Implications for Angle-Specific Joint Torques: A Narrative Review.” *BMC Sports Science, Medicine and Rehabilitation*, vol. 14, Sept. 2022, p. 166, https://doi.org/10.1186/s13102-022-00555-6.

Notes:

The article went into relatively great detail on the relationships between angle and the amount of tensile force found within the sarcomere fibers of the hamstring. Each of the major muscles (BFlh, SM, ST, etc.) were studied at different angles. The researchers were able to make many different valuable conclusions based on their research including where maximum torque is acquired (90 degrees of hip flexion and 70 to 80 degrees of knee flexion to 45 degrees of hip flexion and 10 to 30 degrees of knee flexion). Additionally, researchers were able to determine which of the muscles exerted more force on the ultimate result (Bflh and SM). There were also extensive looks into the various moment arms created by the muscles making up the hamstring and torque angle relations.

Conclusions/action items:

This research is valuable in understanding the hamstring but ultimately the values found don't draw a great correlation to the values needed to consider when fabricating the device. This is because a force that the overall hamstring produces on something in a specific position will most likely have to be considered rather than what was discussed in this article. However, it may be worth revisiting if the team determines these conditions have a major effect on the project.

Ethan Rao - Feb 05, 2024, 10:01 PM CST

Download

Hamstrings_force-length_relationships_and_their_implications_for_angle-specific_joint_torques__a_narrative_review_-_PMC.pdf (3.69 MB)

2024/02/06- Max Hamstring Strength (Eccentric)

Ethan Rao - Feb 06, 2024, 4:04 PM CST

Title: Max Hamstring Strength (Eccentric)

Date: 02/06/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this study to understand the limits of hamstring strength and how they will apply to the design that the team will begin formulating within the next few weeks.

Content:

Search Location/Search Term: Google (Maximum Hamstring Strength in Newtons)

Link:
https://www.sciencedirect.com/science/article/abs/pii/S1466853X2030136X#:~:text=Average%20peak%20force%20for%20males,

Citation: Giakoumis, Michael, et al. “Eccentric Hamstring Strength in Elite Track and Field Athletes on the British Athletics World Class Performance Program.” *Physical Therapy in Sport*, vol. 43, May 2020, pp. 217–23, https://doi.org/10.1016/j.ptsp.2020.03.008.

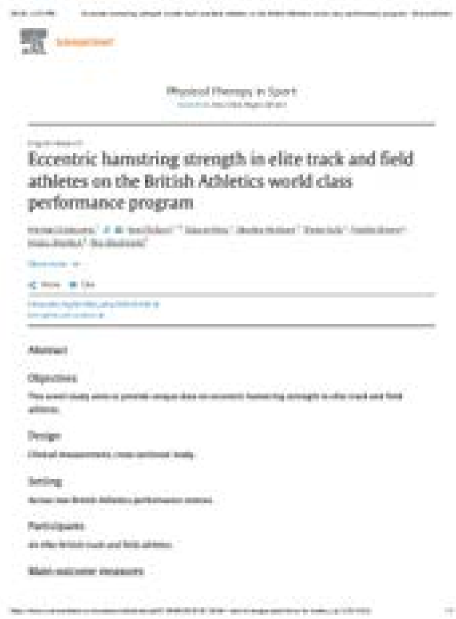
Notes:

- The major goal of the study was to examine eccentric hamstring strength in athletes
  - THOUGHT: The thought would be that hamstring strength would be maximized in a running motion which is what eccentric motions would mimic
  - THOUGHT: Athletes would most likely have a relatively high hamstring strength in relation to the rest of the population
- Evaluations were conducted using a Nordbord device
  - NOTE: Will have to look into what a Nordbord device is and how it specifically functions
  - Has been used before in other studies in order to measure hamstring strength when doing the Nordic Exercise
- Average Peak Forces (Hamstring)
  - Males (418.38 N)
  - Females (318.54 N)
- Right limb was found to be a lot stronger when sprinting... WHY?
- No differences between previously injured and non injured hamstrings were found when observing force and torque
- Data was obtained from 44 athletes (ages 19-33)
- When expressed relative to body weight there was no difference between male and female hamstring strength

Conclusions/action items:

Based on this research, I have gained a better understanding of the maximum force hamstrings will generally be able to exert. Because this study was done in the context of high-level athletes, these numbers most likely will prove a bit high for the average person, but will be useful in taking into account safety with the device.

Ethan Rao - Feb 06, 2024, 4:04 PM CST


Physical Therapy in Sport

Eccentric hamstring strength in elite track and field athletes on the British Athletics world class performance program

Abstract

Objectives

Design

Setting

Participants

Main outcome measures

Download

Eccentric_hamstring_strength_in_elite_track_and_field_athletes_on_the_British_Athletics_world_class_performance_program_-_ScienceDirect.pdf (265 kB)

2024/02/15 - Ferrous Metals in Context of MR

Ethan Rao - Feb 15, 2024, 11:08 AM CST

Title: Ferrous Metals in the Context of MR

Date: 02/15/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to understand some of the reasons why ferrous metals are not able to be used within the context of an MR machine.

Content:

Search Location/Search Term: Google (Reasons why ferrous metals cannot be used in presence of MR)

Link: https://www.ncbi.nlm.nih.gov/books/NBK551669/

Citation: Ghadimi, Maryam, and Amit Sapra. “Magnetic Resonance Imaging Contraindications.” *StatPearls*, StatPearls Publishing, 2024, http://www.ncbi.nlm.nih.gov/books/NBK551669/.

