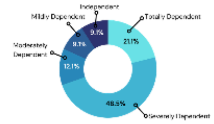
ArmAssist - Year 1

ArmAssist:

A Lightweight, Concealable Active Arm Support that Empowers Individuals Suffering From Muscle Atrophy

Problem

Difficulty Performing Activities of Daily Living (ADLs)



69.6% of Duchenne Muscular Dystrophy (DMD) patients are **severely or totally dependent on others to perform ADLs**

Shortcomings of Current Active Arm Supports

Current active arm supports are **large and cumbersome**

The arm shown to the right weighs more than 10 lbs when including its exterior battery pack

Source: https://abilitechmedical.com/abilitech-assist

- Passive and actively adjustable arm supports provide **insufficient strength for weaker users**
- The large weight of current active arm supports can be attributed to a reliance on **heavy servo motors & pneumatics**
- Muscular atrophy victims require a **slim and lightweight** alternative to **assist them with ADLs**

Solution

Engineering Goal

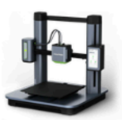
- Develop an **ultra-slim and -lightweight arm support** to empower victims of muscle atrophy
- Achieve the previous goal by designing and manufacturing a **novel artificial muscle mechanism**

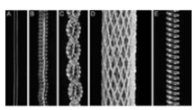
Materials

- 3D Printer
- Hardware:
  - EMG Sensors
  - EasyEDA/PCBWAY
- Voltage Power Supply
- Artificial Muscles:
  - Nylon 6'6 Fibre
  - NiChrome Wire 36g

Background

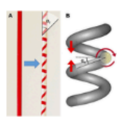
3D printed materials were utilized to construct the arm structure because it allows for **flexible, rapid prototyping** and **cost-effective development**

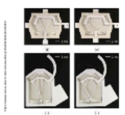




Twisted and coiled polymer (TCP) artificial muscles are small, ultra-lightweight, heat-driven actuators first developed in 2014

TCP artificial muscles utilize the **thermal expansion of a polymer fiber**, such as nylon, coiled into a helical structure to **generate lengthwise contraction** from the untwisting of the coil

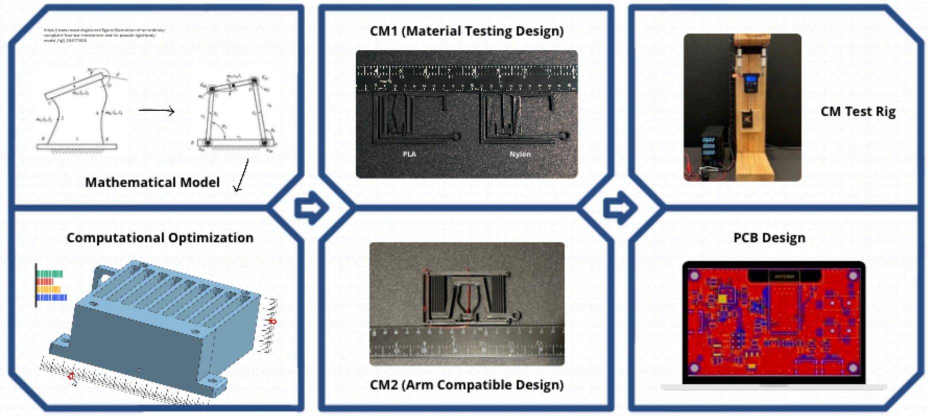




Compliant mechanisms use elements that **flex & bend** to store and transfer energy

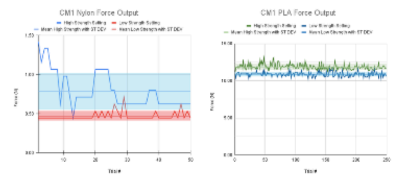
Tunable stiffness mechanisms can passively provide varying degrees of strength

Design & Methodology



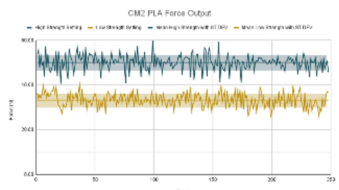
Results

CM1 Performance



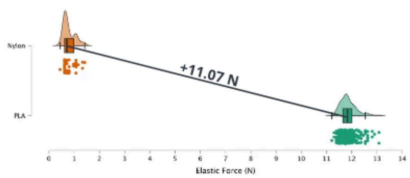
The **Nylon CM** suffered from decreased performance overtime due to **microslip** and **hysteresis**

CM2 Performance



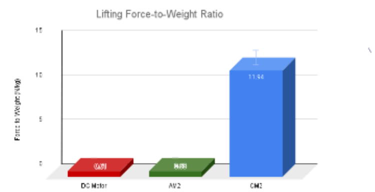
CM2 had a consistent force output (Validated over 250 trials) with a **lifting force equalling current orthotics**

CM1 Comparison



The superior performance in both **force output (~15x)** and **durability** made PLA a **more viable** material for CM2

