e-NABLE: IMPROVED PROSTHETIC GRIP STRENGTH

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ABSTRACT

Major limb loss affected approximately 2.2 million people in the United States in 2020 [1]. Many prosthetic limbs commonly used by these individuals are expensive and difficult to access. e-NABLE is a global community of volunteers that create 3D printed prosthetic hands for individuals in need. The client, tasked the team with modifying the existing *Phoenix Reborn* prosthetic hand to increase the grip of cylindrical objects. The team fabricated a prototype to lengthen the fingers and add a degree of freedom to aid in cylindrical grip. This resulted in greater normal force to the palm of the hand that improved grip. The prototype was tested using a hand dynamometer alongside a series of qualitative tests to compare to the original *Phoenix Reborn*. The results from the testing were analyzed using MATLAB to calculate a p-value of 1.49e-09 showing a statistically significant improvement in the strength of the modified hand.

PROBLEM STATEMENT

Design Motivation:

- Commercially available prosthetic hands are expensive and not economical for families with children who quickly outgrow prosthetics
- Current e-Nable prosthetic designs are limited in the ability and strength of the grip

Objective:

Redesign the current e-Nable prosthetic to improve user quality of use by increasing the functional capabilities of the prosthetic, while maintaining the cost effectiveness of the manufacturing process

BACKGROUND

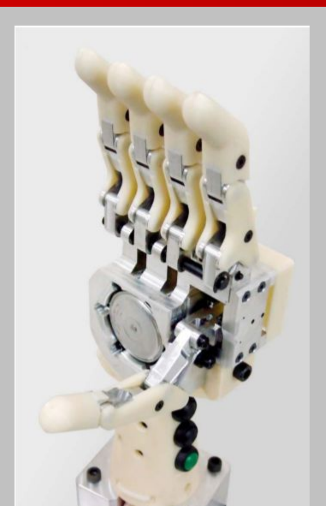

Figure 1. Example of an existing Multi-grip pattern hand [4]

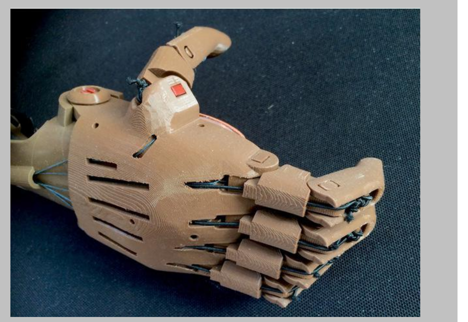

Figure 2. Reborn hand by e-NABLE [5]

- **Prosthetic Use:**
  - From a collection of studies, approximately 34% of prosthetic users use passive prostheses [2]
  - Today, both passive and active prosthesis exist:
    - Passive prosthetics posses static and adjustable elements, but lack mechanical function
    - Active prosthetics possess a mechanical function often controlled from flexion of the user
- **Current Prosthetics**:
  - Competing designs such as the DEKA Hand [3], have more capabilities when it comes to grip configurations
  - Complex, mechanical designs increase grip versatility and overall abilities, at a higher cost ($5,000-$50,000)
  - An e-NABLE hand is produced for under $50
- **Societal Impact:**
  - e-NABLE's global volunteer network provides access to prosthetics that improve the users quality of living. An improved design alternative allows for distribution of a more effective product

DESIGN CRITERIA

- Develop a prosthetic hand that is capable of an improved strength cylindrical grip
- Device must be able to pick up and hold textured and untextured cylinders
- Include a mechanism that limits overextension of the user while using the prosthetic
- Ensure that the low-cost nature of the initial product is maintained with the prototype
- Possess equivalent or less manufacturing intensity than existing e-NABLE models

FINAL DESIGN

PLA Prototype Components:

- Phoenix Reborn Hand
- 4 Male-To-Male Phalanx Extensions
- 4 Male-To-Female Phalanx Extensions
- 10 Short Pins
- 2 Long Pins
- Palm Base Plate