- Three major magnetic fields that pose a safety risk within the context of an MR setting
- Strong Static Magnetic Field
    - Will attract and accelerate toward the center of the machine turning them into dangerous projectiles
    - Can also displace metallic implants in the body
- Radiofrequency Field
    - Can cause tissue heating in the presence of implants; even non-ferrous metals could cause this
    - THOUGHT: I think that in our case, this is not something to be extremely worried about, but it may be something to look into further
- Gradient Field
    - Produce noise within the setting and can cause damage to hearing
    - THOUGHT: In our case, this will not be something that will affect the device
- Different issues of concern
    - Absolute contraindications
        - Cardiac implantable electronic devices
        - Magnetic dental implants
        - Metallic intraocular bodies ????
    - Relative contraindications
        - Artery stents
        - Joint replacement
        - Medication patch
- The article goes into some more detail on restrictions with MRIs but it doesn't really apply to the project. Could be worth looking into more if necessary

Conclusions/action items:

Based on this research, I have a good understanding of the importance of material selection within the context of the project. This has also illuminated the importance of MR compatibility of the device as this could affect other categories within the design matrix as well as the subject's safety when they are helping conduct the study.

Ethan Rao - Feb 15, 2024, 11:12 AM CST

Magnetic Resonance Imaging Contraindications

Download

Magnetic_Resonance_Imaging_Contraindications_-_StatPearls_-_NCBI_Bookshelf.pdf (259 kB)

2024/02/15 - General MR Table Dimensions

Ethan Rao - Feb 15, 2024, 11:39 AM CST

Title: General MR Table Dimensions

Date: 02/15/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to determine the normal dimensions for an MR table in order to determine how important thinking about dimensions and size will be within the design matrix

Content:

Search Location/Term: Google (Normal dimensions for an MR table)

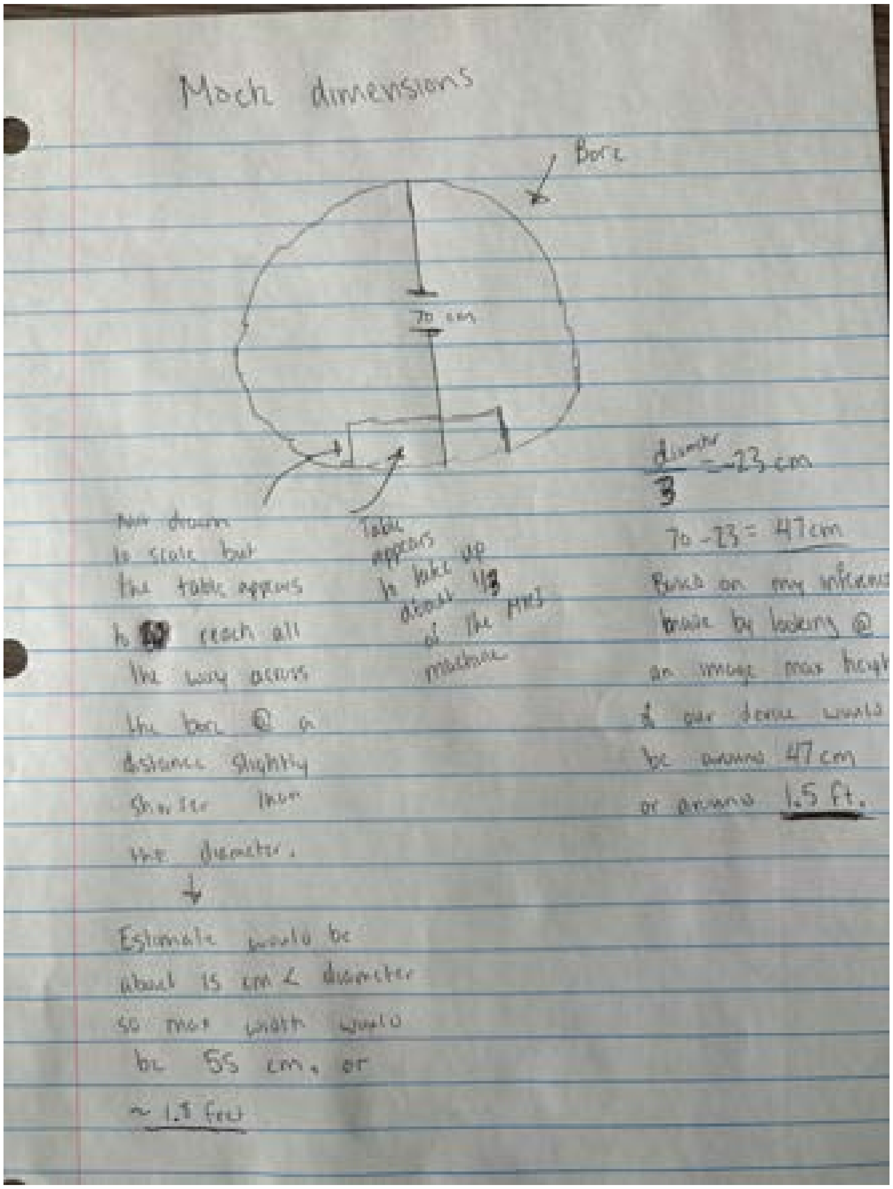
Link:
https://radiology.wisc.edu/research/modalities/mri/equipment/#:~:text=The%20magnet%20bore%20is%2070,transmit%20and%2For%20receive%20coils.

Citation: “Equipment.” *Department of Radiology*, https://radiology.wisc.edu/research/modalities/mri/equipment/. Accessed 15 Feb. 2024.

Notes:

It was very difficult to determine on the page which MRI is the one that the team should specifically be gearing the dimensions towards. Knowing that the machine is a 3 Tesla GE MAGNUS MRI machine, I looked for the one that appears the closest. However, the only dimension offered on the website was the bore diameter being 70 cm. Using this dimension, I tried to infer some other dimensions, but they may not be accurate, meaning that it will be very important to try to get the actual drawing from the client for the machine used.