Force-to-Weight Ratio

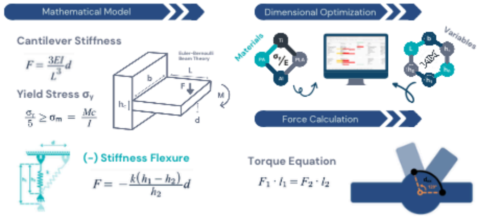


CM2 exhibited the **highest ratio** between **the lifting force** of the orthotic and its **total weight (2000% increase)**

All graphs, visuals, and photographs were created/taken by the student researchers using Canva/Google Drive/JMP/EasyEDA unless stated otherwise

Discussion

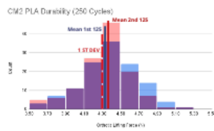
Calculations



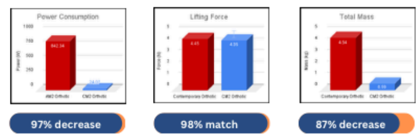
Statistical Analysis

Durability Assessment

The **mean lifting force** produced by CM2 during the 2nd half of the 125 trials was within **1 standard deviation** of that of the 1st, indicating there was **no significant decrease**



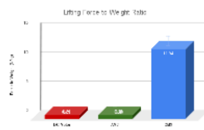
Orthotic Comparison



Force-to-Weight Ratio

There was a **significant increase (p<.0001)** in the force-to-weight values of each actuator (left to right)

CM2 PLA outperformed the DC motor in force-to-weight by a factor of **2000%**



Conclusion

Application

- **Assistance and Rehabilitation of Muscle Atrophy Victims**
  - Custom actuator creates a **lightweight system** that yields **performance exceeding** current powered orthotics
- **Defense/First Responders**
  - Actuator generates a lightweight, high-power systems, unlocking the possibility of **faster-moving first responders**
- **Manufacturing**
  - Provide assistance in **lifting heavy loads**
  - **Reduce risk** of workplace injury

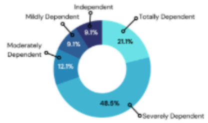
Summary

- **Muscle Atrophy** can **compromise** an individual's ability to complete **Activities of Daily Living (ADL)s**
- Testing indicates that the orthotic device would **assist muscle atrophy patients**, matching existing orthotics in lifting force and **exceeding them in lifting force-to-weight**
- Novel actuators have the potential to create a **new generation of ultra-lightweight orthotics** with potential applications in the **medical**, **defense**, and **manufacturing** industries

ArmAssist - Year 2

Problem

Difficulty Performing Activities of Daily Living (ADLs)



69.6% of Duchenne Muscular Dystrophy (DMD) patients are **severely or totally dependent on others to perform ADLs**

Shortcomings of Current Active Arm Supports

Current active arm supports are **large and cumbersome**

The arm shown to the right weighs more than 10 lbs when including its exterior battery pack

Source: https://abilitechmedical.com/abilitech-assist

- Passive and actively adjustable arm supports provide **insufficient strength for weaker users**
- The large weight of current active arm supports can be attributed to a reliance on **heavy servo motors & pneumatics**
- Muscular atrophy victims require a **slim, lightweight, active arm support** to more effectively **assist them with ADLs**

Solution

Engineering Goal

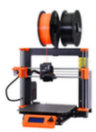
- Develop an **ultra-slim and -lightweight active arm support** to support victims of muscle atrophy
- Achieve the previous goal by designing and manufacturing a **pseudo-passive actuator** using **compliant mechanisms** and **shape memory alloys (SMAs)**

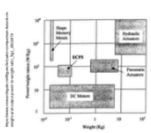
Materials

- 3D Printer
- EasyEDA
- EMG Sensors
- PCBWAY
- Nitinol Shape Memory Alloy
- Portable Charger
- Voltage Power Supply

Background

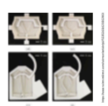
3D printed materials were utilized to construct the arm structure because it allows for **flexible, rapid prototyping** and **cost-effective development**

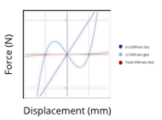




Shape memory alloys possess an extraordinarily **high power/weight ratio** whilst remaining feasible in **ultra-lightweight applications**

Compliant mechanisms (CM) use elements that **flex & bend** to store and transfer energy. These elements can be modeled using **Hooke's Law** (F=kx), with k determined by material & geometry





Incorporating a collapsible negative stiffness flexure in parallel creates a **tunable stiffness spring** (Kuppens et al., 2021)

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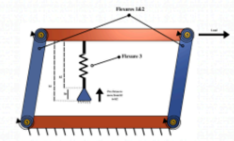
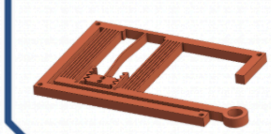
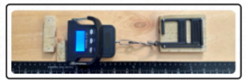
Design & Methodology