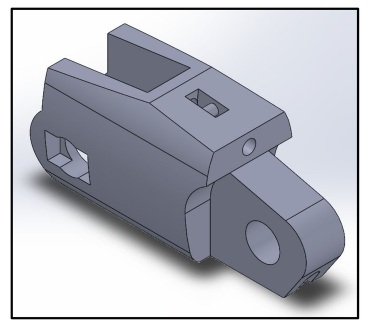

Figure 3. Modified Phalanx Two component

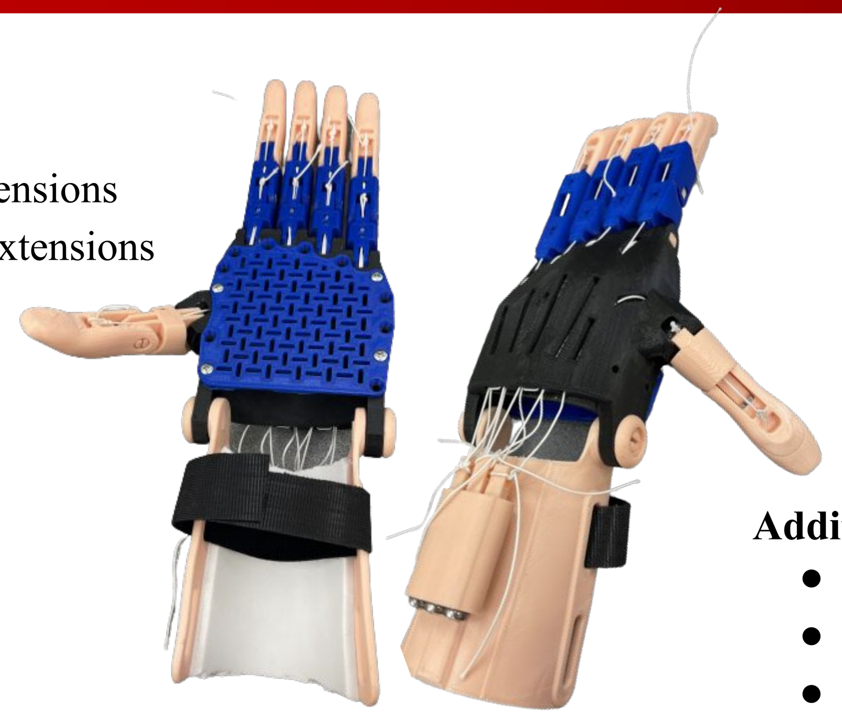

Figure 4. Assembled final hand prototype

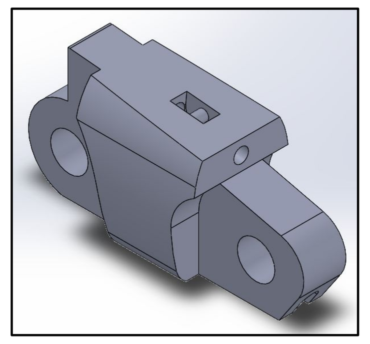

Figure 5. Modified Phalanx One component

Additional Prototype Components:

- Nylon Thread
- Elastic Cord
- Foam Pad
- Velcro

TESTING AND RESULTS

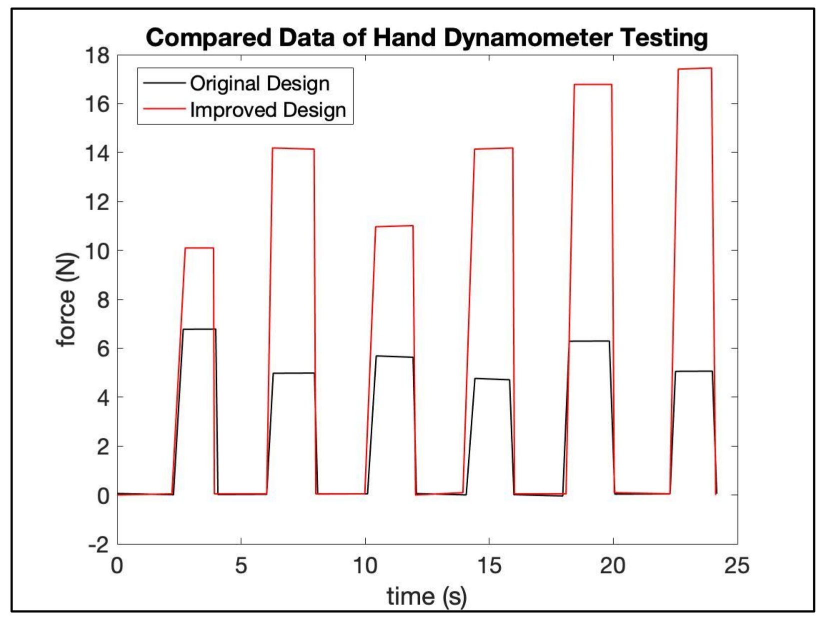

Figure 6. Line graph of grip force vs. time by both hands

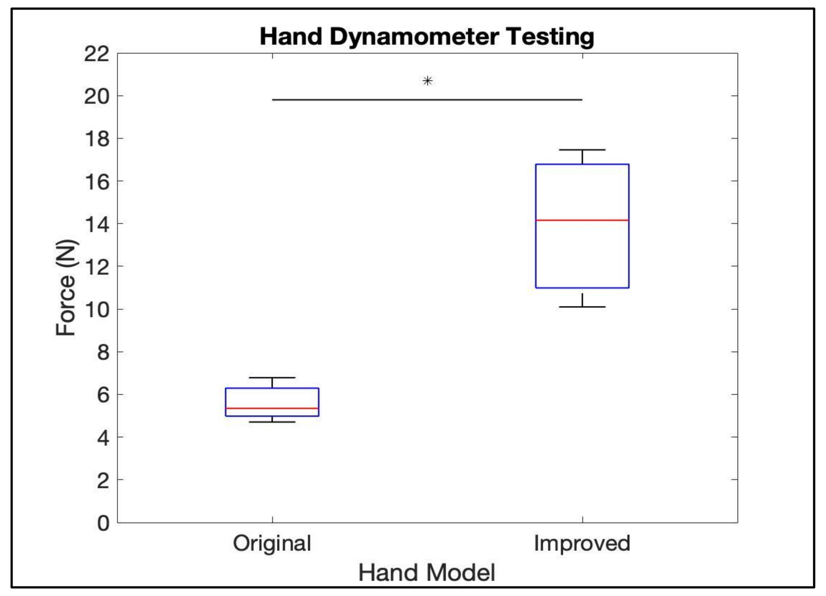

Figure 7. Box plot to show statistical significance of the difference between grip strength

Quantitative Testing:

- The quantitative testing utilized a hand dynamometer to collect data
  - Trials consisted of six contractions of the hand with a hold and rest time of two seconds each
- The data was analyzed in MATLAB
- A two-sided t-test was used to analyze the data
  - The mean difference was found to be statistically significant, generating a p-value of 1.49e-09

Qualitative Testing:

- A series of trials were arranged in which objects were picked up to judge performance, providing an analysis of success in everyday tasks
- Varying weights, sizes, and grip aids were used

Table 1. Qualitative testing information table

	Red Bull	Soda	Arizona Tea	Hydroflask
Diameter (mm)	52.55	65.60	72.75	89.47
Empty-Weight (g)	10	17	29	434
Full-Weight (g)	281	486	713	1350