Mock Calculations:



Conclusions/action items:

This research was helpful in giving me a ballpark estimate of the dimensions we will need to adhere to. I don't think that this should be too much of an issue considering that the only dimension our design will need to adhere to is the width of the MR table as it is not going to be in the bore. Therefore, having roughly 1.8 feet to work with in terms of width would seem to be plenty based on the direction the team is currently thinking of going.

2024/04/23- General Facts on HDPE

Ethan Rao - Apr 23, 2024, 9:40 AM CDT

Title: General Facts on HDPE

Date: 04/23/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to provide some general facts and benefits of using HDPE which will allow the team to more easily validate their choice of material.

Content:

Search Term: High density polyethylene general information (Google)

Link: https://www.acmeplastics.com/what-is-hdpe

Citation: *What Is High Density Polyethylene (HDPE)? | Acme Plastics*. https://www.acmeplastics.com/what-is-hdpe. Accessed 23 Apr. 2024.

- General Information
    - Thermoplastic made from petroleum
    - Very versatile
    - Used in a variety of applications (bottles, cutting boards, piping, etc.)
    - Known for its high tensile strength, high strength to density ratio, impact resistance and melting point
        - THOUGHT: This makes this material a very strong choice for us based on its ability to resist impact and its high tensile strength. It should be able to withstand any load applied to the device
- Benefits
    - Easily meltable and moldable
        - Inherent malleability
        - Remains rigid until high temp.
        - Can easily be molded for use
    - Corrosion Resistance
        - Long lasting and weather resistant
        - Can be easily sterilized by boiling
        - Resistant to many natural strong acids and bases
    - Large Strength to Density Ratio
        - Density: 0.93-0.97 g
    - Easily recyclable

Conclusions/action items:

As a result of this research the team will have an easier time validating/justifying their choice of materials other than that it was MR compatible. This proves that this was a really efficient and effective choice of material for these applications and will allow for a long lasting device.

2024/04/29- Weight Material Research (For Future Work)

Ethan Rao - Apr 29, 2024, 8:27 PM CDT

Title: Weight Material Research

Date: 04/29/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to better understand what options are out there in terms of the weight to be used for the device.

Content:

Link: https://www.kcbj.com/blog/dumbbell-alternatives-around-the-house-29876/#:~:text=A%20great%20alternative%20for%20dumbbells,depending%20upon%20the%20weight%20desired..

Search Term/Location: Google (Alternatives to Using Metal for Weights)

Citation: *Dumbbell Alternatives: Around the House*. https://www.kcbj.com/blog/dumbbell-alternatives-around-the-house-29876/. Accessed 30 Apr. 2024.

Notes:

- THOUGHT: This article mostly details household solutions so they may not be applicable as stated in the article but could present an alternative for smaller weight or, if altered correctly maybe for high weight
- Examples of alternatives for dumbbells are milkjugs, cans, detergent containers; moral of the story here is most anything can be a dumbbell
  - Would need to weigh the object being used so that weight can be recorded
  - Maybe empty a container like this and fill with sand?
- Heavy books in a bookbag are also listed as an option for weight
- Note water, rocks, and concrete as other options to fill containers with in order to perform weighted workouts
  - THOUGHT: I think it basically comes down to what works best in this scenario; there seems to be a plethora of non ferrous options out there that are a little unconventional
- Also mentions elastic bands, however these will not work in the context of our project as we are looking at creating constant tension throughout the entire motion

Conclusions/action items:

As a result of this research, I have determined that the best way to decide on a path forward is to simply meet with the client and discuss potential options. There are many somewhat unconventional methods of weight outside of ferrous metals which means the team will have plenty of options to choose from moving forward.

2024/04/29 - Stainless Steel Screws Research

Ethan Rao - Apr 29, 2024, 9:09 PM CDT

Title: Stainless Steel Screws Research

Date: 04/29/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to assess the viability of utilizing stainless screws in securing the supports so as to allow for a higher maximum weight that the device can handle

Content:

Search Term/Location: Google (Stainless Steel Screws Pros and Cons)

Link: https://wilsongarner.com/stainless-vs-carbon-vs-alloy-steel-fasteners/

Citation: Pinchback, Joseph. "Carbon vs. Alloy vs. Stainless Steel Fasteners: Explained." *Wilson-Garner*, 4 Oct. 2022, https://wilsongarner.com/stainless-vs-carbon-vs-alloy-steel-fasteners/.

Notes:

- Three most common types of fasteners are all types of steel, including stainless steel fasteners
- Things to consider when choosing fastener type is the weight, malleability, ductility, strength, etc (SEE ARTICLE FOR FULL LIST)
    - Could also consider appearance if aesthetics is extremely important to the project
    - THOUGHT: In our case functionality definitely comes first
- Stainless Steel Fasteners
    - Have a max carbon content of 1.2 % and minimum chromium content of 11%
        - Could the chromium content have to do with creating an oxidative layer?
    - Known for shiny appearance and sleek look
    - Most common grades are 304 and 316
        - I would assume 316 is more expensive based on discussions in BME 430, as this what is used commonly medically
    - Offers an aesthetic option
    - Has low strength and hardness comparatively to other metal fasteners
        - THOUGHT: We may be ok as we are not putting these screws under immense loads; they should be able to hold up
        - THOUGHT: This article doesn't take into account the need for non-ferrous materials in our project which is why they favor the stronger ferrous metal screws
- NOTE: The article goes on to go into more detail in relation to other metal fasteners but they are all ferrous and therefore are not relevant to this particular project.

Conclusions/action items:

As a result of this research, I now understand better the implications of stainless steel screws. It may be worth it to do a little research/calculations to determine if they will be strong enough for our application as the article cited relatively low strength and hardness for the material as a reason not to use them in some applications.