Pseudo-Rigid Body Model

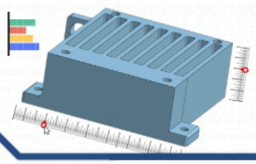
Gen 1 CM (Nylon/PLA)

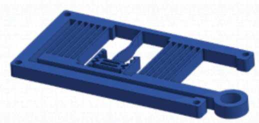




CM Test Rig

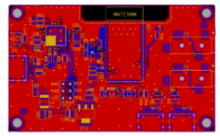
Design/Genetic Optimization





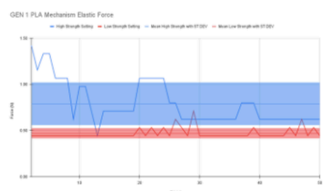
Gen 2 CM (PLA)

PCB Design



Results

GEN 1 Nylon CM



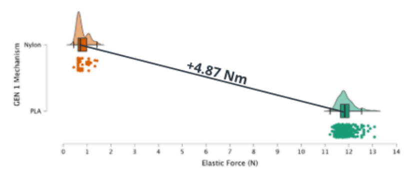
5% Energy Consumption

CM Weight 8.36 g

CM Volume 6.5 cm³

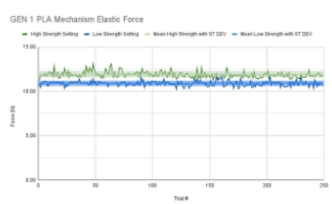
Performance of Nylon GEN 1 CM when displaced 1 cm over 50 trials in **high and low stiffness states**

GEN 1 Comparison



The superior performance in both **force output** and **durability** made PLA a **more viable** base material for the GEN 2 mechanism

GEN 1 PLA CM



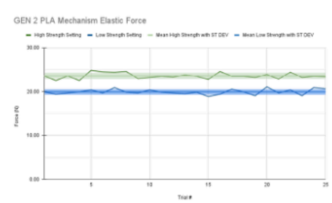
5% Energy Consumption

CM Weight 5.66 g

CM Volume 6.5 cm³

Performance of PLA GEN 1 CM when displaced 1 cm over 250 trials in **high and low stiffness states**

GEN 2 Nylon CM



5% Energy Consumption

CM Weight 4.46 g

CM Volume 4.1 cm³

Performance of PLA GEN 2 CM when displaced 6 mm over 25 trials in **high and low stiffness states**

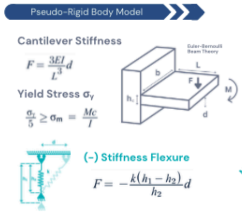
All graphs, visuals, and photographs were created/taken by the student researchers using Canva/Desmos/Google Drive/JASP/PCBWAY unless stated otherwise

Discussion

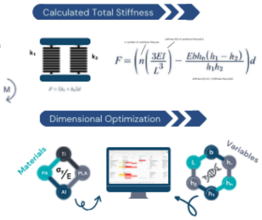
Calculations

Pseudo-Rigid Body Model

Calculated Total Stiffness



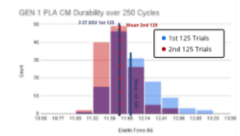
Dimensional Optimization



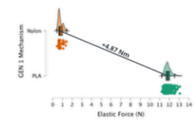
Statistical Analysis

Durability Assessment

The **mean force** produced by the **GEN 1 PLA CM** during the 2nd cycle was within **3 standard deviations** of the 1st, indicating there was **no significant decrease** in output over the 250 trials



Nylon vs. PLA



There was a **significant increase** (p<.0001) in force output **between** the **Nylon** and **PLA GEN 1** mechanisms

As a result, **PLA was used** in the **GEN 2 mechanism**

Torque-to-Weight Ratio

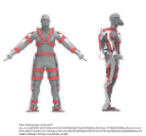
There was a **significant increase (p<.0001)** in the torque-to-weight values of each actuator (clockwise)

The **GEN 2 PLA mechanism outperformed** the DC motor by a factor of **280x**

Conclusion

Application

- **Assistance and Rehabilitation of Muscle Atrophy Victims**
  - Pseudo-compliant actuator creates a **lightweight system** that can **provide strength exceeding** current powered orthotics
- **Defense/First Responders**
  - Actuators generate high-power systems, unlocking the possibility of **faster-moving first responders**
- **Manufacturing**
  - Provide assistance in **lifting heavy loads**
  - **Reduce risk** of workplace injury



Summary

- **Muscle Atrophy** can **compromise** an individual's ability to complete **Activities of Daily Living (ADL)s**
- Testing indicates that the orthotic device would **assist muscular wasting patients**, matching and surpassing existing orthotics in energy-to-weight
- The implementation of **NiTinol** within a **compliant mechanism** system has the potential to create a **new generation of ultra-lightweight orthotics** with potential applications in the **medical, defense,** and **manufacturing** industries