Tri-Axial Hinge Knee Brace

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Overview

- Problem Statement
- Design Constraints
- Motivation
- Background
- Current Device
- Prototype
- Preliminary Testing
- Preliminary Results
- Timeline
- Expenditures

Client Description

- Dr. Sarah Kuehl
  - Project Engineer at Mueller Sports Medicine

Figure 1: Mueller Sports Medicine logo.

Problem Statement

- Tri-Axial Hinge Knee Brace
  - Mimics proper knee flexion
  - Provides desirable amount of knee stabilization
- Current Issues
  - Straight profile does not match patient profile well - causing some discomfort
- Goal
  - Redesign the straight profile to better contour to as many patients with the fewest models

Design Constraints

- Lightweight: Aluminum
- Durable: >1 year
- Restrict Motion
  - Lateral Direction
  - Hyperextension
- Allow for proper range and motion of flexion
  - Tri-Axial Hinge
  - 180°
- Conform to as many patient's legs as possible
  - One-size fits all
- Comfort
- Low cost: < $100

Motivation

- $852 million is spent yearly on knee braces
- The market for knee braces is expected to grow by 4.9% by 2018
- Mueller receives 20+ complaints per month regarding discomfort of current model

Figure 2: Jordy Nelson just after suffering a knee injury

Background

Current Knee Brace

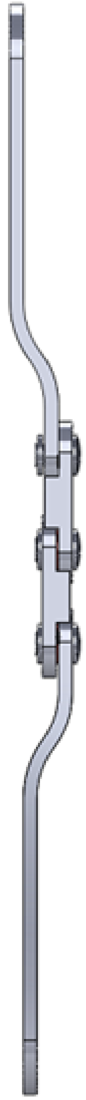
Figure 3 (Left): Current knee brace with tri-axial hinge **Figure 4 (Above):** Close, exposed view of tri-axial hinge

- Fully Enclosed Sleeve
- Velcro Straps for fit
- Straight Arm Profile

Tri-Axial Hinge Motion

Figures 5-8: The Tri-Axial Hinge is capable of 180° of motion.

Current Design



Figures 9 & 10: The current design that Mueller Sports Medicine uses in their knee braces.

Average Leg Dimensions

Knee to Mid-Thigh Angle = 20°

Knee to Mid-Calf Angle = 8°

Figure 11: Image showing where leg measurements were taken.

- Upper Leg Length = 47.73 cm
- Mid-Thigh Circumference = 51.62 cm
- ¼ Thigh Circumference = 41.68 cm
- Knee Circumference = 37.49 cm
- ¼ Calf Circumference = 35.91 cm
- Mid-Calf Circumference = 36.40 cm
- Lower Leg Length = 45.32 cm

Prototype

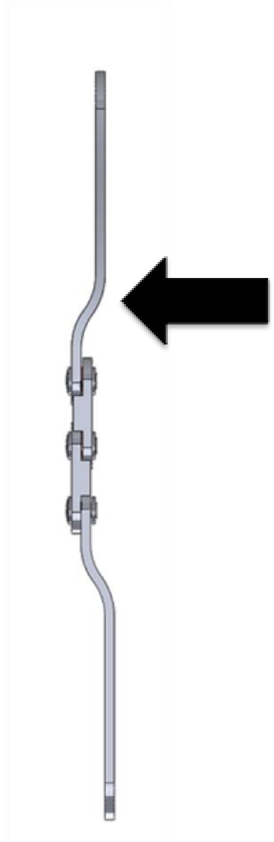


Figure 12: The flat profile of the original design by Mueller

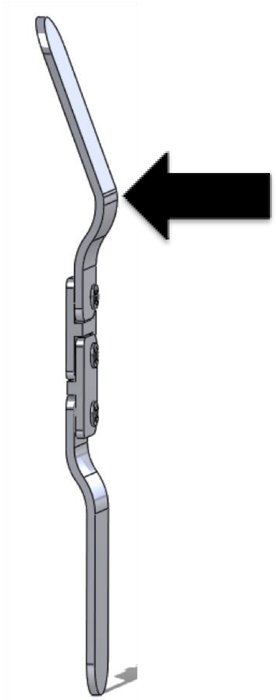


Figure 13: The original prototype which includes an angled arm structure to better conform to the leg

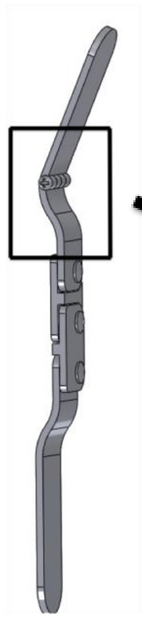


Figure 14: The adjustable hinge prototype which features a two screw locking mechanism

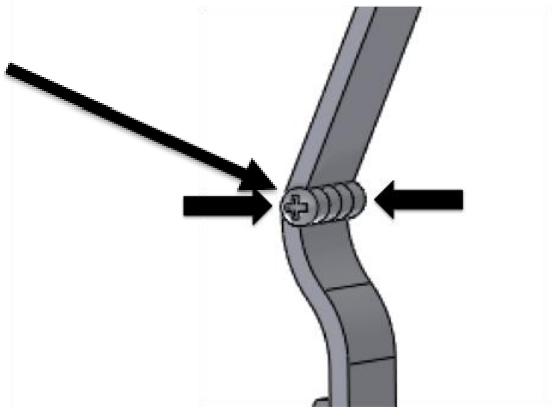


Figure 15: A closer look at the two screw locking system, which will allow the user to adjust to their individual leg.