2024/05/02- Carbon Fiber Viability Research

Ethan Rao - May 02, 2024, 4:29 PM CDT

Title: Carbon Fiber Viability Research

Date: 05/02/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to reverify that one of our prototype's main material choices is effective for this particular application before the device moves closer to being used in the field.

Content:

Search Location/Search Term: Google (General Facts on Carbon Fiber)

Link: https://www.innovativecomposite.com/what-is-carbon-fiber/#:~:text=It%20is%20a%20very%20strong,manufacturing%20material%20for%20many%20parts.

Citation: g-innovative. “What Is Carbon Fiber?” *Innovative Composite Engineering*, 15 Jan. 2015, https://www.innovativecomposite.com/what-is-carbon-fiber/.

Notes:

- A polymeric material
  - THOUGHT: Means it is non-ferrous and will be viable within an MR environment as long as traces of metal are not used in its formation
- Very strong and lightweight material
- 5 times stronger than steel and twice as stiff
  - Means it will be an ideal component to make up the rod of the device
- It's also much lighter than steel
- Made of thin strong filaments of carbon
- Gets its strength from being twisted together like yarn
- Can be laid over a mold to meet a prospective shape
  - Most likely how the carbon fiber rod we are using in our device was made
- High in chemical resistance and low in thermal expansion
  - Means it will not be affected by most conditions
- History
  - Dates back to 1879
  - 1958 is when high performance carbon fiber began to be used
  - Inefficient at first but have been modified to have better properties

Conclusions/action items:

Based on this research, I have been able to verify that this material choice was actually very good for the application we chose it for and will be ideal within an MR environment as it contains no ferrous materials.

2024/05/02- PLA Verification Research

Ethan Rao - May 02, 2024, 4:45 PM CDT

Title: PLA Verification Research

Date: 05/02/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to assess the material we chose for 3D printing to ensure that it is appropriate before the device moves into the field

Content:

Search Location/Search Term: Google (PLA material general facts)

Link: https://lawprintpack.co.uk/packaging/8-things-you-need-to-know-about-pla-plastic/

Citation: McCauley, Kate. "8 Things You Need To Know About PLA Plastic." *Law Print & Packaging Management*, 10 Oct. 2017, https://lawprintpack.co.uk/packaging/8-things-you-need-to-know-about-pla-plastic/.

Notes:

- PLA stands for Poly-Lactic Acid
- Designed to replace petroleum based plastics like PET
  PLA is a constantly renewable resource as it is processed from natural resources rather than oil
- Great ecological benefits in using this over other 3D printed material
- To produce the PLA you need to grow a lot of corn so there appears to be some ethical issues as this could be used a food rather than a 3D printable plastic

Conclusions/action items:

This research was more focused on the ecological benefits of PLA. Therefore, based on this research I was unable to affirm our material choice. However, based on our preliminary research this material was an excellent choice for its usage in the design.

2024/02/23- Standard for Marking Devices in the MR Environment

Ethan Rao - Feb 23, 2024, 11:50 AM CST

Title: Standard for Marking Devices Used Within the Medical Device Setting

Date: 02/23/24

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to understand some of the standards used within the PDS a little bit better so I am better able to present this section during the Preliminary Presentation

Content:

Search Term/Search Location: Nikhil did research on this standard

Citation: *Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment*. https://www.astm.org/f2503-20.html. Accessed 23 Feb. 2024.

Link: https://www.astm.org/f2503-20.html

Notes:

- This standard came into practice due to the dangerous nature of the magnetic fields when ferrous metals are present in the MR room
- List of Hazards
  - Mechanical Causes
    - Magnetically displaced force
  - Electromagnetic
    - Induction
  - Acoustic Causes (sound)
  - Malfunction of items within the body
- The standard goes on to list some of the practices to be used when labeling the device
  - This brings into focus the potential importance of the labeling that was discussed in class this week
  - THOUGHT: May need to determine at the end of the project how to get proper labeling on the machine in the context of both utilizing the device as well as for MR safety

Conclusions/action items:

As a result of looking into this standard a little bit, I feel that I will be able to better explain the standards and specifications that may be important criteria to discuss when discussing PDS requirements in the Preliminary Presentation, as well as understand better how to incorporate this into the design.

2024/04/23- Information on OSHA Standards for Lifting

Ethan Rao - Apr 23, 2024, 9:51 AM CDT

Title: Information on OSHA Standards for Lifting

Date: 04/23/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this research is to look into what OSHA would require in relation to the weight of our device, as this could be a potential safety hazard if it is too heavy.

Content:

Search Term: OSHA Standards for Lifting

Link: https://www.osha.gov/laws-regs/standardinterpretations/2013-06-04-0#:~:text=The%20lifting%20equation%20establishes%20a,easy%20it%20is%20to%20hold

Citation: https://www.osha.gov/laws-regs/standardinterpretations/2013-06-04-0#:~:text=The%20lifting%20equation%20establishes%20a,easy%20it%20is%20to%20hold (NOT SURE HOW TO CITE; WAS AN INQUIRY ABOUT LIFTING WEIGHTS IN WORKPLACE BY AN INDIVIDUAL)

- OSHA does not have a direct standard based on the amount of weight that someone can lift while on the job
- There is a mathematical model that NIOSH used in order to determine if the amount being lifted based on the situation is appropriate/safe
- Some other factors they look into with this model are
  - How often object is being lifted
  - How high it is being lifted
  - If the object must be held away from the body while lifting
  - Where origin of lift occurs
- The model starts with the limit of 51 pounds but this changes based on the mentioned factors among others based on the situation
- THOUGHT: Based on the situation, the device would have a different max limit. I would say it is safe to try to keep it around/lower than 50 pounds. This will allow for relatively easy movement by 1-2 people.

Conclusions/action items:

As a result of this research, I better understand the parameters in terms of weight that the team will be constrained by. This will be important to consider as we finalize the finished product.