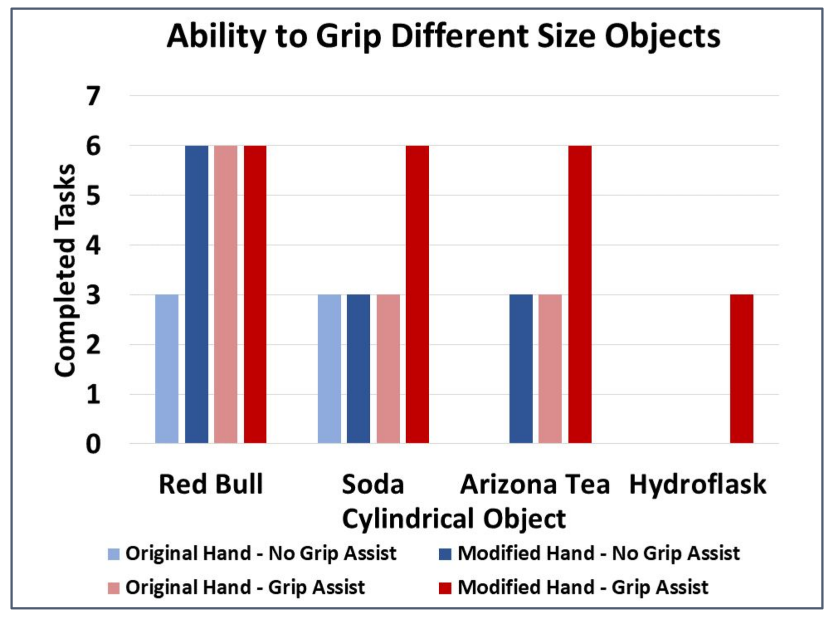

Figure 8. Histogram of qualitative performance by size

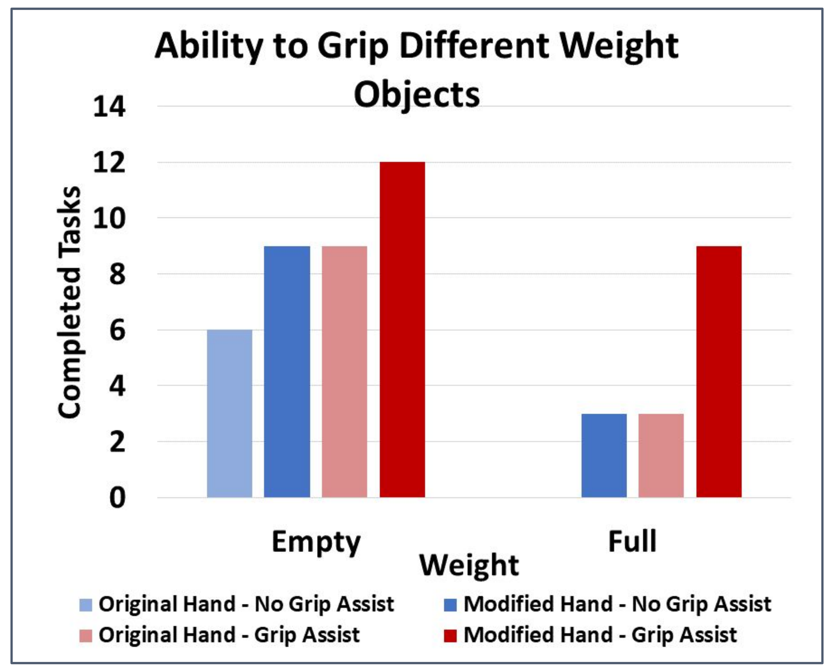

Figure 9. Histogram of qualitative performance by weight

DISCUSSION

- The new design displayed improvement in grip strength when compared to the original design
- Measures of crush force and versatility were significantly improved
- Both improvements can be attributed to the improved ability of the new design to contour to a cylindrical element - highlighting the importance of the modified phalanx components and the new cable routing procedure
- Possible sources of error:
  - Insufficient grip of original design around the dynamometer
  - Slight variability in assembly between configurations in regards to the tension system and retraction system
  - Variability in user force input

FUTURE WORK

Improvements:

- Rework the thumb positioning in relation to other fingers to improve grip capability by allowing for productive movements in the gripping action
- Integrate a pulley system to leverage principles of mechanical advantage increasing overall grip strength with less user force input
- Redesign the contour of the palm and fingers of the hand to facilitate higher surface area contact with objects

Testing:

- Using a paint or ink on the prosthetic to calculate a hand-object contact surface area to use for pressure distribution/friction calculations for a typical interaction
- Use a system of Force Sensitive Resistors attached to the hand to produce a map of the exerted forces on an object to indicate the versatility and strength of different parts of the hand

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- Ken Bice - e-NABLE

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