Preliminary Static Testing

- Compression Test
  - MTS Machine
  - Loaded until failure
- Finite Element Analysis
  - Used Solidworks part
  - Determined failure strength of ABS+ plastic
  - Determined failure strength of 1060 Aluminum

Figure 16: Static testing setup of the Y-arm design in the MTS machine.

Preliminary Dynamic Testing

- Force Sensitive Resistors (FSRs)
  - FSRs change resistance when a load is applied
  - Used a voltage divider circuit and Arduino Uno to convert voltages to forces
  - 1 placed on distal end of each hinge
  - Walking, Squatting, and Standing Up

Figure 17: FSRs are attached to the hinges inside the knee brace being worn by a team member.

Preliminary Static Results

- MTS data of ABS+ matched FEA results
- FEA of aluminum can predict MTS results
- Only bends at design specification load

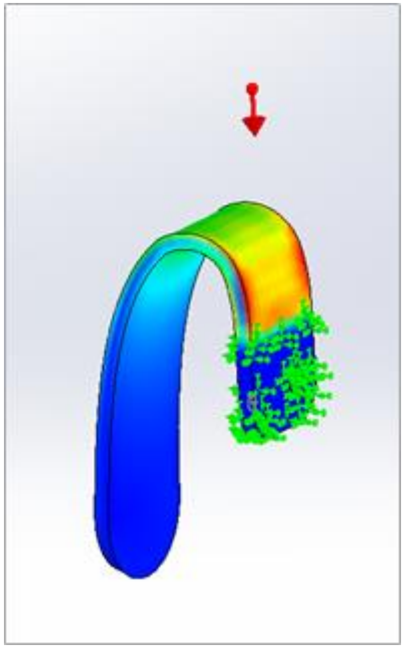


Figure 18: FEA results of a load of 163 lbs applied to ABS+.

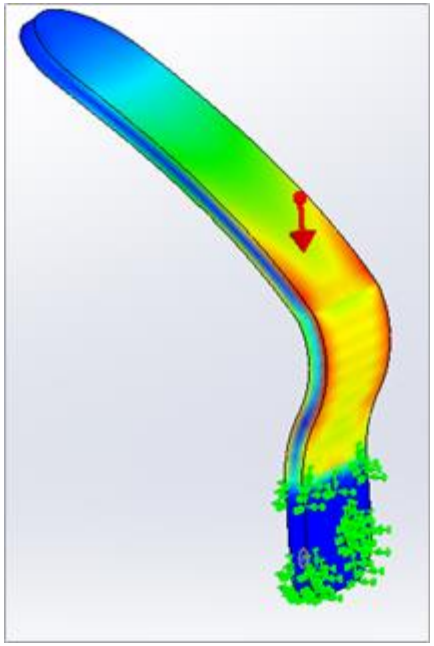
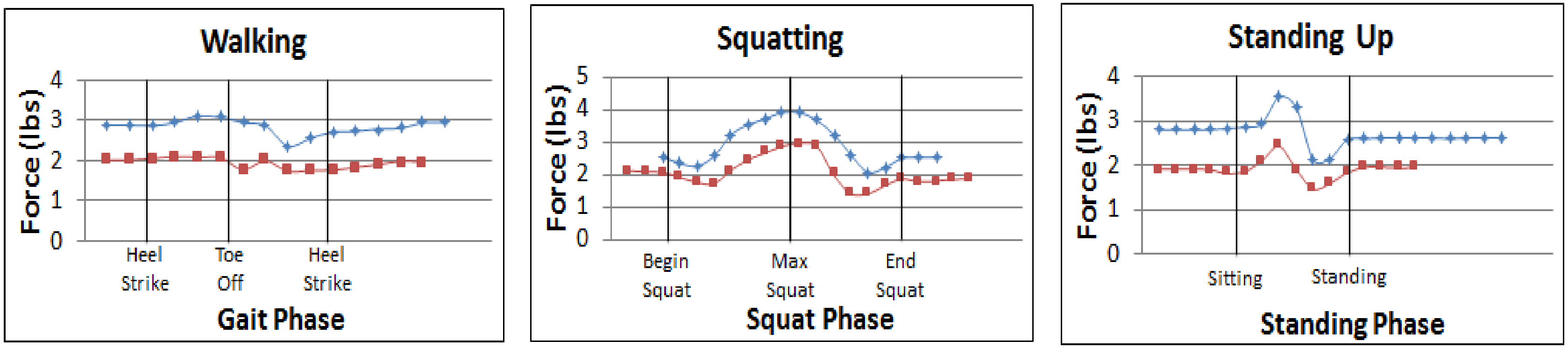