2024/02/12 - Individual Design 1: Bicycle Pedal Design

Ethan Rao - Feb 15, 2024, 10:34 AM CST

Title: Individual Design 1: Bicycle Pedal Design

Date: 02/12/2024

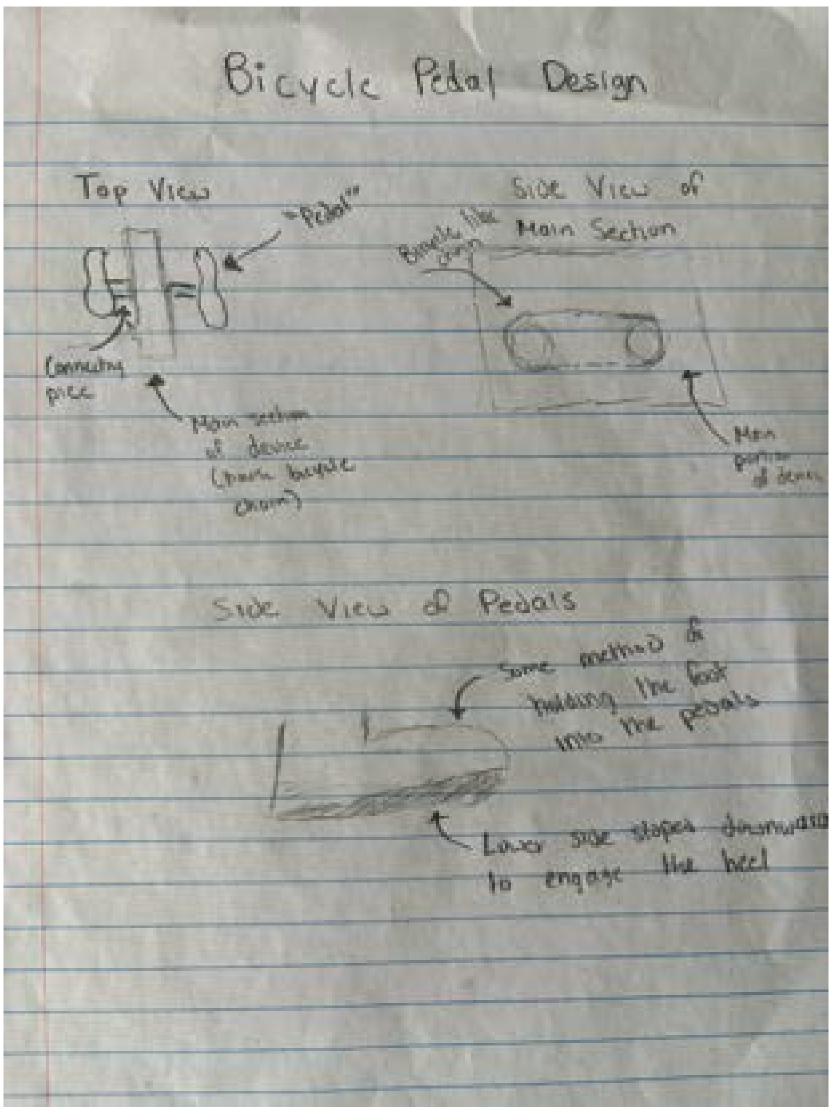
Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to include an image of an individual design as well as explain how it would be expected to function should the team choose to use it going forward.

Content:

Image of Design:



Explanation of Function: The main thing that represents and advantage of this design is the quick transfer from a concentric to eccentric movement for the hamstring. As the pedal is pushed outward and reaches maximum extension there would be an immediate shift to a puling motion to pull the pedal back towards the body. The main issue in function is the limited range of extension and contraction that was noticed following the drawing of the diagram included.

Therefore, this design is most likely not going to be functional in the case of this project, but is a creative way of activating the hamstrings.

Conclusions/action items:

This design offers a lot of potential in a lot of the criteria that the team was looking into. However, it may be relatively difficult to fabricate due to the addition of a bicycle chain like device that would have to provide that tension in the case of this design. There is also the question of materials as traditionally, bicycle chains are made up of ferrous metals so there would have to be research into other materials that would be viable

2024/02/12- Individual Design 2 (Heel Slide Design)

Ethan Rao - Feb 15, 2024, 10:35 AM CST

Title: Individual Design 2 (Heel Slide Design)

Date: 02/12/2024

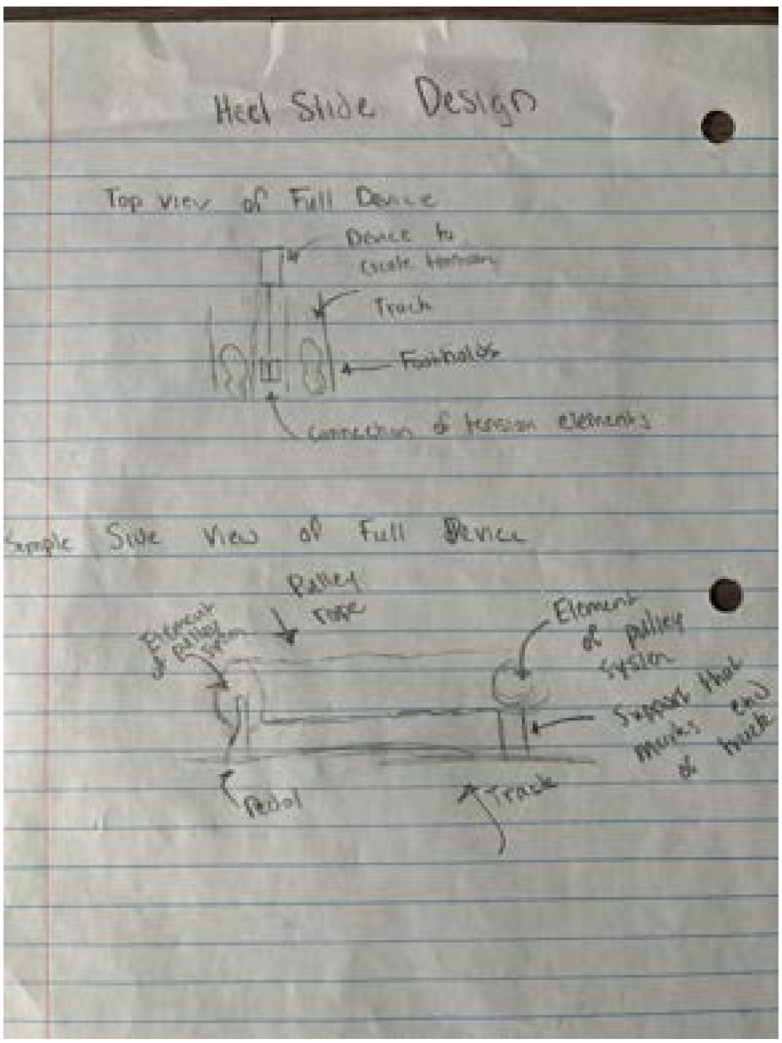
Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to present an image of one of the individual designs that sort of combined what we had seen from different hamstring loading devices that have been used in previous studies.

Content:

Image of Design:



Description of Function: This design combines elements that the team had seen in previous hamstring loading devices to make one that may be able to allow for constant tension. The device in the middle is a method by which the tension in the pulley system is transferred to the pedals. The pedals would then be pushed allowing for extension. Then, the pedals would be designed to allow for a pulling motion to bring them back to original position.

Conclusions/action items:

This design is somewhat similar to what the team had previously seen in a combination of hamstring loading devices researched. By combining seperate elements, the team may be able to optimize the design in order to allow for eccentric, isometric and concentric contractions of the hamstring as well as an effective method of measuring to be determine in later design considerations.

2024/02/15 - Thoughts on Brainstorm

Ethan Rao - Feb 15, 2024, 10:49 AM CST

Title: Thoughts on Brainstorm

Date: 02/15/2024

Content by: Everyone

Present: Everyone

Goals: The goal of this entry is just to display some of my thoughts on the designs presented in the brainstorm and what kind of criteria would best fit these designs.

Content:

Designs Thoughts: Overall, I think that everyone came up with some very good ideas. Some were combinations or already existing designs that would optimize usage in the case of this project, some were completely novel. Overall, the design that seemed to achieve what the client was looking for the best in my opinion was Nikhil's design. It seemed relatively easy to fabricate, allowing the team to complete it in a semester. It also offered a reliable and relatively simple way of conducting calculations to determine some of the specific forces acting within the design. The other designs all had pros to offer as well, but they were more complicated in terms of really making sure the team was able to calculate what was going on. Therefore, I think that the design mentioned previously should be the design we move forward with.

Criteria Thoughts: The team discussed a lot of different criteria when looking into what was going to go into the design matrix. Two of the criteria that I think are going to have to be included are Safety and Cost. These inherently must be a part of the design matrix. But, I think that some of the higher weighted criteria could be discussed. In my opinion MR-compatibility as well as efficacy are probably the two highest weighted in that they are going to be what impacts the design's success the most. I would say safety and cost are extremely important in every situation, but in the case of this project, there won't be safety concerns as long as the device is MR-compatible and there shouldn't be cost concerns.

Conclusions/action items:

Based on the brainstorm, as well as sharing some thoughts about it, I have definitely come to the conclusion that Nikhil's One-Post design is the one that I would vote to move forward with. Additionally, it has allowed me to think about some of the criteria for the design matrix. There will definitely need to be some additional research done to effectively rank the criteria as well.