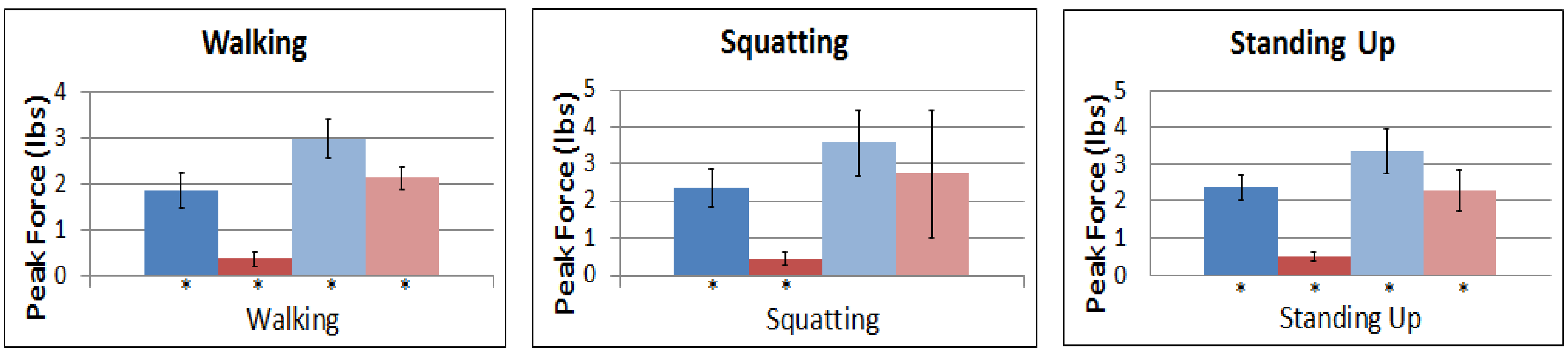
Figure 19: FEA results of a load of 300 lbs applied to 1060 Aluminum.

Preliminary Dynamic Results



Straight Arm
Y-Arm

Tables 1-3: The results of preliminary dynamic testing shows the force of both the straight and Y-Arm designs on the thigh as the subject performs various movements.



Straigh Arm Inside
Y-Arm Inside
Straight Arm Outside
Y-Arm Outside

Tables 4-6: The results of preliminary dynamic testing shows the peak force of both the straight and Y-Arm designs on the thigh as the subject performs various movements. * represent a significant difference ($p<0.05$)

Areas of Improvement

- Alter knee brace sleeve to accommodate prototype
- Static Testing
  - Verify aluminum FEA results by testing the fabricated Y-arm
  - Test the compressive strength of the Adjustable Hinge design
- Dynamic Testing
  - Strengthen FSR wires to prevent damage
  - Develop proper attachment of FSRs

Future Dynamic Testing

Combination of

- FSRs
  - Measure the pinch forces from the hinge
- Motion capture
  - Compute forces impacting knee as well as the torque it generates
- Electromyography (EMG)
  - Determine muscle activation and if brace affects muscle forces

Figure 20: An example of motion capture testing to analyze gait.

Timeline

Fabrication and Evaluation Goals	**Target Date**
Fabricate and calibrate force sensitive resistors (FSRs)	3/4
Conduct compression testing using MTS machine	3/4
Write code for determining determining knee joint power from motion capture	3/11
Create dynamic testing protocol	3/11
Conduct FSR, Motion Capture, EMG data	4/15
Analyze and compare dynamic testing data to control data	4/29
Determine significance of knee brace in relation to knee torque, pinch forces, and muscle activation	4/29

Table 7: The projected timeline for the rest of the semester

Expenditures

ITEMS PURCHASED	
Tefzel Wire (100 yds)	$24.30
Round Force-Sensitive Resistor (8)	$66.73
3D Printing (3 Y-arms, 3 Adjustable-Hinge)	$58.53
Stock Aluminum	$105.88
Total Cost of Items Purchased	$255.44
ITEMS TO BE PURCHASED	
Round Force-Sensitive Resistor (8)	$66.73
Total Cost of Items to be Purchased	$66.73
TOTAL EXPECTED COST (out of $500 budget)	**$322.17**

Table 8: The current and planned expenditures for this project through the rest of the semester

Acknowledgements

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- All of our data subjects
- All of the BME Resources

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Questions?