2024/02/23- Attempt at FBD for Hamstring

Ethan Rao - Feb 23, 2024, 12:47 PM CST

Title: Attempt at FBD of the Hamstring

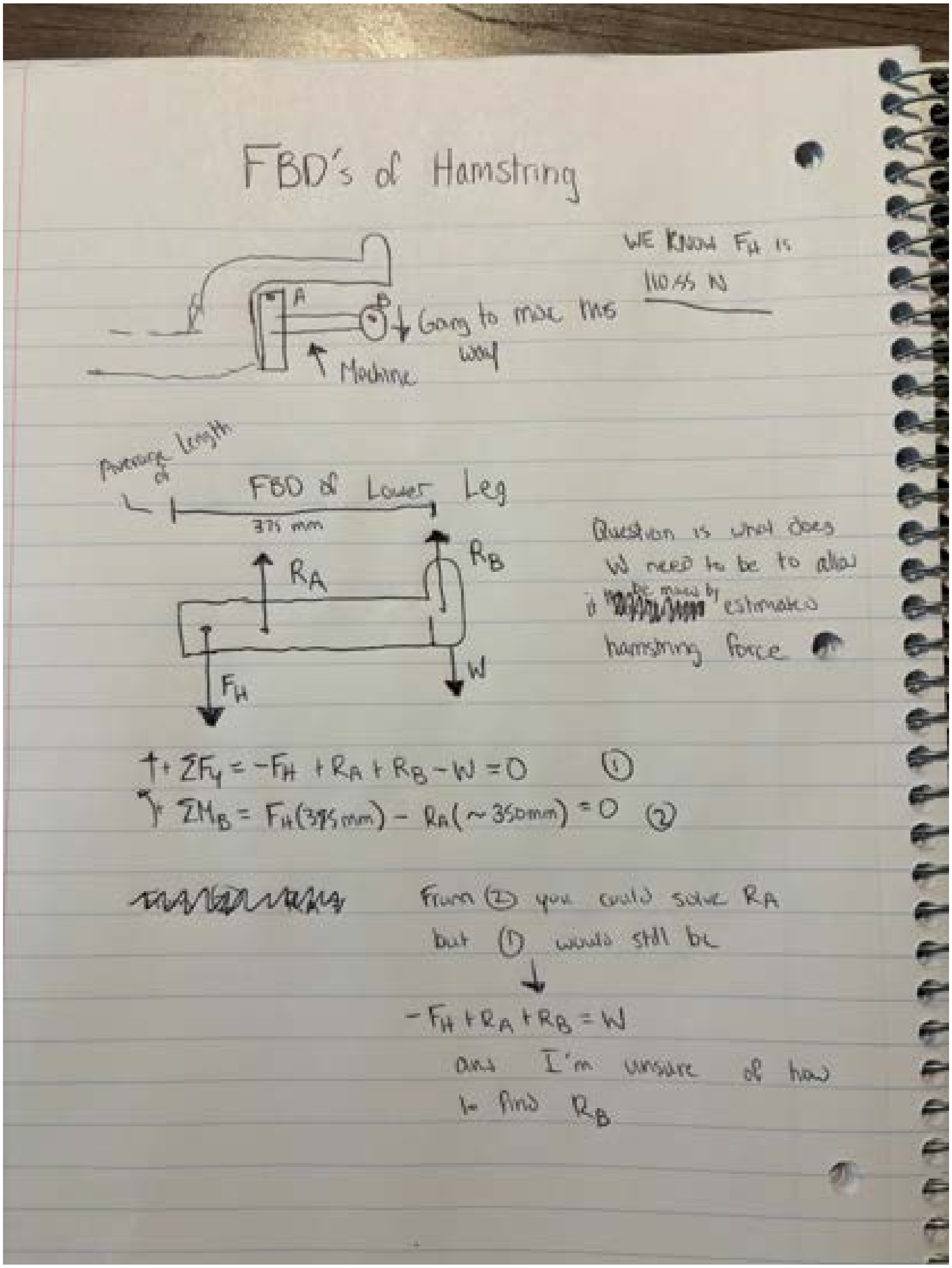
Date: 02/23/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry was to make an attempt at creating an FBD for the system the team is looking to fabricate.

Content:



Conclusions/action items:

Based on this FBD, I feel there may be some calculations the team is going to have to work together to determine. However, the idea will allow for the team to choose an effective weight for the design that was chosen.

2024/03/18- Thoughts on Materials Chosen

Ethan Rao - Mar 18, 2024, 10:07 PM CDT

Title: Thoughts on Materials Chosen

Date: 03/18/2024

Content by: Ethan Rao (Thoughts), Micah Schoff (Chart)

Present: Ethan Rao

Goals: The goal of this entry is to evaluate the materials that Micah worked on putting together for the Preliminary Report. In this way, we will be able to double check that all of the materials will be suitable for what we are looking for

Content:

Materials Chart (Preliminary Report) - Micah

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link
Heel Slider										
HDPE	Plastic Sheet: 0.5 in Thick, 12 in W x 48 in L, Black, Opaque, 4,600 psi Tensile Strength	Zoro	1ZAX7	Grainger	1ZAX7	N/A	2	$49.38	$98.76	Grainger
Epoxy	J-B WELD Epoxy Adhesive: KwikWeld, Ambient Cured, 10 fl oz, Tube, Dark Gray, Paste	J-B WELD	8271	Grainger	14G802	N/A	1	$23.17	$23.17	Grainger
PLA	PLA is a 3D printable material measured in grams	N/A	N/A	Makerspace	N/A	N/A	50	$0.08	$4.00	Makerspace
Felt	Wool felt strip with acrylic adheseive	Zoro	2FGZ7	Grainger	2FGZ7	N/A	1	$0.14	$0.14	Grainger
HDPE Rod	Plastic Rod: 8 ft Plastic Lg, Off-White, Opaque, 4,500 psi Tensile Strength, 2.75 ft-lb/in	Grainger	22JL41	Grainger	22JL41	N/A	1	$19.00	$19.00	Grainger
Synthetic Winch Line	Synthetic line with tensile stregth of 10,000 lbs. Used for cable. 50 ft	Ucreative	Mfr	Amazon	Mfr	N/A	1	$19.99	$19.99	Amazon
								TOTAL:	**$165.06**	

Thoughts:

- I think HDPE will be a really good choice as I know that it is non ferrous and it should be relatively cheap in terms of acquiring a good amount of it
- The only thing that I know we have discussed may not work is utilizing epoxy as it may not hold it together under the amount of force we are looking at
  - We're going to have to find an alternative; likely non-ferrous fasteners
  - There appear to be several different options in terms of finding some sort of answer here (Search Term: Non ferrous Screws)
- The felt used in conjunction with the HDPE will hopefully allow us to get close to frictionless
  - I personally am not sure that this will but we'll have to find out during testing
- Again I think the synthetic wire will be a good choice as it will not disrupt the magnetic field that the machine generates
  - Interestingly, it sounds like using a wire that does have some ferrous material may be viable?
- We're going to have to formulate a list of materials for the pulley design that I am working on
  - I am thinking wood for the base, or we could use more HDPE
  - Likely will need a 2x2 base for the wood
  - Will utilize two roughly 4 ft long piece of wood for the connections
  - Likely will 3D print the pulley and the rod it will be attached to

Conclusions/action items:

Based on this entry, I think there still is some work to be done in terms of materials that will need to get done this week. Essentially the goals for the week will remain working on materials as well as the design portion of the project. That way the team will be able to order materials before Spring Break as well as finalize the designs.

2024/04/09 - Calculations for Rod Diameter

Ethan Rao - Apr 09, 2024, 6:12 PM CDT

Title: Calculations for Rod Diameter

Date: 04/09/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this work is to compute the diameter necessary for the rod in order to prevent failures due to bending.

Content:

IMAGE OF WORK DONE ATTACHED BELOW

Conclusions/action items:

As a result of this work, the team was able to come up with an effective final materials list that will be presented to the client later this week.

Ethan Rao - Apr 09, 2024, 6:13 PM CDT

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IMG_2932.HEIC (3.16 MB)

2024/04/23- Safety Concern Addressed

Ethan Rao - Apr 23, 2024, 9:24 AM CDT

Title: Safety Concern Addressed

Date: 04/23/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to detail my work on making sure there are no safety concerns with the triangle supports that we will be incorporating into the final design.

Content:

Essentially, once the triangle supports were cut out of the block, everything seemed good. However, upon closer inspected the edges of the triangle were pretty sharp and could have resulted in injury. In order to remedy this situation, I worked through and sanded the edges to blunt them and ensure the safety of users of the device.

Image of Sanded Edge:

Conclusions/action items:

As a result of this action, we have avoided a potential safety hazard. This is extremely important when working on a design project, as the safety of the users is of paramount importance.

2024/04/29- Individual Evaluation of Future Work

Ethan Rao - Apr 29, 2024, 8:08 PM CDT

Title: Individual Evaluation of Future Work

Date: 04/29/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to evaluate the final prototype, and make some individual notes on what I consider to be necessary future improvements.

Content:

Fabrication:

- There certainly is a need to improve the supports for the sideposts somehow
  - Potentially need to research better materials for screws
  - Find other ways of connection for the side posts
  - Explore something that was suggested by others during fabrication like an A frame (Micah) or L brackets (Nikhil)
- It would be beneficial to conduct additional testing, to make sure that each portion of the device meets design criteria
  - Determining actual max tensile force for the rod/pulley part of the system through testing
    - MTS Testing?
  - Testing within the context of the actual study (MR environment)
    - Would allow us to see if the device causes too much head movement/strain (these factors will influence the images seen in fMRI)
- Work with Dr. Crawford to determine what will be used as weight for the device
- Clean up some of the rough edges of the prototype (the prototype should ultimately look nice)

Conclusions/action items:

While the team does not have a ton left to do with the project, there are certainly a few things to clean up going forward. By completing these objectives, the team will have completed a successful prototype to be used with this research project and potentially beyond.

2024/04/30- Different Screw Configurations

Ethan Rao - Apr 30, 2024, 10:53 AM CDT

Title: Different Screw Configurations

Date: 04/30/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to assess a few different configurations that I came up with in terms of how to position screws to best support the shear forces applied to this section of the design.

Content:

Evaluations

4 Corners Design: This design looks to be the most ineffective to me. The screws are placed at unoptimal locations and most likely will allow for easier failure rates at one or multiple screws. Therefore, this may not improve too much on the current design.

Middle of Each Side Design: This design I could see as being slightly better than the 4 corners design. This is due to the screws being placed in a more optimal location to support the stress that may come from different directions.

3X3 Configuration Design: Overall, I would think that this design would yield the best results in terms of strength. However, due to the amount of screws it represents the most amount of work in terms of threading and tapping. Additionally, it represents the highest cost as we will need a large amount of screws in order to make this design work.

Conclusions/action items:

As a result of this entry, I was able to determine what may be some effective configurations for stainless steel screws should the team decide to go that route for this design.

Ethan Rao - Apr 30, 2024, 10:53 AM CDT

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IMG_2987.HEIC (2.77 MB)

2024/04/30- Potential Different Support Designs

Ethan Rao - Apr 30, 2024, 11:04 AM CDT

Title: Potential Different Support Designs

Date: 04/30/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is to assess some alternative support designs than the one that the team decided to move forward with at first.

Content:

Larger Triangular Supports: Larger triangular supports were the most obvious thing that came to mind. As they would reach farther up the design as well as most likely present a thicker support, they have the potential to work. However, this would require a pretty expensive purchase in order to meet the material requirements which pretty much rules this one out for me

A Frame (Micah Suggested): Micah suggested something like an A frame in order to support the design. I would be curious to find out more how we would be able to implement something like this in the design.

Supports All the Way Up the Side Posts: This would be represented by rectangular pieces being screwed in along the entire length of each side post connecting the two. Again it represents probably a lot of fabrication time and a lot of material cost. Therefore, this may not be a good option either and will impede the weight's motion in the prototype.

Conclusions/action items:

Based on the ideas I discussed, I was unable to find a much better way to support the design than the way in which it is supported now. It may be useful to find better ways to connect these supports to provide more stability.

2024/05/02- Final Thoughts on the Project

Ethan Rao - May 02, 2024, 5:01 PM CDT

Title: Final Thoughts on the Project

Date: 05/02/2024

Content by: Ethan Rao

Present: Ethan Rao

Goals: The goal of this entry is just to convey some final thoughts on the project

Content:

Overall: I think overall, the team did a really good job in designing this device. Most everything should be functional for multiple years besides the supports which the team will continue to work on going forward to ensure the design is effective when finally presented to the client.

Fabrication: Fabrication was pretty tough for this project overall as it had to be MR compatible. It also resulted in a reasonably expensive prototype. However, the quality of design and the ability of the device to meet the criteria put forth made some of these fabrication and material choice challenges well worth it.

Design: I think the design process flowed really well for the team overall. We were able to come up with some crazy ideas to solve the problem, and ultimately were able to move forward with a design that works really well for this application. Hopefully, we will be able to carry this strong design process into senior design projects.

Conclusions/action items:

As a result of this entry, I have been able to put a few final thoughts in terms of the project as the semester comes to a close. It will be important to get this project to completion in the coming weeks so that Dr. Crawford is able to utilize this device in his research going forward.

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

Caelen Nickel - Jan 31, 2024, 2:31 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: