

Final Design Report: Extend-a-Stick

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Table of Contents

Executive Summary.....	1
Introduction.....	2
Users and Major Requirements.....	3
Our Approach.....	5
Design Concept and Rationale: The Extend-a-Stick.....	6
Limitations and Directions for Future Development.....	13
Conclusion.....	14
Appendix A: Secondary Research: Muscular Dystrophy and Sit-to-Stand Background.....	15
Appendix B: Existing Therapeutic and Assistive Approaches for Muscular Dystrophy and Sit-to-Stand Mobility.....	23
Appendix C: Initial Project Partner Interview and Sit-to-Stand Demonstration.....	28
Appendix D: User Observation of Sit-to Stand Movements in Various Environments.....	34
Appendix E: Observation of Sit-to Stand Movements in the User’s Home Environment.....	39
Appendix F: Mockups [Round 1- October 21st].....	45
Appendix G: User Testing.....	51
Appendix H: Design Review Summary.....	55
Appendix I: Spring Power Alternatives and Linear Actuator Specifications.....	57
Appendix J: Expert Interview with Professor Nicholas Marchuk.....	63
Appendix K: Walking Stick Construction Materials.....	66
Appendix L: Methods of Construction.....	73
Appendix M: Bill of Materials.....	86
Appendix N: Project Definition.....	87
Appendix O: Instructions for Use.....	91
List of Figures.....	94
Figure 1: Design Approach.....	94
Figure 2: Concept drawing of the Extend-a-Stick.....	95
Figure 3: The linear actuator fully extended and fully retracted.....	96
Figure 4: The cushioned horizontal handle.....	97
Figure 5: The Battery Case and Shell.....	97
Figure 6: 12 V Lithium ion drill battery.....	98
Figure 7: One-legged Rubber Base.....	99
Figure 8: Four-legged Rubber Base.....	99

Executive Summary

Problem Statement and Significance

Muscular dystrophy presents significant challenges for individuals performing essential daily activities, such as sit-to-stand movements. Patients typically experience progressive weakness of various muscle groups, which limits their mobility and independence. In a study of 77 adults with muscular dystrophy, more than 50% of them are dependent on mobility-related daily activities (see Appendix A). As muscular dystrophy patients use impacted muscle groups, those muscle groups continue to weaken. Developing a solution that can restore the independence of individuals with muscular dystrophy is of great significance.

Our project partner, Mr. Monil Gandhi, experiences difficulty with sit-to-stand movements due to lower-body weakness caused by muscular dystrophy. In 12 weeks, Team 13.3 aimed to design a solution that would provide Mr. Gandhi with the necessary assistance to safely and independently perform sit-to-stand movements from various seated positions and environments.

The Extend-a-Stick

To respond to these challenges, we designed the Extend-a-Stick, a piston-powered extendable walking stick. The Extend-a-Stick allows the user to lean their body on the walking stick and elevate to standing height, a feature that provides 220 pounds of force and can lift the user up to 20 inches. With the additional use of a 4Ah rechargeable battery, the Extend-a-Stick supports 400 extensions and retractions per charge.

Through interviews, observations, and user testing with Mr. Gandhi, Team 13.3 optimized our design to meet the following requirements:

- **Motorized:** The Extend-a-Stick's motor reduces muscle exertion, mitigating potential progression of muscular dystrophy.
- **Portable:** The Extend-a-Stick weighs just over 5 lbs. It also has a soft, cushioned handle that makes use comfortable, not strenuous.
- **Discreet:** The Extend-a-Stick is black, blending into most environments. With a case covering the electrical wiring, it looks like the average walking stick.
- **Versatile:** Not only does the Extend-a-Stick function as a sit-to-stand aid, it too fits into Mr. Gandhi's daily life as a walking stick. It can be used in any location in which there is sufficient space for a walking stick.
- **Stable:** The Extend-a-Stick's exchangeable rubber bases provide ample friction with any ground surface. Additionally, the linear actuator's steady extension ensures stability and safety when standing.

Anyone who has difficulty with sit-to-stand movements can benefit from the Extend-a-Stick.

Introduction

Our project partner is Mr. Monil Gandhi, a graduate of Northwestern's McCormick School of Engineering and an investor for Novastone. He has Emery-Dreifuss muscular dystrophy, a strain that affects ~33,000 people worldwide (~1 in 250,000), which impacts the strength and range of motion of many of his muscles. As a result, he has difficulty standing up from certain positions, especially free standing chairs from a low height.

Team 13.3 was asked to design a sit-to-stand aid that reduces strain on someone with muscular dystrophy's leg muscles. This solution can aid anyone who has muscular dystrophy or standing issues due to leg weakness, helping millions of people worldwide. Our team had 12 weeks to complete this project, and a budget of \$150. A short timespan for ideation and fabrication and a small, confining, budget comprised our two biggest constraints.

Few solutions to our specific design challenge exist worldwide, and the few that do are not discreet or lightweight—making our solution valuable and efficacious. The current solutions are all seat lifts. While functional, seat lifts are not optimal for our project partner because they angle the user. Additionally, using a seat lift requires inconvenient transportation. However, Mr. Gandhi already uses a walking stick, so using ours would not add any load to day-to-day transportation.

This report will describe our solution: an actuated, extendable walking stick, how the product solves the complex design problem, and how it incorporates into our partner's daily life: discreet and lightweight. Afterwards, we will detail our research and fabrication processes and summaries of our testing and limitations.

Users and Major Requirements

Primary User

Muscular Dystrophy Patients with STS Movement Difficulty

The primary user of this project is an adult affected by muscular dystrophy, a genetic disease that causes progressive weakening of skeletal muscles and leads to significant limitations in performing daily activities such as the sit-to-stand (STS) movement (see Appendix A). The user's lower body strength is severely impacted, making it extremely difficult to stand up from sitting independently without external assistance or an appropriate seat height (see Appendix C). Additionally, the weakening of upper body muscles such as triceps also worsens the condition as the user cannot generate sufficient force to pull or push himself up from a seated position.

Based on the initial user interview and further user observations, the user had difficulty in carrying heavy objects in daily situations, thus he explicitly mentioned that the design should be portable. Additionally, the user mentioned that the device should be designed to be discreet as he didn't want to attract any unwanted public attention. Moreover, team 13.3 observed that our partner normally requires a stable physical structure to support him while standing up, thus the device should be strong enough to bear his whole body weight (see Appendices C, D, and E).

Secondary User

Patients' Families or Friends

The secondary users of this project are family members, friends, or caregivers who assist patients with muscular dystrophy in daily activities. Even though secondary users may not directly interact with the device, they often play a crucial role in supporting user's safety and mobility. Secondary users may help transport the device, ensure it is placed correctly, and provide physical support when needed.

Major Requirements

Portable

Due to the progressive weakening of various muscle groups, our user has difficulty in both performing daily activities such as STS and carrying heavy objects. Therefore, the device should be designed to be lightweight and portable enough that enable the user to carry and use it independently in everyday life.

Discreet

Based on the user interview, one important requirement of our design is that it's discreet. Specifically, since the device will be used in public settings, it should be quiet during operation to minimize noise and avoid drawing unnecessary attention. Additionally, the appearance of the device should not attract unwanted public attention (see Appendix C).

Strong, Stable, and Safe

Based on user observations, our partner normally requires a stable physical structure to support him while standing up. Therefore, ensuring the device is strong enough to bear his weight, stable enough while lifting him, and safe enough while operating is significant (see Appendix D and Appendix E).

Easily Deployed

The device should be designed to enable the user to use it independently and set it up easily without any external assistance. In this case, the user's independence can be maximally restored

Comfortable

Since the user is going to put his body weight on the device, and the operation time of the device might take a minute, it's ideal to design the device to be ergonomic and comfortable to use.

Our Approach

This flowchart outlines our design approach over the course of the 12 weeks.

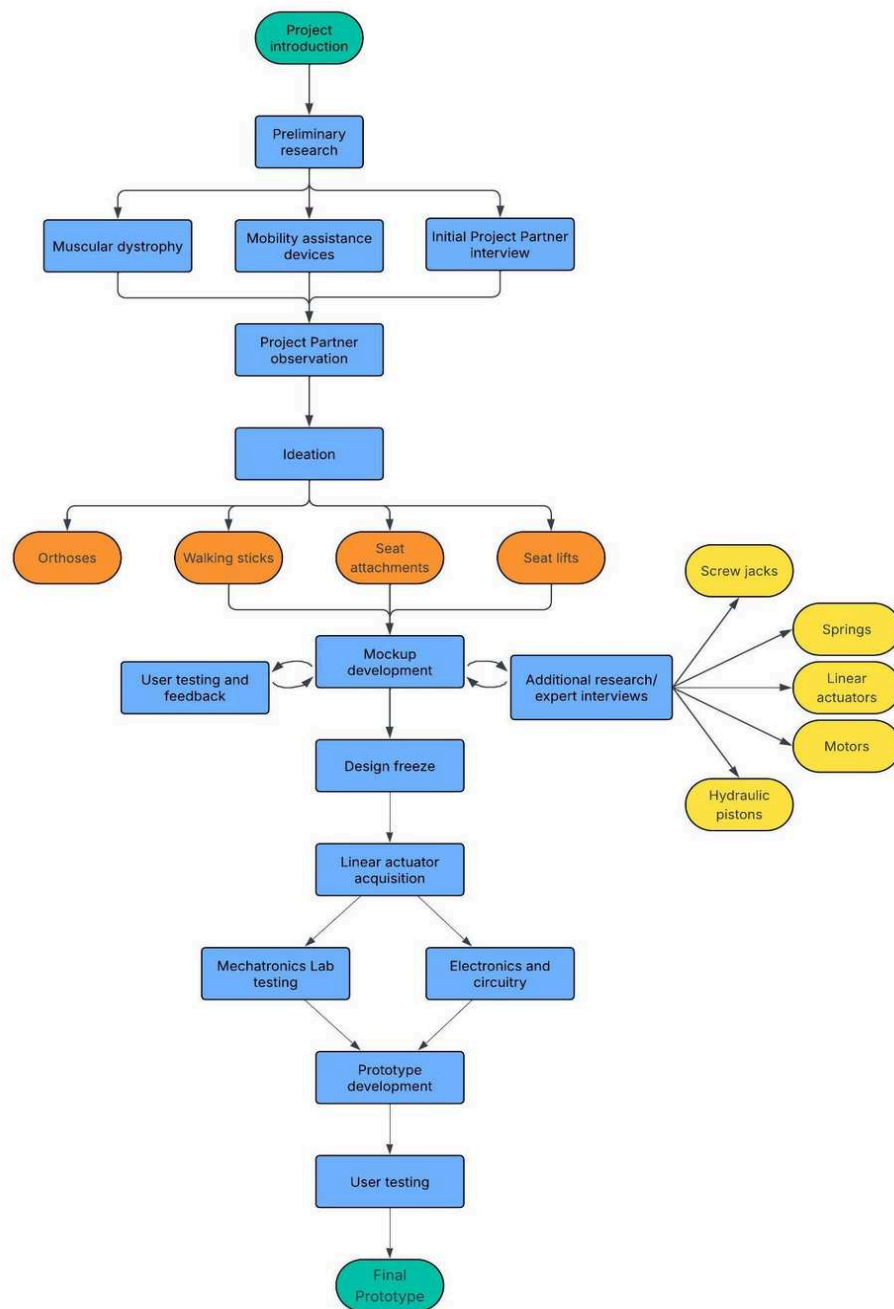


Figure 1: Our design approach.
Graphic created by Axel Hinz using Lucidcharts.

Design Concept and Rationale: The Extend-a-Stick

The Extend-a-Stick is a discreet, portable, and simple product that minimizes muscle strain when sitting down or standing up from chairs of different heights and sizes. It features a linear actuator that retracts and extends in a controllable manner that allows the user to place their weight onto the Extend-a-Stick and, with the flip of a switch, be lowered down to a lower elevation or pushed up to higher elevation depending on their current need (See Appendix O).

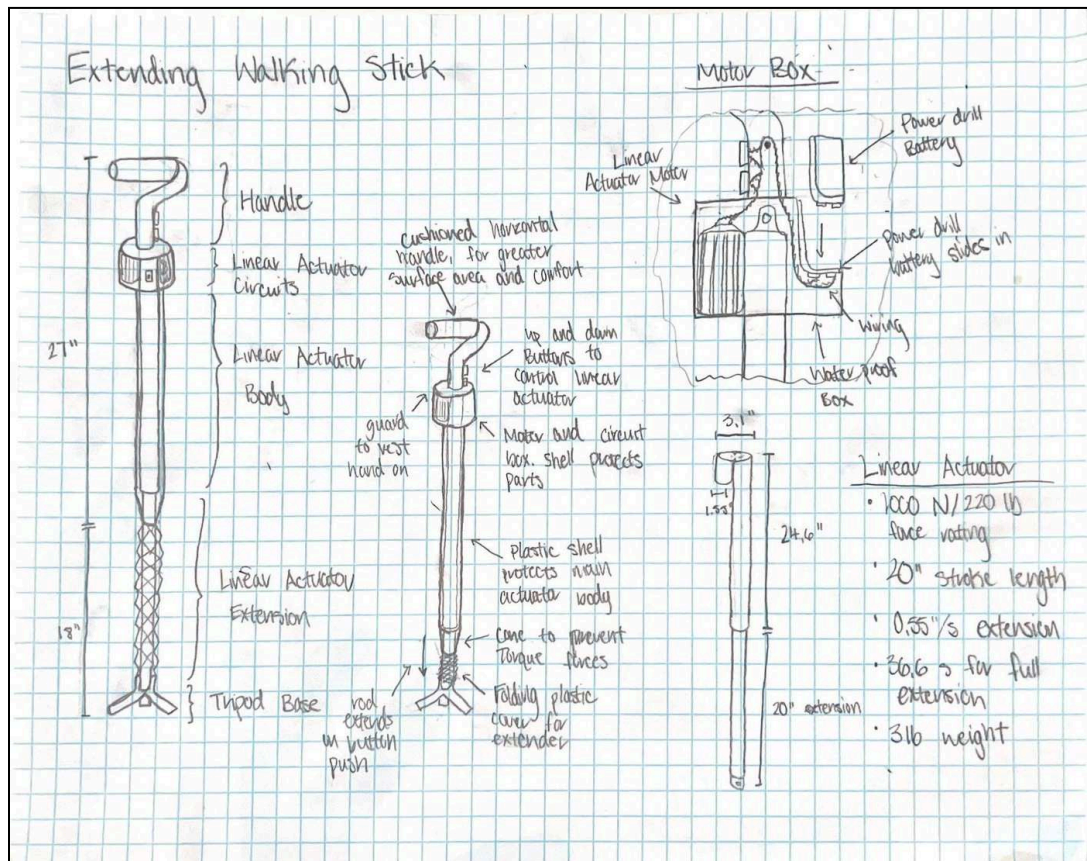


Figure 2: Concept drawing of the Extend-a-Stick.
Graphic by Maxwell Kaung.

Components, Materials, and Key Decisions

Linear Actuator

The centerpiece of the Extend-a-Stick is a VEVOR 12-volt aluminum alloy linear actuator which measures to 44.6 inches when fully extended. The drawing in Figure 3 depicts the linear actuator when fully extended and fully retracted, respectively.

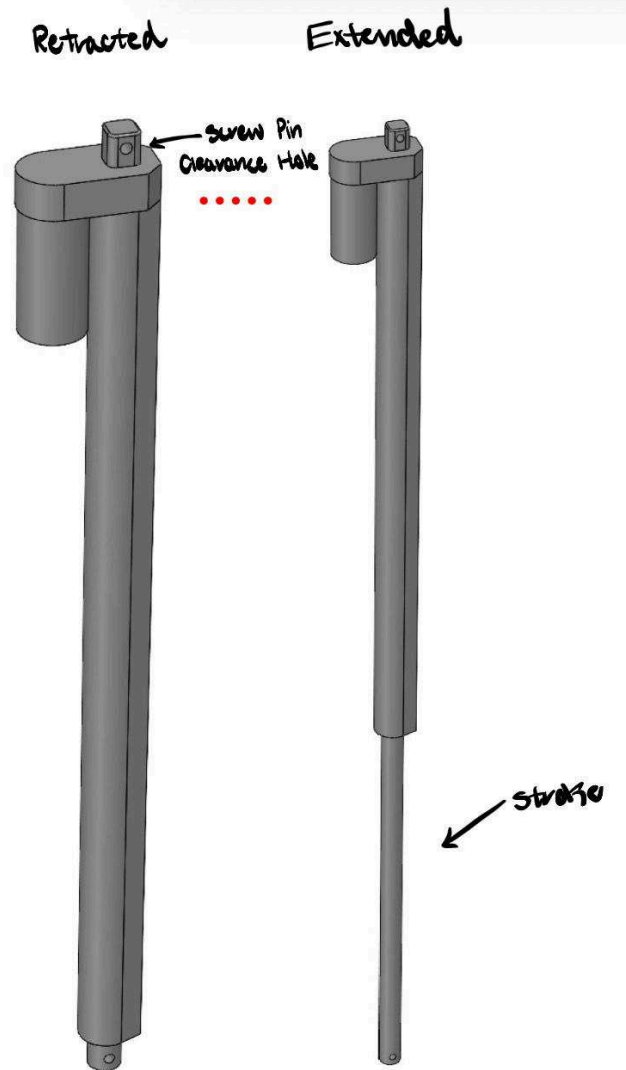


Figure 3: Linear Actuator Fully Extended and Fully Retracted.
Graphic by Max Kaung using SolidWorks.

Rationale

Our chosen linear actuator balances mobility, utility, and durability. Its aluminum alloy casing is both durable and relatively lightweight, ensuring both portability and lasting strength. It can be used indoors and outdoors in many situations because its IP54 rating gives it both splash and dust resistance. Additionally, it is rated for loads of up to 1000 Newtons (220 pounds), which exceeds our user's required load capacity by 20 percent. It also features a 20-inch stroke length that guarantees ease of use for all seat heights and user heights, and its competitive 0.55-inch travel speed ensures a fast but controlled movement during use (See Appendix I).

Cushioned Horizontal Handle

The handle of Extend-a-Stick is a heavily cushioned horizontal cane handle attached to the top of the linear actuator and motor box. The handle is used for both gripping the walking stick during normal use and for supporting the user's core during extension and retraction.

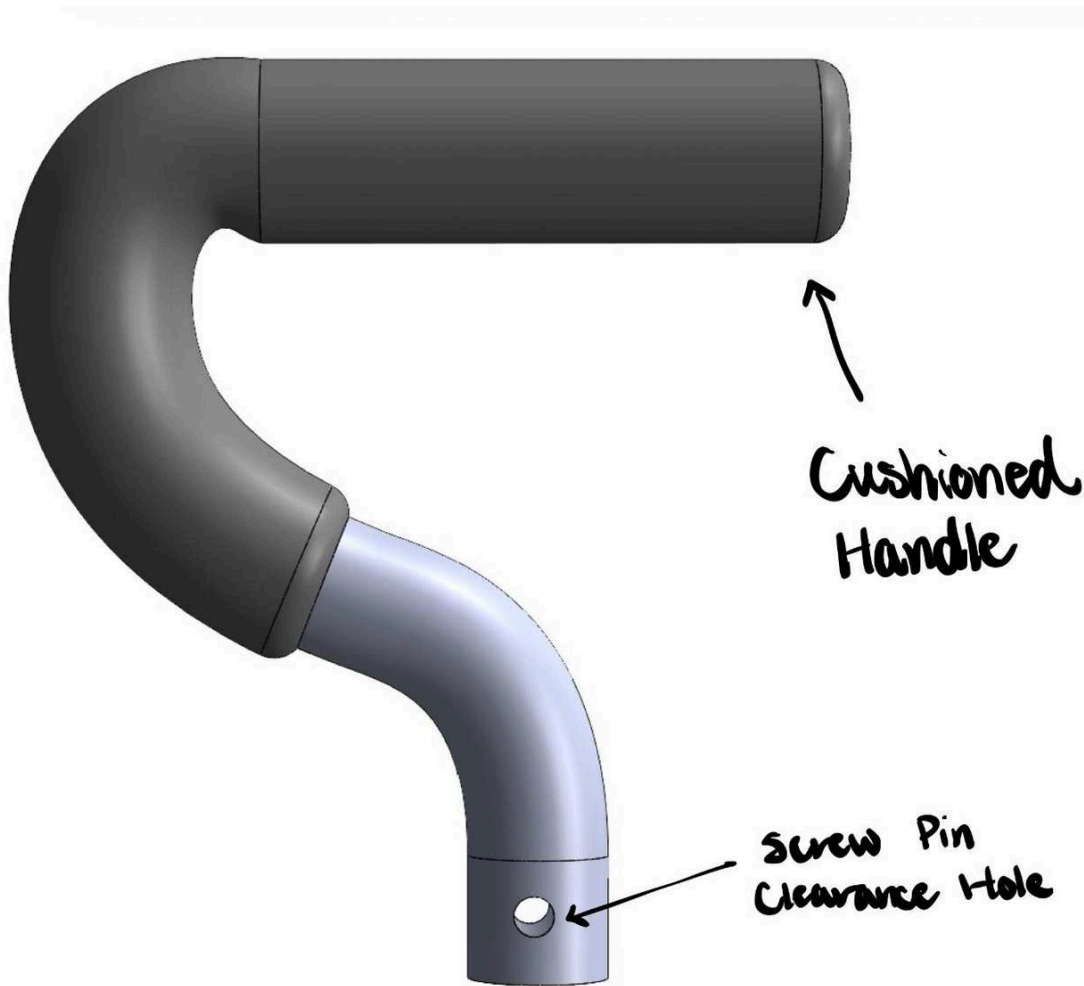


Figure 4: The Cushioned Horizontal Handle.

Graphic by Maxwell Kaung using SolidWorks

Rationale

Our use of a horizontal handle over a vertical one allows the user to maintain more surface contact with the walking stick during extensions and retraction, thereby increasing the walking stick's ability to stabilize the user's core. Additionally, the larger surface area spreads out the user's weight over the entire handle rather than a single point, reducing the force applied to a point on the user's hand or abdomen.

The use of a cushion for the top of the handle further spreads out the force applied to a single point on the user's body during extension and retraction, making the process of leaning over the walking stick more comfortable.

3D Printed Motor Box Shell

The Extend-a-Stick uses a fitted shell that slides over the top of the linear actuator to harbor the actuator's electrical parts. The motor box shell fits perfectly over the motor and switch of the linear actuator, and contains a slot for a drill battery latch onto.

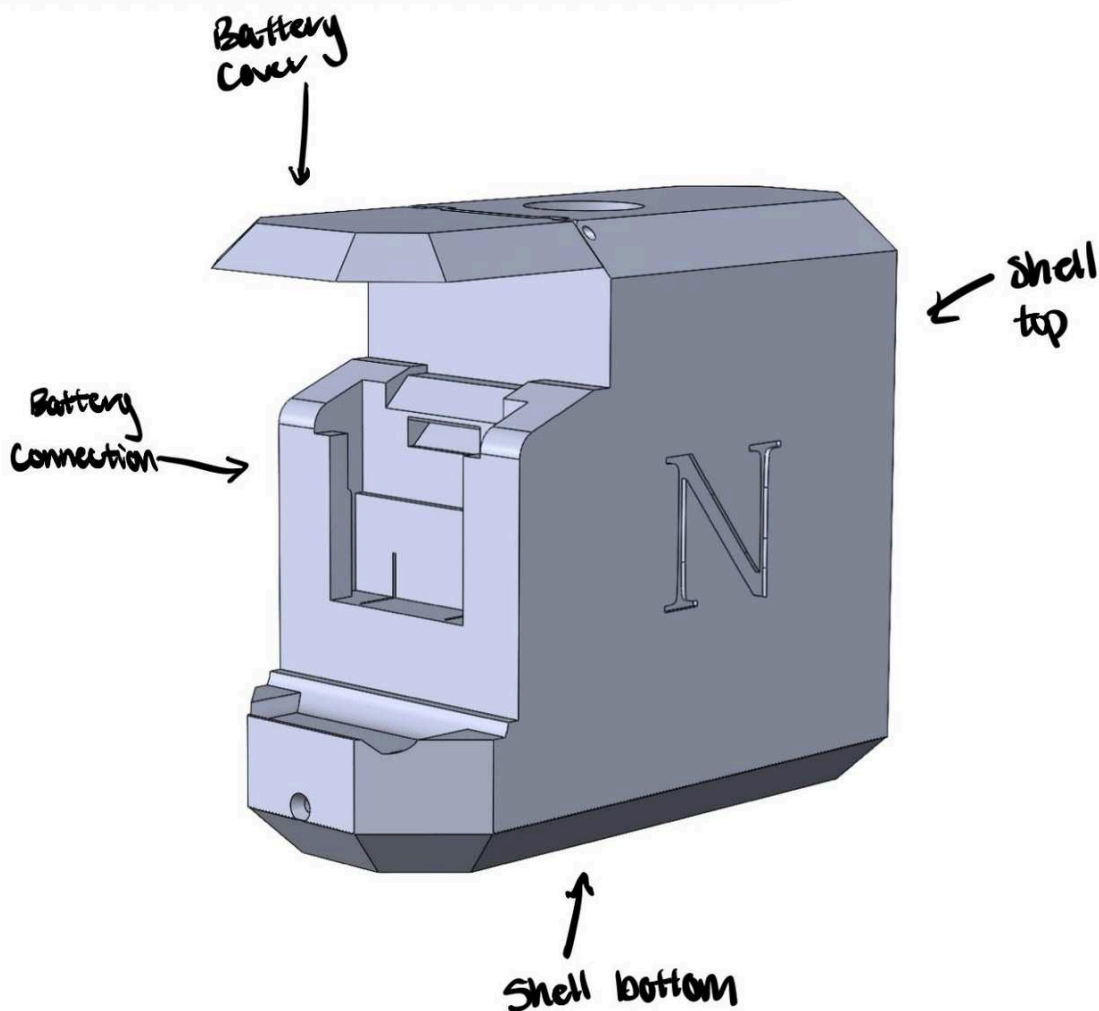


Figure 5: The Battery Case and Shell.
Graphic by Maxwell Kaung using SolidWorks

Rationale

The motor box was chosen to be 3D printed with PLA, a relatively strong and lightweight plastic. A 3D printed design also allowed for a custom and complex connector design for the

drill battery to fit into. The shell was printed with 4 wall layers and 0.2 inch wall thickness to balance strength and size, as well as black PLA to match its color with the linear actuator and increase discreteness. A battery cover was also attached to the motor box to provide protection to the battery plates from water and dust.

Rechargeable Drill Battery

The Extend-a-Stick uses a 12V 4 Ah rechargeable drill battery to power the linear actuator. The drill battery slots into the side of the motor box to begin powering the walking stick, and is able to be removed from the motor box to be recharged.



Figure 6: 12 V Lithium ion drill battery.
Graphic by Maxwell Kaung.

Rationale

We chose a 12 V drill battery because it matches the rated voltage of the linear actuator motor, reducing the risk of overheating or mechanical damage within the motor. The drill battery's positive and negative terminals are built-in receptacles that make it easy to design the male connection on the 3D-printed box shell, and allow it to lock into place like it would in a power drill. Additionally, the 4 Ah capacity allows for over 400 full extensions and retractions of the linear actuator, resulting in fewer recharge cycles.

Rubber Bases

We decided to implement rubber bases at the base of the Extend-a-Stick. We acquired one-legged and four-legged bases and gave them both to Mr. Gandhi. They are exchangeable and he can use whichever he likes.

Rationale

We chose to use rubber bases because they have high surface-to-surface friction. Therefore, the Extend-a-Stick will be less likely to slip out from under a user as downward force is applied to it. A one-legged base takes up less space but has less contact with the ground and therefore less friction (more slipping). A four-legged base takes up more space but has more contact with the ground, more friction, and less slipping.



Figure 7: One-legged Rubber Base.
Photo taken by Alexander Patt



Figure 8: Four-legged Rubber Base.
Photo taken by Alexander Patt

Limitations and Directions for Future Development

The Extend-a-Stick is a fully functional solution to our design problem. In 12 weeks, with a \$150 budget, we ideated, designed, and fabricated an electrical-powered, rechargeable, discreet, portable, safe, and sturdy extendable walking stick that serves as a sit-to-stand aid for a user with weakened leg muscles.

With a larger budget and more time, though, the Extend-a-Stick can be improved upon.

Expanded Testing

Though we were able to test the electrical specs of our linear actuator, we were unable to test the actual downward or radial force load capacity of the linear actuator. We relied on the specs found online (220 lbs of force, see Appendix M) but did not test our linear actuator. Future teams should test these as not knowing the exact number can be dangerous for a heavier user approaching the theorized 220 lbs limit.

Safety and Fault Analyses

For budgetary reasons, we used a \$33.99 linear actuator in our final prototype. Industry standard linear actuators cost thousands of dollars (See Appendix I). While functional, our linear actuator runs on a 12 V battery and can only support ~220 lbs. Additionally, there is no way of knowing when the linear actuator may begin to falter, but a more expensive one would likely last longer. With its low power, the linear actuator moves slowly and loudly. These two aspects make the use of our prototype inefficient and less discreet than desired. A higher quality (more expensive) linear actuator would mitigate both of these issues and the safety concerns from eventual wear and tear. Future teams may also choose to use lightweight foam inside of the case surrounding the motor to effectively soundproof it.

Alternative Solutions

One of our theorized solutions to the design problem was a “seat lift elevator.” The user would sit on the device, and it would elevate the user to their optimal standing height. They can then stand up much more simply and comfortably. However, the energy necessary to pull off this design, the lightweight materials and motors made it unfeasible with our budget and time. We recommend this design, used in tandem with the Extend-a-Stick, as the optimal solution.

Conclusion

To recall, our design challenge was to fabricate a sit-to-stand aid that alleviates the strain placed on leg muscles when standing up. Not only did we make a sit-to-stand aid, we also made a walking stick that integrates into Mr. Gandhi's life, as he was already using a walking stick. Mr. Gandhi wanted a device that was discreet, portable, strong, safe, and sturdy, easily deployable, and comfortable.

The extend-a-stick meets all of Mr. Gandhi's requirements, and functions as a solution to the design problem.

As mentioned in the Executive Summary. The Extend-a-Stick is:

- **Motorized:** The Extend-a-Stick's motor reduces muscle exertion, mitigating potential progression of muscular dystrophy.
- **Portable:** The Extend-a-Stick weighs just over 5 lbs. It also has a soft, cushioned handle that makes use comfortable, not strenuous.
- **Discreet:** The Extend-a-Stick is black, blending into most environments. With a case covering the electrical wiring, it looks like the average walking stick.
- **Versatile:** Not only does the Extend-a-Stick function as a sit-to-stand aid, it too fits into Mr. Gandhi's daily life as a walking stick. It can be used in any location in which there is sufficient space for a walking stick. At a maximum height of 52 inches, it too functions as the first "tall" cane.
- **Stable:** The Extend-a-Stick's exchangeable rubber bases provide ample friction with any ground surface. Additionally, the linear actuator's steady extension ensures stability and safety when standing.

If mass-produced, the Extend-a-Stick would benefit from a higher quality linear actuator, and a more resilient material composing the battery case. A higher quality linear actuator could support more weight, move faster, and move quieter. Additionally, if the battery case was aluminum rather than plastic, it would not crack when dropped (something that can often happen to walking sticks).

Appendix A: Secondary Research: Muscular Dystrophy and Sit-to-Stand Background

Introduction

The topic of this appendix is background research on the genetic disorder Muscular Dystrophy (MD) and the sit-to-stand motion. We researched this topic because our project partner, Monil Ghandi, has muscular dystrophy. We wanted to attain a background level of understanding of the disorder before interviewing him and figuring out ways to mitigate the strain placed on leg muscles in his sit-to-stand movements.

Research areas:

- What is muscular dystrophy's effect on joints and muscles?
- What muscle groups are involved in sit-to-stand movement?
- Which muscles does MD typically affect?
- How does MD progress?

Methods

We looked for sources in medical databases about Muscular Dystrophy and the Sit-to-Stand motion. Databases we found were from the government, and a few miscellaneous databases off Google.

- **Databases, Search Engines, Websites:**
 - PubMed: (National Library of Medicine's Database)
 - Longdom Publishing SL
 - PLOS Medicine Journal
- **Keywords:**
 - "Muscular Dystrophy," "MD," "Muscle," "Joint," "Stand-up," "Sit-down," "Sit-to-stand," "muscle weakness," "tendon weakness."
- **Date Range:**
 - N/A
- **Inclusion / exclusion factors:**
 - N/A
- **Number of sources:**
 - 14
- **Other kinds of sources:**
 - N/A

Results

Table 1: Muscular Dystrophy Findings

Table 1 elicits the types, effects on the patient and progression of muscular dystrophy for different kinds

Topic	Findings	Source
Duchenne/Becker muscular dystrophy (DMD/BMD)	-Caused by a mutation of the dystrophin gene -Lack of dystrophin causes muscle regeneration to diminish over time -BMD typically has later onset and higher dystrophin levels ~14/100,000 males ages 5-24 are affected	[10] [12]
Emery-Dreifuss muscular dystrophy (EDMD)	-joint contractures -progressive weakness -affects the heart - impacts ~33,000 people worldwide (~1 in 250,000)	[18]
Myotonic dystrophy (DM)	-Caused by expansion of DNA tandem repeats in certain genes -Weakness of distal muscles, gradual muscle weakness, impairment of motor function -Onset occurs in adulthood	[7]
MD's Effect on Muscles	-“Continuous weakness” -“Diminishing and degeneration of the muscles, size, mass, and bulk” -“Change in overall posture and reduction of weight”	[1]
MD's Effect on Joints	-As MD wears away at muscles, extra strain is placed on joints -Symptoms: increased rigidity, contractures, symmetric weakness, deterioration, tendon shortness	[1]
MD's Progression	-MD progresses differently depending on the patient and type -Ranges from “potential improvements to rapid deterioration” -Assessments: North star ambulatory assessment, six minute walk test, four stairs climb, MRI, patient reported outcomes -Vignos scale and brook scale used to classify severity of MD	[7] [6]

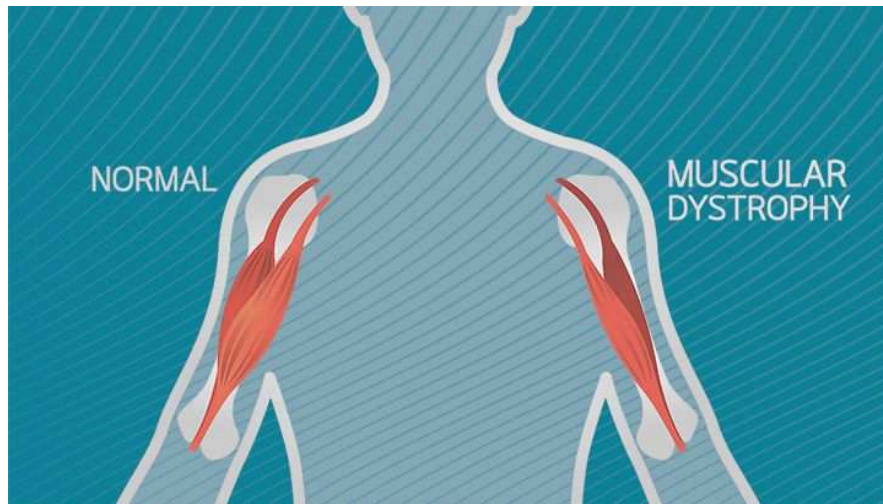


Figure 1: A Bicep with and without Muscular Dystrophy, Source: [15]
Notice the muscle atrophy on the right arm (the one with MD).

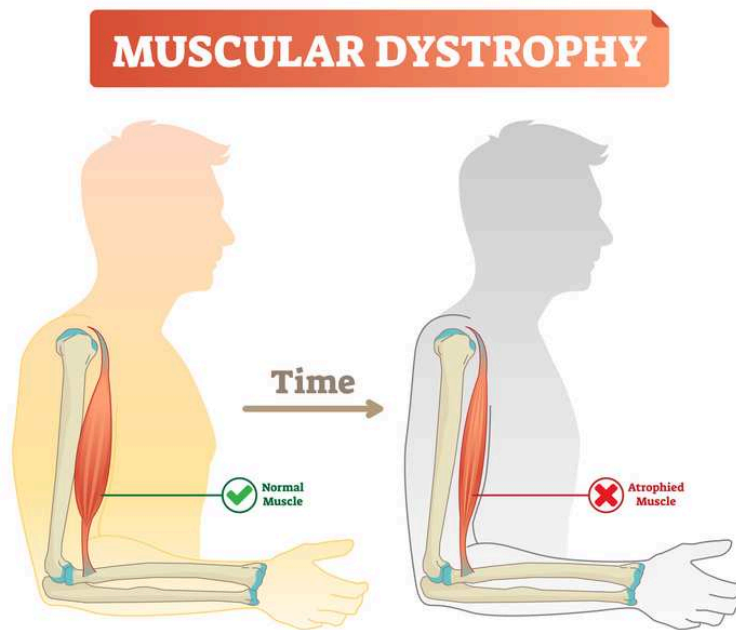


Figure 2: A Joint with and without Muscular Dystrophy, Source: [2]
Notice the muscle atrophy on the bicep on the right compared to the fully developed muscle on the left.

Our project partner's reasoning for coming to DTC with his issue is his trouble with Sit-to-Stand. If we can isolate which muscles are used in Sit-to-Stand and figure out how to best support those muscles with our design, then our project will be most effective.

Table 2: Sit-to-Stand Findings

Topic	Findings	Source
Muscle Groups used in Sit-to-Stand	-Many muscle groups are used when standing up: quads, hamstrings, calves, glutes, lower abdominal muscles	[5]
Specific Leg Muscles	-Vastus Medialis, Rectus Femoris, Tibialis Anterior, Biceps Femoris, Soleus, Erector Spinae	[4]

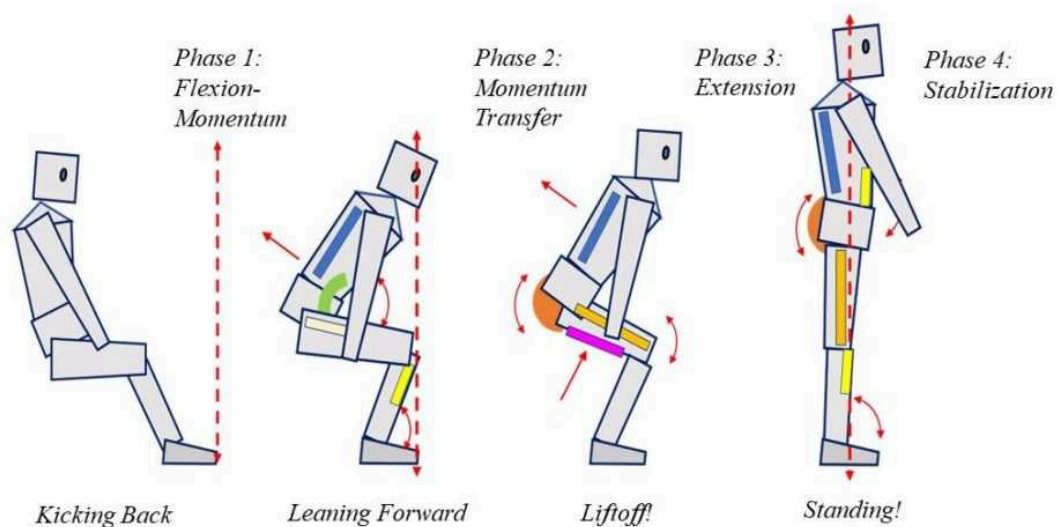


Figure 4: The muscles used in standing up [17]

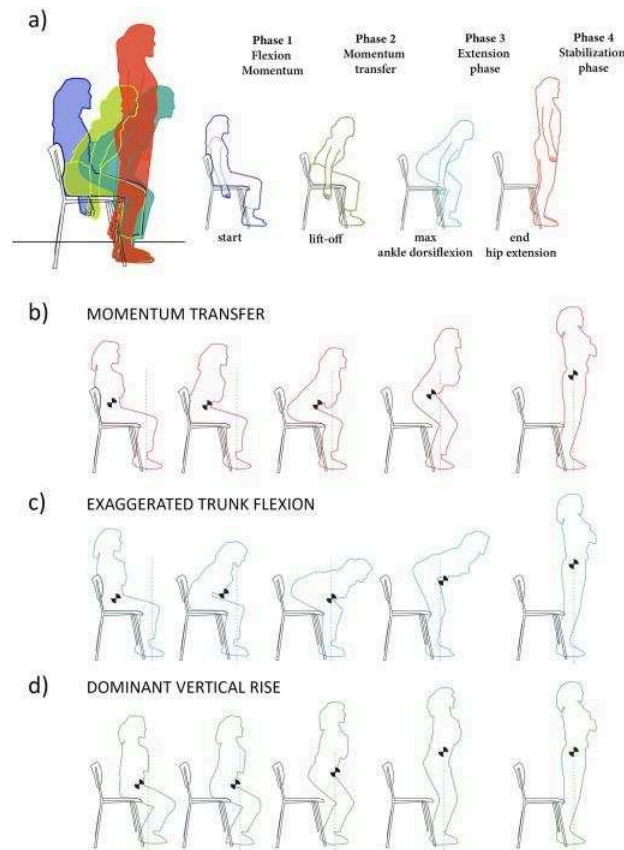


Figure 5: The process of standing up [16]

Analysis, Conclusions and Recommendations

Analysis

The clearest pattern we have noticed in all of the muscular dystrophy research our group conducted is weakness. Muscular dystrophy weakens muscles, which weakens joints and tendons. The disorder appears to cause a positive feedback loop. Muscle/joint/tendon systems in legs rely on each other, as each gets increasingly weaker, those around it get overused, until they too are weak. It also seems like muscular dystrophy only tends to get worse. It seems the best case scenario for one with MD is “potential improvement,” while the alternative on the other extreme is “rapid deterioration.” [7]

As for Sit-to-Stand, it is a more complex process than it feels like. A slew of muscles are used in standing up from a seated position, and the seat height appears to be a key factor in which specific muscles are used most. However, it seems the quads, hamstrings, and glutes are always a factor. Upper body muscles can also play a vital role in support for the rest of the body, especially in the case of someone with weaker leg muscles/joints.

Key conclusions and recommendations

- Our project partner's leg muscles may get weaker over time, especially with overuse.
- Our design should look to alleviate leg muscles strain, and/or rely more on upper body strength.
- Our design can re-invent the process of standing up to use different muscle groups than the typical, overworked ones.
- Interview physical therapists to find exercises that simulate the strain from Sit-to-Stand to help with simulation.
- Investigate further into the specific type of muscular dystrophy that our project partner has.
- Ask project partner about any recent newfound weakness.

References

- [1] B. Alaniz, T. Alghamdi, H. Alhaji, H. Alghalaf, H. Aldossary, K. Aldajani, R. Altoaibi, and S. S. Moihiuddin, "A comprehensive review study on muscular dystrophy and its associated impact on health and individuals," *Orthopedic & Muscular System: Current Research*, vol. 8, no. 1, Art. no. 265, Dec. 2018.
- [2] M. McConnell, "Muscular dystrophy – Mitchell McConnell AEP," *Vision Health*, <https://www.visionexercisephysiology.com.au/muscular-dystrophy-mitchell-mcconnell-aep/> (accessed Sep. 22, 2025).
- [3] "Muscular dystrophy," *National Institute of Neurological Disorders and Stroke*, <https://www.ninds.nih.gov/health-information/disorders/muscular-dystrophy> (accessed Sep. 18, 2025).
- [4] C. Roldán-Jiménez, P. Bennett, and A. I. Cuesta-Vargas, "Muscular Activity and Fatigue in Lower-Limb and Trunk Muscles during Different Sit-To-Stand Tests," *PLOS ONE*, vol. 10, no. 10, p. e0141675, Oct. 2015, doi: <https://doi.org/10.1371/journal.pone.0141675>.
- [5] A. Sigust, "The Muscles You Use to Sit and Stand: A Complete Guide," *EverydayHealth.com*, 2025. <https://www.everydayhealth.com/workouts-activities/the-muscles-used-sit-stand> (accessed Sep. 20, 2025).
- [6] Y.-J. Lue, R.-F. Lin, S.-S. Chen, and Y.-M. Lu, "Measurement of the Functional Status of Patients with Different Types of Muscular Dystrophy," *The Kaohsiung Journal of Medical Sciences*, vol. 25, no. 6, pp. 325–333, Jun. 2009, doi: [https://doi.org/10.1016/s1607-551x\(09\)70523-6](https://doi.org/10.1016/s1607-551x(09)70523-6).
- [7] S. Benemei, F. Gatto, L. Boni, and M. Pane, "‘If You Cannot Measure it, You Cannot Improve it’. Outcome Measures in Duchenne Muscular Dystrophy: Current and Future Perspectives," *Acta Neurologica Belgica*, vol. 1, no. 12, Jul. 2024, doi: <https://doi.org/10.1007/s13760-024-02600-2>.
- [8] Mayo Clinic, "Muscular Dystrophy - Diagnosis and Treatment - Mayo Clinic," *Mayoclinic.org*, Feb. 11, 2022. <https://www.mayoclinic.org/diseases-conditions/muscular-dystrophy/diagnosis-treatment/drc-20375394>
- [9] Parent Project Muscular Dystrophy, "Progression," *Parent Project Muscular Dystrophy*, Sep. 28, 2021. <https://www.parentprojectmd.org/about-duchenne/what-is-duchenne/progression>
- [10] V. Venugopal and S. Pavlakis, "Duchenne Muscular Dystrophy," in *StatPearls, Treasure Island (FL): StatPearls Publishing*, 2025. Accessed: Sept. 22, 2025. [Online]. Available: <http://www.ncbi.nlm.nih.gov/books/NBK482346/>

- [11] “Duchenne Vs Becker Muscular Dystrophy | Key Differences Explained,” Knya. Accessed: Sept. 22, 2025. [Online]. Available: <https://knyamed.com/blogs/difference-between/duchenne-vs-becker-muscular-dystrophy>
- [12] CDC, “Types of Muscular Dystrophy,” Muscular Dystrophy. Accessed: Sept. 22, 2025. [Online]. Available: <https://www.cdc.gov/muscular-dystrophy/types/index.html>
- [13] D. G. Vydra and A. Rayi, “Myotonic Dystrophy,” in StatPearls, Treasure Island (FL): StatPearls Publishing, 2025. Accessed: Sept. 22, 2025. [Online]. Available: <http://www.ncbi.nlm.nih.gov/books/NBK557446/>
- [14] P. A. Romitti et al., “Prevalence of Duchenne and Becker muscular dystrophies in the United States,” *Pediatrics*, vol. 135, no. 3, pp. 513–521, Mar. 2015, doi: 10.1542/peds.2014-2044.
- [15] B. P. Dunleavy, “What are the signs and symptoms of muscular dystrophy?,” EverydayHealth.com, <https://www.everydayhealth.com/genetic-diseases/what-are-the-signs-and-symptoms-of-muscular-dystrophy/> (accessed Sep. 22, 2025).
- [16] E. van der Kruk, “Compensation due to age-related decline in sit-to-stand and sit-to-walk - sciencedirect,” ScienceDirect, <https://www.sciencedirect.com/science/article/pii/S0021929021001913> (accessed Oct. 3, 2025).
- [17] “Sit to stand,” HackMyMS, <https://hackmymms.com/index.php/sit-to-stand/> (accessed Oct. 29, 2025).
- [18] MedlinePlus, “Emery-Dreifuss muscular dystrophy,” MedlinePlus, <https://medlineplus.gov/genetics/condition/emery-dreifuss-muscular-dystrophy/#:~:text=Emery%2DDreifuss%20muscular%20dystrophy%20is,increased%20risk%20of%20sudden%20death.> (accessed Dec. 8, 2025).

Appendix B: Existing Therapeutic and Assistive Approaches for Muscular Dystrophy and Sit-to-Stand Mobility

Introduction

This appendix conducts secondary research on existing approaches addressing muscular dystrophy and related mobility issues. Specifically, this appendix is going to focus on the assistive technologies designed for helping sit-to-stand (STS) movement. The objective of this appendix is to identify the strengths and limitations of existing solutions, evaluate the applicability of those solutions in our research case, and obtain potential design inspirations.

This appendix tries to answer the following key questions:

- What is muscular dystrophy and what are some typical challenges it poses?
- Are there existing solutions to cure or relieve muscular dystrophy?
- What are some mobility aids designed for sit-to-stand movement?
- How effective are these aids in terms of usability, portability, or even biomechanics?
- What are some areas for improvements?

Methods

- **Databases:** Google Scholar, PubMed, ScienceDirect, ResearchGate, JSTOR, EBSCO, and Semantic Scholar
- **Keywords:** “muscular dystrophy,” “sit-to-stand,” “mobility aids,” “assistive devices,” “orthoses,” “exoskeleton,” “rehabilitation robotics.”
- **Date range:** 2007-2024
- **Inclusion factors:** Peer-reviewed studies published on engineer or medical journals directly relevant to muscular dystrophy and STS
- **Exclusion factors:** General mobility aids not related to STS,
- **Number of sources:** 10 references

Results

Muscular Dystrophy

Muscular dystrophy is a type of muscle disease that leads progressive weakening in skeletal muscles (muscles attached to bones responsible for movement, posture, and temperature regulation), and it differs in parameters like which muscles are primarily affected, the degree of weakness of bones, how fast they become worse, and when the symptoms for this disorder begin [2]. In our partner's case, the weakening of muscle groups located at the lower body made him especially struggle on STS.

Existing Assistive Solutions

Unfortunately, there is no present cure for muscular dystrophy. Current treatment approaches include “optimizing growth and development, promoting well-balanced diet, participating in physical and recreational activity, and delaying the onset of secondary complications through ongoing medical and psychosocial support [10].”

Additionally, there is an approach to slow the progressive weakening of muscles. Using orthotics support with the combination of using certain medications at early stages of disease can extend a patient's walking ability for years. Typical examples include knee-ankle-foot orthoses (KAFOs), and medications such as corticosteroids [8].

Physical supports also serve as an important part of restoring a patient's independence and treating muscular dystrophy. The table below summarizes the assistive devices found during the research and evaluates their effectiveness for STS movement.

Table 1: Assistive devices for STS movement

Device(s)	Function	Strength(s)	Limitation(s)	Source
Typical standing devices (frames, sticks, orthoses)	Provide strong and stable physical support	Using standing support could preserve muscle strength and joint via a stretch that occurs during standing. Relatively cheap compared to other devices.	Not effortless	[1]
Smarter wheelchair with seat lift	Provide autonomous mobility aids with lifting seat	Having independence to a great extent	Not portable	[2]

Multi-functional assistive device	Provide mobility aids while having effortless standing support	Follow natural body trajectories for standing assist, which minimize joint stress and reduce compensatory behaviors	Not portable and still under development	[3]
Exoskeletons (CUHK, HAL)	Provide extra strength to lower limbs	Effective restore the moving ability of patients	Not portable and hard to wear. Expensive compared to other devices	[5]
Pressure-sensor STS chair	Lifting seats with adaptive force support	Effortless standing process due to the adaptive lifting process	Prototype stage and not yet matured	[6]
Vertical lift walker	Provide physical support with energy released by the spring attached below	Lightweight, non-powered	Limited using circumstances	[7]
Powered orthoses	Provide extra torque on knee	Strong standing support	Heavy and not user friendly	[9]

Analysis, Conclusions, and Recommendations

Analysis

While having those effective assistive devices for STS movement listed in Table 1, there are still several places that need to pay attention to when the project progresses. First, portability should always play a great role in this project's design. Devices such as wheelchairs can sometimes be unportable. Second, usability is another important concern in the final design. While exoskeletons can provide extremely effective support on lower limbs, they are cumbersome and hard to equip independently. Thirdly, in order to prevent the brain from learning unhealthy compensatory behaviors, the final design of this project should follow natural human body trajectories. This is because the natural trajectory minimizes stress on joints and unnecessary movement of muscles, which is ideal due to the effortless process.

Additionally, it is important to notice that each muscular dystrophy patient has slightly different symptoms that might bring variations on the ideal selection of assistive devices. In our partner's case, the weakening of the lower body as well as the triceps bring difficulties in not only

standing up but also pulling up. Therefore, it's significant to take individual considerations into the final design.

Key Conclusions and Recommendations

- Prioritize portability, usability, as well as STS biomechanics into the final design.
- Taking into account the individual needs of our partner. For instance, his triceps doesn't allow him to pull him up or serve as a stable source of support. Then the design shouldn't require him to use that part of the body.
- Explore hybrid solutions but not solely focus on one exact device.
- Research on cheap, lightweight, and strong material that can bear enough weight.

References

- [1] K. Pedlow, S. McDonough, S. Lennon, C. Kerr, and I. Bradbury, “Assisted standing for Duchenne muscular dystrophy,” *Cochrane Database of Systematic Reviews*, Oct. 2019, doi: <https://doi.org/10.1002/14651858.cd011550.pub2>.
- [2] A. Tony Thomas, K. V. Mahesh Kumar, S. K. Thangarasu, and S. Naveen Saravanan, “Design and Development of Mobile AID for Muscular Dystrophy,” *IOP Conference Series: Materials Science and Engineering*, vol. 1055, no. 1, p. 012046, Feb. 2021, doi: <https://doi.org/10.1088/1757-899x/1055/1/012046>.
- [3] Anurag Purwar, K. Bhargava, and E. Behan, “A multi-functional mobility assist device for sit-to-stand motion,” *International Journal of Industrial Ergonomics*, vol. 93, pp. 103396–103396, Jan. 2023, doi: <https://doi.org/10.1016/j.ergon.2022.103396>.
- [4] F.-C. Wang, C.-H. Yu, Y.-L. Lin, and C.-E. Tsai, “Optimization of the Sit-to-Stand Motion,” *IEEE/ICME International Conference on Complex Medical Engineering*, pp. 1248–1253, May 2007, doi: <https://doi.org/10.1109/iccme.2007.4381943>.
- [5] Y. Xu *et al.*, “Design and Evaluation of the Sit-to-Stand Movement Assistive Device for Elderly,” *Actuators*, vol. 13, no. 3, pp. 102–102, Mar. 2024, doi: <https://doi.org/10.3390/act13030102>.
- [6] K. Lee, S. Ha, K. Lee, S. Hong, H. Shin, and G. Lee, “Development of a sit-to-stand assistive device with pressure sensor for elderly and disabled: a feasibility test,” *Physical and Engineering Sciences in Medicine*, vol. 44, no. 3, pp. 677–682, Jun. 2021, doi: <https://doi.org/10.1007/s13246-021-01015-0>.
- [7] T. C. Bulea and R. J. Triolo, “Design and Experimental Evaluation of a Vertical Lift Walker for Sit-to-Stand Transition Assistance,” *Journal of Medical Devices*, vol. 6, no. 1, Mar. 2012, doi: <https://doi.org/10.1115/1.4005786>.
- [8] A. C. Pardo, T. Do, T. Ryder, A. Meyer, L. Miles, and B. L. Wong, “Combination of steroids and ischial weight-bearing knee ankle foot orthoses in Duchenne’s muscular dystrophy prolongs ambulation past 20years of age – A case report,” *Neuromuscular Disorders*, vol. 21, no. 11, pp. 800–802, Nov. 2011, doi: <https://doi.org/10.1016/j.nmd.2011.06.006>.
- [9] W. R. Eby and E. Kubica, “Modeling and Control Considerations for Powered Lower-Limb Orthoses: A Design Study for Assisted STS,” *Journal of Medical Devices*, vol. 1, no. 2, pp. 126–139, Sep. 2006, doi: <https://doi.org/10.1115/1.2735969>.

[10] J. Mah, “Current and Emerging Treatment Strategies for Duchenne Muscular Dystrophy,” *Neuropsychiatric Disease and Treatment*, vol. Volume 12, no. 12, pp. 1795–1807, Jul. 2016, doi: <https://doi.org/10.2147/ndt.s93873>.

Appendix C: Initial Project Partner Interview and Sit-to-Stand Demonstration

Date: September 24, 2025

Time: 5:00 PM—5:40 PM

Location: DTC Classroom, Ford Design Center, Room G211

Team members in attendance: Max Kaung, Kevin Yan, Alex Patt

Other key attendees: DTC Section 13 Teams 1, 2, and 4

Project partner

- Monil Gandhi
- CIO
- Self-employed

Initial Interview

Mr. Monil Gandhi visited Northwestern University campus and was interviewed in our DTC classroom. The interview was conducted by having each team ask a series of questions. We were granted permission by the project partner to take photos and video recordings of his sit-to-stand motions.

The purpose of this interview was to receive answers from our project partner for preliminary questions about his muscular dystrophy. This included the type of muscular dystrophy he has, his current methods of standing up from a sitting position, and his requirements for the project design.

Design problem overview

In his project description, Mr. Gandhi stated that he has a muscular disease called muscular dystrophy, which has progressed in his leg muscles to the extent that he finds standing up from chairs of typical heights to be very difficult and exertive, especially when sitting for long periods of time. In order to stand up from a sitting position, Mr. Gandhi requires a walking stick or table to support his weight and allow him to use his upper body as he stands up. However, he has found that the walking sticks and tables are not always stable enough to support his weight, nor are they always an option depending on the context of where he is sitting. Other solutions and compensatory strategies Mr. Gandhi uses require high amounts of effort and sufficient space, which is not ideal. Consequently, Mr. Gandhi would like a device that could allow him to rise from a sitting position independently while expending less energy. He is not particularly interested in a solution that allows him to stand up faster but rather one that would decrease the effort of sit-to-stand (STS) motions while also being relatively portable and discreet in public. Mr. Gandhi specifically mentioned restaurants and theaters as locations where he would like this device to be suitable.

Mr. Gandhi's Muscular Dystrophy

Muscular dystrophy is a disease that causes the degeneration and weakening of muscles. Muscular dystrophy typically continues to worsen over time, causing some muscles to be unable to support any weight, and ultimately leading muscles in the heart and lungs to degenerate and cause death.

Mr. Gandhi explained that he was diagnosed with a type of muscular dystrophy called Emery Dreifuss. This type of muscular dystrophy is connected to muscle weakness throughout the upper and lower body, as well as stiff joints with limited ranges of motion.

Muscles Influenced by Emery Dreifuss

Mr. Gandhi explained that his muscular dystrophy primarily causes weakness in his lower body leg muscles, such as his quadriceps, which makes it difficult to stand up or walk. In fact, without a walking stick to act as support or when sitting in particularly low chairs, he is completely unable to stand up without assistance. Because of the hassle of STS motion, he often chooses to stand. Additionally, he commented on the tightness and weakness in his hamstrings and heels, making it difficult for him to walk without locking his knees and standing on the balls of his feet. Regarding his upper body strength, Mr. Gandhi stated that his arm and shoulder strength is weaker, but not so weak that it significantly impairs his daily life. His range of motion in his arms is very limited, with his right elbow being constrained to about 90 degrees or less and his left arm at angles less than 120 degrees. Fortunately, his muscular dystrophy has not influenced his grip strength significantly.

Mr. Gandhi communicated that he had managed the cardiac issues related to his muscular dystrophy and that his difficulty in STS motions was to be the main focus of this project. Overall, his muscular dystrophy is relatively stable, and so the solution does not need to overly accommodate for progressions in his condition.

Personal Solutions and Strategies to STS Motion

Mr. Gandhi explained the multiple methods he uses to more easily stand up from a sitting position and also demonstrated the process of standing up from sitting with a walking stick or using a table. Mr. Gandhi explained his STS motion in three main steps:

1. Prop his weight on his walking stick or on the table using his forearms
2. Widen his stance and lock his knees
3. Slowly shuffle his legs together to fully stand up

This strategy allows Mr. Gandhi to utilize more of his upper body strength while reducing the strain on his quads by locking his knees. When bracing on the table, due to having a weaker and tighter right elbow, he usually places his right hand on the table and raises his elbow up. His left forearm lies flat on the table to eliminate the elbow as a point of failure when using his shoulder to push up.



Figure 1. (Left) Mr. Gandhi standing up from a tall chair using a table. His left forearm is braced on the table as he widens his stance and locks his knees.

Figure 2. (Right) Mr. Gandhi completing his sit-to-stand motion. He reaches and upright position by shuffling his legs together.

Photos by DTC section 13 teams.



Figure 3. (Left) Mr. Gandhi standing up from a seated position using his hiking stick. His hiking stick is placed between his legs and braced against his shoulder so he can use his upper body to raise his hips and straighten his legs. He adopts a wide stance so he can lock his knees at a lower height.

Figure 4. (Right) Mr. Gandhi completing his sit-to-stand motion with his hiking stick. The height of the hiking stick allows him to support himself with his right arm without straightening it.

Photos by DTC section 13 teams.

When rising from a booth, he described a different method of standing up, where he rotates around and places his knee on the seat, grabbing the top of the booth behind him to help pull his weight up and straighten his legs.

STS Assistive Devices

The primary device Mr. Gandhi uses to aid his STS motions on a daily basis is his hiking stick. Mr. Gandhi reported that his hiking stick is extendable, allowing him to set it to a taller height

that he can lean on to reach a standing position. Additionally, the hiking stick has a rubber tip, allowing it to both support his weight when standing and absorb impacts when walking with it. Outside of his hiking stick, Mr. Gandhi has not looked into or tested any other mobility devices for STS motion. When prompted for a reason why he has not tried seat lifts, he explained that his muscular dystrophy only recently progressed to a point where he would like a device to help him stand.

Project Requirements and Regulations

Mr. Gandhi helped clarify both the types of seats he would like to be able to independently stand from as well as other requirements for the product.

Product Functionality: Locations, Chairs, and Contexts

The product should be able to accommodate STS motion in:

- Low to average height chairs
- Seats with limited standing space
- Seats without tables
- Seats with/without armrests
- Seats with soft ground in front
- Soft compressing chairs
- Restaurant chairs
- Restaurant booths
- Theater/Auditorium seats
- Car passenger seat (if possible)

Product Functionality: Requirements

- The product does not need to allow him to complete STS motion faster, but it should significantly reduce the effort required to stand and be a product that he can use independently.
- The product should not force him to lean backwards, as he feels unstable.
- The product should be as discreet as possible, as he would like to use it in public without drawing attention.
- The product shouldn't raise his seat while sitting, as he would like to sit at the same level as his peers.
- The product should be relatively light and portable, allowing him to bring it to any scenario without more than a backpack.

Future Contact

Mr. Gandhi will be able to answer all questions and visit Northwestern University campus for interviews and observation sessions every Wednesday from 5:00-6:30 pm. He is also willing to accommodate observation sessions at his home in Lincoln Park.

Analysis, conclusions and next steps

This interview with Mr. Gandhi provided very useful information on the process he used to stand up as well as the specifications he wants for the product. Mr. Gandhi has a type of muscular dystrophy called Emery Dreifuss, which should be further researched to gain insight on the specific muscles that are weakened and the disease's progression. Mr. Gandhi's demonstrations of STS motion with a table and with his hiking stick allows us to identify strategies that he finds helpful, and those strategies can be incorporated into the final product. For example, the product may benefit from focusing on increasing his seat height or providing a stable surface to push off from. Mr. Gandhi also clarified the specifications he would like for the product, most important being that he does not necessarily need the product to increase the speed of his STS motion, that the product should focus on being as discreet as possible, and that the product should be functional in public seats like a restaurant or theater. Future research should focus on further investigation of the exact processes of Mr. Gandhi's STS motion. Mr. Gandhi confirmed his ability to attend a 10/1/2025 observation session in the same DTC classroom.

Next Steps

- Conduct research on the symptoms and progression of the Emery Dreifuss type of muscular dystrophy.
- Conduct research on the typical dimensions of the chairs and seats Mr. Gandhi would like the product to help him stand up from.
- Continue to research existing STS assistive devices.
- Develop an observation plan for the 10/1/2025 observation session and gather chairs to observe STS movement from.
- Attend the user observation, observing Mr. Gandhi's STS motions for various types of chairs.
- Develop plan and acquire any necessary materials for the following observation session at Mr. Gandhi's home in Lincoln Park.

Appendix D: User Observation of Sit-to Stand Movements in Various Environments

Date: Wednesday, October 1, 2025

Time: 5:00 PM – 6:00 PM

Location: Ford G211

Team members in attendance: Axel, Max, Kevin

Other key attendees: Mr. Gandhi, members of teams 1, 2, and 4

Objectives

1. Obtain various qualitative measurements from Mr. Gandhi, including height, weight, hip-to-floor height, and elbow ROM
2. Observe how Project Partner approaches sit-to-stand movement from various chairs of different heights and constitutions

Observation conditions

The observation was conducted in a small classroom setting with adequate lighting for video capture and enough open space for Mr. Gandhi to move freely and complete all requested tasks. Chairs and tables of various heights around the room meant that some extra movement was required for Mr. Gandhi to progress through the observation. Mr. Gandhi completed tasks at the front of the room with approximately 15 observers present, of which a majority were notetakers.

Session overview

1. Brief overview of observation goals and tasks
2. Observation and recording of sit-to-stand motion from various chair heights and assisted with various table heights
3. Follow-up inquiries related to various motions to gauge user's level of comfort and muscular strain
4. Collection of user measurements including height, weight, hip-to-floor height, hand length, arm length, and optimal leverage point height
5. Questions about user's experiences in challenging environments and solutions/tricks user has developed to tackle difficult situations
6. Observation and recording of sit-to-stand motion from booth-style seating
7. Debrief and scheduling/planning of next observation

User overview: Mr. Monil Gandhi

- Emery Dreifuss muscular dystrophy
- Uses walking stick for everyday mobility assistance
- Muscle weakness targeting both upper and lower body
- Greatly increases difficulty of sit-to-stand movements



Figure 1: Walking stick. Mr. Gandhi uses this extendable walking stick (pictured above) when walking for added stability. The stick is extendable and features a rubber tip which improves traction and shock absorption for any movements he performs with it.

Photo by Axel Hinz

Observation Session 1: Chair/surface heights

Sit-to-stand movement from stool (25.5 inches)

1. *Adjusts stance:* Mr. Gandhi shifts forward in the chair and widens his stance as much as possible. He explains that this gives him a stable enough base to push off from when attempting the STS movement. He comments that chair arms and other environmental obstacles can make this more difficult to accomplish.
2. *Pushes off of table:* Mr. Gandhi places his left forearm and right hand on the surface in front of him to maximize the leverage of his arms. He explains that his left arm is stronger than his right, so despite his right-handedness, he often relies more on his left arm in the STS movement. In one motion, he leans forward onto the surface and then pushes off the surface with his arms to reach a wide standing position.
3. *Adjusts stance again:* Now in a standing position, Mr. Gandhi shuffles his feet inwards to reach a comfortable standing position. He explains that his knees need to be locked when standing and walking because it is the only way he can adequately support his weight, so this movement must be done with outstretched legs.



Figure 2: Mr. Gandhi pushes off from the table. Notice that he places much of his weight on the table and relies heavily on his upper-body strength to complete the motion. While he doesn't comment on the difficulty of the motion, it is evident from his facial expressions and the relatively long period of motion that the movement is physically taxing.

Photo by Axel Hinz



Figure 3: Mr. Gandhi reaches a standing position. Notice that he locks his knees outwards to ensure a stable standing position. He is then able to remove his hands from the surface and complete the motion by shuffling his feet inward.

Photo by Axel Hinz

Data collection

- Height: 5' 11"
- Weight: 175 lbs.
- Floor-to-hip height: 43.5"
- Hand length: 8"
- Forearm length: 13.5"
- Optimal leverage surface height: 35"
- Left arm can bend to angles less than 120°
- Right arm bent at around 90°, mostly fixed in place

Observation trends:

The sit-to-stand movement was assessed using multiple chair heights and types, and some general trends could be observed throughout the observation. These trends are listed below in no order of importance:

- Higher chairs resulted in less muscle strain during sit-to-stand movement. This was observed through total time elapsed between sitting and standing, which decreased with increasing chair height, as well as facial cues and user comments that confirmed this.
- Higher chairs required a higher surface off of which to push. However, the user confirmed that for standard chair height (between 19"-23"), the optimal surface height was 35".
- Chairs without arms (like stools and barstools) were less challenging for the user to approach because they allowed for a wider leg stance, which was confirmed by user comments when asked.

Other variations:

Some variations to the movement were observed when user interacted with different chairs and surfaces, and they are listed below:

- From higher chairs, Mr. Gandhi was able to complete the movement without leaning on his left forearm.
- From booth-style seating, Mr. Gandhi is able to rotate his torso and use the rigid seat back of the booth to push himself up (pictured below in Figure 4)



Figure 4: Mr. Gandhi pushes off from a simulated booth-style seat. He is able to get enough leverage to raise his torso to standing height by pulling himself up on the back of the booth and pushing with his legs.

Photo by Axel Hinz

Analysis, Conclusions, and Next Steps

Table 1: Critical Observations and Potential Responses

Observation	Opportunity	Possible Follow-up
Lower seats more difficult for Mr. Gandhi to stand up from	Reduce the impact of chair height on the movement	Seat lifts and boosters that increase height or reduce gravitational force
Surface misalignment with chair (too high or too low) makes STS movement too difficult	Find way to adjust surface height for minimal muscle strain	Clip-on or folding adjustable platform
Mr. Gandhi would prefer discreet and portable solution	Incorporate solution into existing products that Mr. Gandhi already uses	Create attachment or modification for walking stick

Final conclusions/concerns:

- Keep in mind that space is an important factor in our design. The observation takes place in a large room with enough space for the user to comfortably stretch out. What happens when this is not possible? Can our solution be designed for these situations?
- Continue to observe user interactions with chair, floor space, surface, and any other tools/objects (like walking stick) that can influence or guide our design
- Make sure to capitalize on being in user's own space to take note of ways that he already manages his condition and finds mobility solutions

Appendix E: Observation of Sit-to Stand Movements in the User's Home Environment

Date: October 7, 2025

Time: 5:50 PM – 6:30 PM

Location: Project Partner's Condominium

Team members in attendance: Axel Hinz, Maxwell Kaung

Other key attendees: Members of teams 1, 2, and 4

Project partner

- Monil Gandhi
- CIO
- Self-employed

Observation conditions

The observation was conducted in Monil Gandhi's (Mr. Gandhi) condominium with what was assumed to be a near ideal amount of lighting and space for his sit-to-stand (STS) movements. The lighting was adequate for photo capture, and permission from Mr. Gandhi was obtained to take photos of him and his condominium. Sit-to-stand testing was initially conducted in the lobby of the condo before moving to Mr. Gandhi's personal condo space and testing STS movements with his personal furniture.

Objectives

1. Observe and possibly take photos of the furniture in Mr. Gandhi's home, and record any features of the furniture that impact his sit-to-stand movement
2. Obtain various qualitative measurements from the furniture in Mr. Gandhi's home, such as the height of the chair seats and the height of the tables
3. Observe how Mr. Gandhi's sit-to-stand movement is different when standing from chairs and seat heights he is familiar with

Session overview

1. Brief overview of observation goals and tasks
2. Observation and recording of STS movements from various chairs in the lobby of the condo
3. Initial questions generated between observation sessions and relating to Mr. Gandhi's initial STS movements
4. Observation and recording of STS movements from different furniture items in Mr. Gandhi's living space
5. Collection of furniture measurements including chair height and table height
6. Questions about Mr. Gandhi's preference in his furniture and reason for choosing to use certain furniture items
7. Clarification on the environments Mr. Gandhi would like the design to assist his STS movements in

Observation Session 2: Personal Living Space and Furniture

Mr. Gandhi demonstrated STS movement in three different chair types and stated that he always preferred to sit down in these three types of chairs only. Mr. Gandhi primarily sat in mid-height chairs at his dining table, tall barstools at his island, and on a soft low couch next to the wall.

Mid-height dining table chair

Table 1: The properties of Mr. Gandhi's dining table chairs

Chair Description	Height	Material
A thin gray chair with an average height for a dining table. It has a flat seat, a thin backboard, four legs, and no armrests.	21 in	Leather-like, firm cushion

Mr. Gandhi standing from this chair was the most similar to his STS process when standing from a chair in the Ford DTC classroom from observation session 1. He braced his left forearm on the dining table in front of him and pushed up with his shoulders while widening his stance in order to lock his knees. Then he shuffled his feet together to reach a fully upright position, just as he did in observation session 1.

Mr. Gandhi noted that standing from this chair is more difficult than standing from his barstools, but that the height of this chair is fairly average and will be a common chair height that he will need assistance to stand up from. He usually sits in the chair at the end of the dining table, as it gives him more space to widen his stance when standing.



Figure 1: Mr. Gandhi's dining table setup. The chairs at the dining table are relatively low compared to Mr. Gandhi's ideal chair height, which is more similar to the height of his barstools. Importantly, the table is at the ideal height for Mr. Gandhi to brace his weight when standing up.

Photo by Maxwell Kaung

Figure 2: Dining table chair. The chairs are without a soft cushion or armrests. Mr. Gandhi states that having those features makes the STS movement more difficult due to lowering his sitting height or getting in the way of his hip rotation.

Photo by Axel Hinz

High barstool

Table 2: The properties of Mr. Gandhi's barstools

Chair Description	Height	Material
A tall stool with a solid wooden seat and minimalist form. The seat is slightly concave up, with a metal bar a few inches high serving as a back guard.	N/A	Wood seat, metal legs

Mr. Gandhi again used a very similar motion to stand up from this chair compared to the lower dining table chair. He used the basic process of bracing against the counter, widening his stance, and then shuffling his feet together. The stool being at a higher level meant that he was able to use less effort and start with his legs closer together.

Mr. Gandhi stated that this would be the ideal height to stand up from, should our design influence the height that he starts at. He still needs a surface near him to brace against or stabilize him.



Figure 3: Mr. Gandhi's barstools and countertop. The barstools are significantly taller than the dining table chairs, making them easier for Mr. Gandhi to stand up from. The stool seats are concave up, however Mr. Gandhi did not state whether this had any effect on his STS movement. *Photo by Maxwell Kaung*

Low-height couch

Table 1: The properties of Mr. Gandhi's living room couch

Chair Description	Height	Material
A long L-shaped couch fairly low to the ground. The couch is made with a very soft and compressive foam, covered with a gray fabric. The armrests are completely perpendicular to the seat, and the couch is placed against the wall.	N/A	Fabric, soft cushion, solid armrests

To stand up from the couch, Mr. Gandhi relied on the wall on his left to support himself rather than a table in front of him. Mr. Gandhi followed a similar process to when standing up from a booth, first lifting his waist and rotating around to face the couch, all while using the wall to support his weight. He then widens his stance and slowly pushes off of the wall to shuffle his legs together and stand upright.

Mr. Gandhi noted that he needs the wall to stand up safely and therefore only sits on the far right side of the couch. We found it surprising that he was comfortable sitting down at such a low height, especially with the height decrease from the compression of the cushion.

Forward-slanted seating was briefly tested by having Mr. Gandhi sit on a sloped foam block. Mr. Gandhi explained that he would slip forward off the seat due to the high angle and low-friction surface, and expressed concern about slanted seat lifts causing him to lose balance and fall forward.



Figure 3: Mr. Gandhi's living room couch. The couch seemed especially difficult for Mr. Gandhi to stand up from due to its extra low seat height and soft cushions. Mr. Gandhi used the booth STS process from observation session 1 and the wall to his left in order to stand up, making it significantly less difficult.

Photo by Axel Hinz

Observation trends:

Mr. Gandhi's sit-to-stand movement was determined to be very similar to his movements in observation session 1. The characteristics of the chairs and seating in Mr. Gandhi's living space was the primary focus during observation.

- Mr. Gandhi uses many different types of chairs in his living space, from tall barstools to a very low, soft couch.
- Similar to observation session 1, Mr. Gandhi is able to stand up from mid-height to tall chairs if he has a stable surface in front of him to bear his upper body weight and stabilize him. In lower chairs, he is able to stand up if the chair has a tall backboard or a nearby wall.

- The most difficult type of chair for Mr. Gandhi to stand up from is a low bench with no nearby table or wall from him to grab onto, such as a park bench.

Analysis, Conclusions, and Next Steps

Table 1: Critical Observations and Potential Responses

Observation	Opportunity	Possible Follow-up
Chairs near a table or wall are significantly easier to stand up from.	Find a way to add a stable surface to support his weight.	Foldable tables that can attach to the chair or rest on the ground.
Low seats require a method of spinning around in his seat, which is inhibited by armrests.	Find mechanisms that can create a force to help him stand up forward.	Powered seat lifts or walking sticks to push him up and forward.
Slanted seat lifts can cause slippage from the seat and imbalance.	Find solutions that reduce his need to balance on his own.	Seat lifts that retain a flat seat.

Final conclusions/concerns:

- A major concern for the project is the conflict between being applicable to many different kinds of chairs and remaining discreet and lightweight. Low seats with no surfaces to attach to are the most difficult to find a solution for.
- While using a force like a spring to make the STS motion effortless is important, even more important is ensuring that the project is safe and stable to use and that there is little risk of the user falling over.
- Again, a major route for solution is bringing the user to the optimal height for standing up, as it has been shown to be one of the safest and easiest ways for Mr. Gandhi to stand up.

Appendix F: Mockups

Mockup 1: Spring Walking Sticks

To address the mobility challenges brought by muscular dystrophy, our project partner currently uses a walking stick as a solution. This design aims to enhance the functionality of conventional walking sticks by integrating a spring mechanism to provide additional lifting assistance. For comfortability concern, this design explores two handle options for the walking sticks. The design also includes height adjustability, allowing the user to achieve an optimal position for sit-to-stand movements across seats of varying heights. There were two mockups developed for this design. The first features a PVC tube with a cushioned handle, while the second incorporates a PVC tube, a cane-style handle, and a locking mechanism.

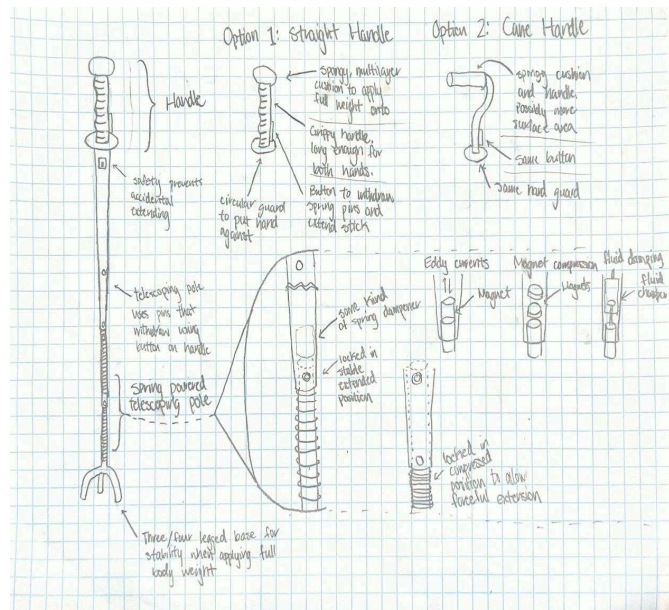


Figure 1: Spring walking sticks. A cushion is placed on the top of the PVC tube to form a rough walking stick. The sketch shows the full design including two optional handles, the illustration of the adjustable feature, the spring mechanism, and the stabilized feet.

Photo by Jixin Yan, graphic by Max Kaung.



Figure 2: Spring walking sticks with cane handle. The cane handle is used in this mockup, as well as the adjustable feature. There are multiple holes on the PVC tube which allow the extendable tube inside to lock at different holes, thus achieving the desired functionality.

Photos by Jixin Yan

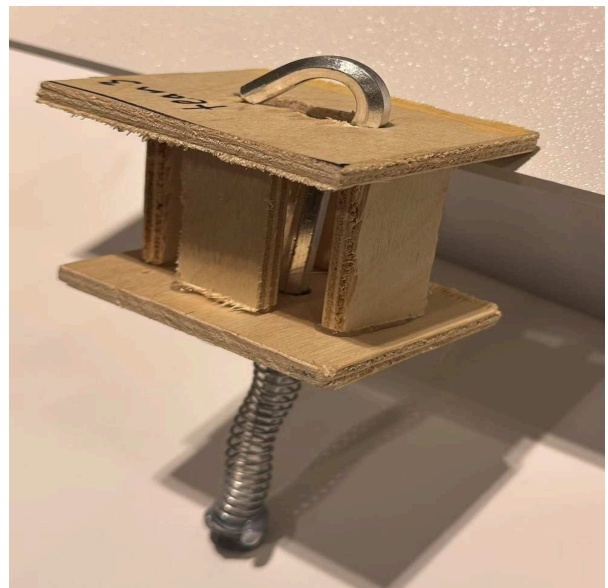


Figure 3: Spring mechanism. The spring mechanism has two states – compressed state and normal state. The compress state locks the spring to stabilize the walking stick, while the normal state allows the spring to function and provide elastic force.

Photos by Jixin Yan

The limitation of this design would be the requirement of our project's partner's upper body strength. Even though the spring mechanism provides uplifting assistance, it still requires quite an amount of force applied by the user. Based on observations, muscular dystrophy also severely impacts the strength of our partner's upper body strength. Therefore, it would be doubtful to fully rely on this design to perform sit-to-stand movement.

- Question 1: Which handle is more comfortable for the user to use?
- Question 2: Is the height adjustable feature effective when used at different settings?
- Question 3: How to make sure the spring mechanism provides sufficient force while keeping the walking stick stabilized?

Mockup 2: Adjustable Spring Seat Lift

Due to progressive lower-limb weakness caused by muscular dystrophy, our project partner experienced difficulty performing sit-to-stand (STS) movement. This design aims to provide additional lifting assistance through a spring mechanism. Considering our partner's preference to maintain the same height as others while using the device, a locking mechanism is integrated enabling height adjustment and stabilization of the seat. The mockup consists of two pieces of wood panels connected together using a hinge, representing the “seat” and the “lift” components. Due to various constraints, certain features can only be simulated in the current stage of development. Cushions are used instead of spring to provide lifting force, and adhesive tape is used for the locking mechanism.

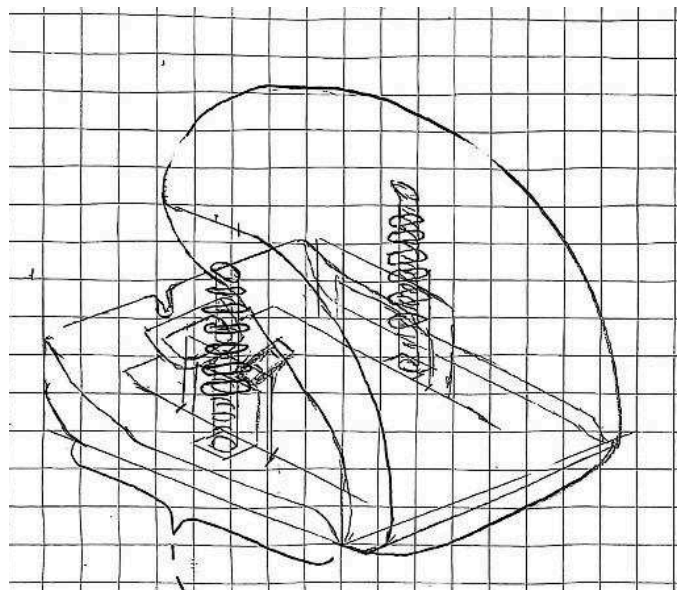


Figure 4: Adjustable spring seat lift. Two cushions are placed at two corners on the “lift” component to provide lifting force. A hinge is used to connect the “seat” and the “lift”

components. Between two cushions and at the bottom of the “seat” component, a pair of adhesive tape is used to achieve the locking mechanism. The sketch depicts the full design, with two strong springs to provide sufficient lifting assistance for an adult. Beside the spring, locking mechanism is achieved by having different holes that allow the seat to be locked.

Photo and graphic by Jixin Yan.

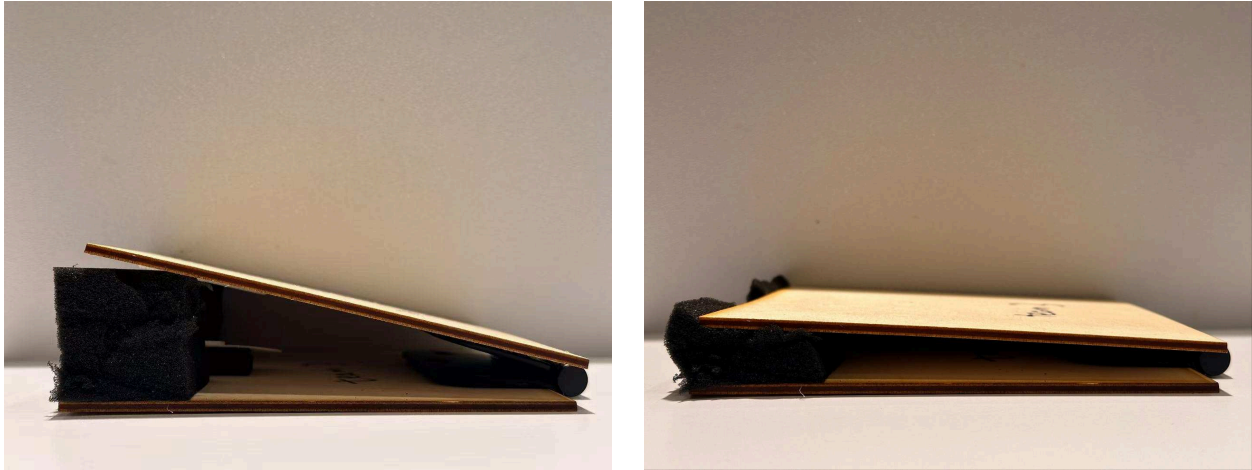


Figure 5: Illustration of the seat lift’s locking mechanism. As the “seat” component is pressed, two adhesive tapes will stick together and hence achieve the locking mechanism.

Photos by Jixin Yan.

The design is effective for providing the lifting force and satisfies the user’s preference. However, there are several limitations. First, portability would be a concern. Even though the weight won’t be that heavy, the size of the whole design would be difficult to carry in daily scenarios. Second, the lifting force functions only when the user slightly shifts their weight off the seat, allowing the spring to release stored elastic energy. However, based on observation, our project partner might have difficulty doing that without a stable physical support to lean his body weight. Therefore, the design might be dysfunctional if there isn’t any support structure.

- Question 1: How to ensure the spring (cushion) provides enough lifting assistance?
- Question 2: How easy would it be to carry the device in daily scenarios?
- Question 3: Would it be easier if seat lift is used in combination with other devices like walking sticks?

Mockup 3: Portable Support Plane

Based on previous observations, our project partner requires a stable surface to lean on during sit-to-stand movements, enabling the use of upper-body strength to reduce lower-limb strain. This design provides a portable and attachable plane that can be assembled onto a seat in different environments. It would be particularly helpful in settings like stadiums where normally no supporting structures are available beside seats. The plane is designed to be extendable for portability and have a foldable cross leg under the plane for stability. However, for the current

mockup, certain features like extendability, the cross leg, and the attachability are not fully achieved yet due to various constraints. The mockup, made from two separate pieces of wood panels and connected together using a hinge to simulate the extendable feature. The primary goal of this mockup is to clarify the feasibility and direction of the design. Therefore, during user testing, our project partner will be asked to evaluate the comfort and practicality of using this mockup in daily scenarios.

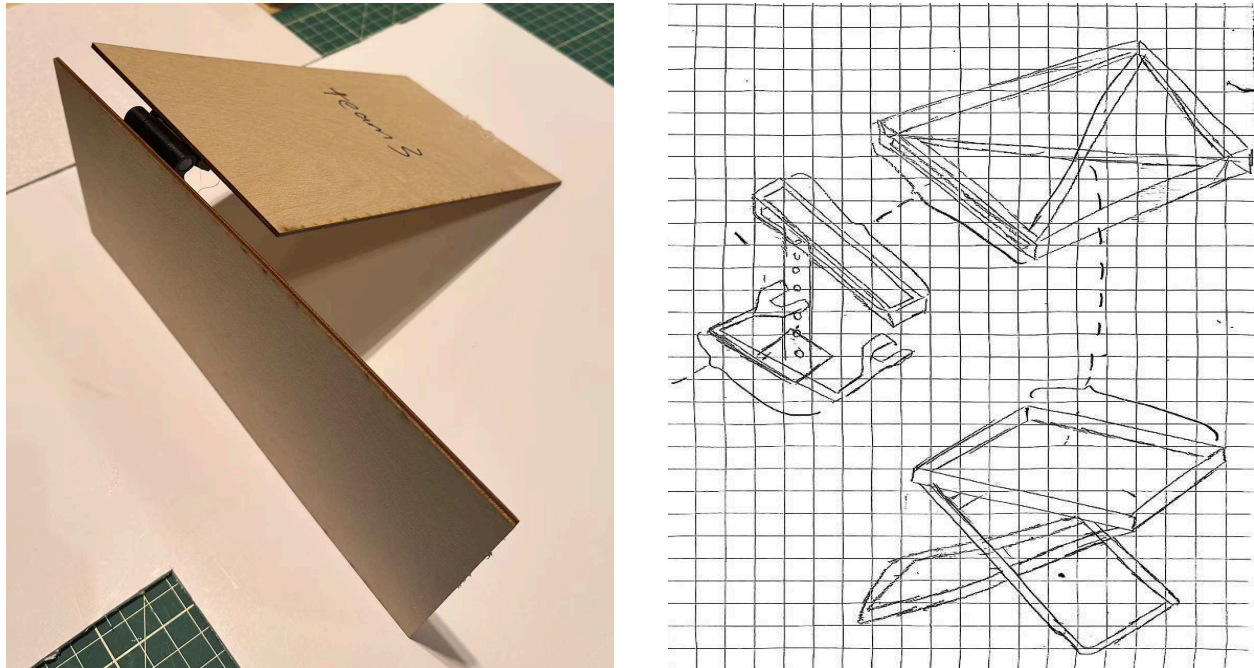


Figure 6: Portable support plane. Two wood panels are connected using a hinge, allowing a maximum rotation angle of 180° . The left panel serves as the attached plane, while the right panel acts as the support plane. A pair of clamps secures the product to the seat, with adjustable height feature achieved through multiple locking holes. A cross-leg structure beneath the support plane enhances the stability of the structure.

Photo and graphic by Jixin Yan.

Even though the design intuitively works well based on user observation, the underlying physics and biomechanics behind the design could be difficult to achieve due to distinct influencing factors in different environments. Additionally, the design needs to be more customized to work perfectly. Otherwise, there might be safety concerns due to stability and design issues.

- Question 1: How to make the connection between the support plane and the attached plane strong enough to bear a human body weight?
- Question 2: How to make the space between the support plane and user's body adequate and comfortable while having STS?
- Question 3: How easy would the design be to deploy on different types of seats?

Appendix G: User Testing

Date: 10/22/25

Time: 5:00-6:00 PM

Location: Ford G211

Team members in attendance: Alexander Patt, Axel Hinz, Max Kaung, Jixin Yan

Other key attendees: other groups from DTC1 Fall Section 13, Project Partner

Objective:

1. Obtain user's thoughts on our initial ideas/mockups
2. Obtain user's range of motion/stability with walking stick
3. Obtain user's annotations of mockup sketches (inflatable seat, walking stick, spring seat)

Testing conditions

- Illuminated Ford classroom with 16 DTC Students
- Each group of 4 is present with mockups, seated at their respective tables.
- The room has many steel 'spinny' chairs, a front area, a projector screen, and a computer that is connected to the projector in the corner.

Testing session overview

1. The user was given an overview of the session that asks them to interact with mockups in various ways
2. The user used walking stick mockup
3. The user provided thoughts on horizontal handle
4. The user provided thoughts on the spring compression/lock system. Bottom or top? Would this mechanism be supportive/helpful?
5. The user analyzed/annotated our blown-up sketch
6. The user saw a mockup of the spring seat lift, answered questions about the spring locked seat lift/cushion. User analyzed/annotated the mockup's blown-up sketch
7. The user answered questions about the idea of a seat lift elevator. User provided thoughts on if getting to optimal standing height is most important for him, an elevator+walking stick combo?
8. The user answered questions about if there were any topics he wishes were asked about

User overview

- Monil Gandhi
- Project Partner
- Engineer
- Muscular Dystrophy
- Mid 30s
- Weakness in leg muscles, especially quads and hamstrings; leads to difficulty standing up

Interview Part 1—Walking Sticks and Spring Lock: Mockups 1-3

Our mockups, while life-sized, are not yet prepared to withstand full human bodyweight, so the majority of information gathered was interview-based. Our project partner himself is our best source for idea refinement and analysis.

Table 1: Mockup/Design Inquiry:

Mockup Number (Appendix F for images)	Question	Answers/Commentary
1	How do you feel about using a horizontal handle? Would it be better than the vertical handle you currently use?	• Mr. Gandhi would definitely support a refined walking stick as part of the solution • Likes idea of horizontal handle • Would need to hold close to body to stabilize core • Stick would need a strong, supportive base. • Mr. Gandhi thinks springs can wear out and be too unstable. • However, Mr. Gandhi is not opposed to a mechanism where the stick is relenting when sitting down and strong and sturdy when standing up; it just needs refinement from its current state.
2		
3	How do you feel about the spring-lock mechanism?	

Interview Part 2—Seat Lift and Seat Clip: Mockups 4-5

Table 2: Mockup/Design Inquiry

Mockup Number (Appendix F for images)	Question	Answers/Commentary
4	What do you think of the seat lift? Should we use springs? Should we lock the seat into place?	• Partner is concerned about slippage on an angled seat lift • He is also worried about using springs for support • A seat lift would need to have a surface with a lot of friction to be useful. • He would rather just be at an optimal height. • In theory, a table would be useful, but physics/dimension are too complicated; an inclusive walking stick would be better.
5	Would table clipping to seat lift help with sit-to-stand?	

Interview Part 3: Seat Lift Elevator

Our group theorized about lifting our project partner's seat to his optimal stand-up height (what he has described as barstool-height), so we wondered if elevating him to that height would be better than support from a sub-optimal height

Q: Would a seat-lift “elevator” that elevates you to your optimal height, (so long as your starting seated height is below or equal to your optimal height) in tandem with a sturdy walking stick with a flat top, work?

A: Yes; that would be optimal.

Analysis and Implications for the Design

- Conclusion 1: No springs and no seat lift. The project partner expressed great apprehension towards having springs anywhere at all in the design. A material that serves the function that springs serve, support and coil, may work; but springs themselves are too variable to support human bodyweight. Similarly, an angled seat, unless it has a lot of friction, is too problematic and can cause slipping.
- Conclusion 2: Stemming from conclusion 1: we need to research more materials. A spring-like material such as foamcore or memory foam will be important for our

design. Additionally, a sturdy, supportive, and frictional material will be super important for our final product.

- Conclusion 3: Solutional Analysis: The best theoretical solution is a seat lift elevator, Mr. Gandhi said himself. However, we would need to find an energy source that lifts a seat up, and a new mechanism (or a repurposing of the current spring-lock one) that locks it into place. The most promising solution: an extendable walking stick. It will provide support and can be incorporated easily into his day-to-day life. It is also more likely to fall under budget.

Appendix H: Design Review Summary

Date: October 30, 2025

Time: 3:30 PM — 4:00 PM

Location: DTC Classroom, Ford Design Center, Room G211

Team members in attendance: Alex Patt, Max Kaung, Axel Hinz, Kevin Yan

Other key attendees: Team 1, Team 2, Team 4, Professor Carmichael, Professor Brown

Table 1: Design Review Responses

Design attribute (component, feature, etc.)	Positive feedback	Negative feedback	Suggestions and additional comments
Materials for Seat Elevator	N/A	- Budget constraint if we use lightweight and strong material - Will be difficult to balance strength, portability, and cost	- Consult specialists to discover the ideal materials - Conduct secondary research on materials
Working Mechanisms for Seat Elevator	- Electricity powered mechanisms are a good improvement from springs - Gears or other mechanical advantage mechanisms could work for elevator	- Difficulty of the transformation from electricity into mechanical advantage - There might be no physical support for the partner to push up after elevating - A large raising seat may not be very discreet	- Scissor lift mechanism - Carjack mechanism - Adjustable supports that can slide into locking place on upper platform
Walking stick spring mechanism	N/A	- A strong spring may be required to lift Mr. Gandhi's weight, which can be difficult to control and possibly dangerous - The springs and stick weight need to be tuned for the project partner's weight, which limits	- Still planning to use a screwjack mechanism

		his methods of standing up	
Walking stick base	- Keeping partner's current walking stick bottom (rubber tip)	- The walking stick may slip with the project partner's whole weight	- Use a rubber or tripod base to give more support

Followup

Given the review feedback, Team 13.3 plans the following:

- Converge on one design for our final project
- Refine mockup, sketch, and ideas in preparation
- Conduct further research on mechanisms and materials for final project
- Generate a materials list for the final project
- Identify which materials will need to be bought externally
- Begin prototyping the outer base of the final project

Appendix I: Spring Power Alternatives and Linear Actuator Specifications

Introduction

This appendix covers all secondary research on potential mechanical force alternatives to compression spring power. In the context of an automatically extending walking stick intended to lift the average individual's body weight, mechanical mechanisms as an alternative to spring power were explored and analyzed. Following the analysis, linear actuators were chosen as the mechanism to be used in the final product, and linear actuator manufacturing methods as well as market options were further researched.

This appendix tries to answer the following key questions:

- What are methods of dampening the extension rate of a spring?
- What are mechanical methods of vertically lifting heavy loads?
- How fast, strong, stable, and easy to use are these mechanical mechanisms?
- What are some affordable linear actuator models suitable for lifting a person?

Methods

- **Databases:** Google Scholar, ScienceDirect, ResearchGate, JSTOR, EBSCO, and Semantic Scholar
- **Keywords:** “spring alternative”, vertical”, “upward”, “lifting force”, “mechanism”, “heavy duty”, “linear actuator”
- **Number of sources:** 8

Results

Mechanisms of Vertical Lifting

Several methods of vertical, linear force application were considered, each with different drawbacks in the context of a discreet, portable, and affordable method of lifting a person from a sitting position. Each method encountered problems in either cost, size, safety, or manufacturability.

Table 1: Mechanisms of Vertical Lifting

Mechanism	Function	Strength (s)	Limitation (s)	Source
Compressed Spring	Pre-compressed springs extend during standing motion to propel upward	Very affordable and does not require electricity	Springs must have a high spring constant to apply a noticeable force when standing, making them difficult to pre-compress	Previous research
Fluid Damped Spring	Compressed springs push through a fluid chamber to slow the spring extension	Fluid dampers can be purchased online	Difficult to install and may lower the spring force	[1]
Magnet Damped Spring	Compressed springs push against alternating, suspended magnets to slow spring extension	Magnets are easily accessible	Technically difficult to manufacture and requires extremely strong magnets	[2]
Scissor Jack	Crossed metal bars hinged at the center slowly slide together to lift a plate	Structurally extremely stable and can apply a great amount of force	Very heavy and bulky, not compatible with a walking stick profile	[3]
Hydraulic Piston	Fluid fills a chamber to push a piston upward	Can apply the most force	Very heavy and extremely expensive	[4]
Screw Jack	A long vertical lead screw spins to allow a non-spinning nut to slowly rise up the screw	Small profile and can lift very high amounts of weight with varying speeds	Difficult to build and requires strong screws and nuts	[5]
Linear Actuator	A worm gear motorized screw jack contained in an aluminum shell	Benefits of the screw jack, but more reliable and durable	Relatively slow lift and fairly expensive	[6]

Linear Actuators

Linear actuators were decided to be the most promising mechanism, especially for a walking stick design. Different manufacturers and models of linear actuators were researched with the following requirements:

- Lifts at least 160 lbs (~700 N)
- Has an extension length between 16 inches and 24 inches
- Extends at a rate close to 0.5 in/s

Two main linear actuators were considered:

Option 1: VEVOR Linear Actuator 12V, 20 Inch High Speed 0.55"/s Linear Actuator, 220lbs/1000N Linear Motion Actuator with Mounting Bracket and IP54 Protection

- Vendor: VEVOR
- Stroke length: 20 inches
- Total length: 44.6 inches
- Extension rate: 0.55 in/s
- Lifting force: 220 lbs
- Other features: Dust and water resistant



Option 2: 1000N/220lb 18"/450mm Stroke 14mm/s 12V Linear Actuator Kit

-

Analysis, Conclusions, and Recommendations

After exploring various lifting mechanisms as alternatives to springs, the mechanisms were analyzed within the context of applying them in a walking stick design. Spring mechanisms have a small enough profile to discreetly fit within a walking stick; however, they are difficult to construct and require a large amount of force to compress. A compressed spring also poses safety concerns should the spring extend at an unpredictable time. Scissor jacks require a large amount of space, hydraulic pistons are exceedingly expensive, and both are too heavy for a walking stick design. Screw jacks were considered; however, they are difficult to manufacture, and once linear

actuators were discovered, they were immediately identified to be a safer and simpler version of the screw jack.

Following the choice of utilizing a linear actuator, VEVOR and Daier linear actuators meeting the force, extension length, and extension rate were found. The VEVOR linear actuator has a slightly longer extension length and total length than the Daier actuator; therefore, it may be able to lift the user to a greater variety of heights. However, it is also limited by its minimum length of 24.6 inches. The Daier linear actuator also comes installed with a 3-mode switch, while the VEVOR actuator is water-resistant.

Key Conclusions and Recommendations

- Stability and structural integrity are major considerations with the walking stick design. The use of a linear actuator provides a strong structure and a slow and steady extension, but balance is still a problem to be considered.
- Redesign a walking stick model centered around the use of a linear actuator.
- Decide between the linear actuator models. One provides a greater extension length, and the other provides a 3-mode switch
- Consider which activation method to use. Buttons and switches have different advantages, and each one can also click into place or automatically return to the unactivated position

References

- [1] ZHILI, “What Is an Oil Damper and How Do They Work?,” *Zhili Gas Spring*, Sep. 15, 2022. <https://www.zhiligasspring.com/news/what-is-an-oil-damper-and-how-do-they-work.html>
- [2] B. Hunting, “What Is Magnetic Ride Control, And How Does It Differ From Traditional Suspension?,” *DrivingLine*, Aug. 19, 2022. <https://www.drivingline.com/articles/what-is-magnetic-ride-control-and-how-does-it-differ-from-traditional-suspension/>
- [3] M. Patil and S. Kachave, “DESIGN AND ANALYSIS OF SCISSOR JACK,” Jan. 2015. Available: https://www.ijmerr.com/v4n1/ijmerr_v4n1_36.pdf
- [4] Magister Hydraulics, “Hydraulic Cylinders for Sale | Magister Hydraulics,” *Magister Hydraulics*, 2025. <https://www.magisterhyd.com/hydraulics-shop/product-category/hydraulic-cylinders/?srsltid=AfmBOorx7nULXJ-YfAqB2ShlFSuuRyF-YlrbmBnS1sOVegWRassovkki> (accessed Dec. 08, 2025).
- [5] “Screw Jacks 101,” *Columbus McKinnon*. <https://www.cmco.com/en-us/products/power-and-motion-technology/actuators/mechanical-actuators/screw-jacks/>
- [6] R. Dickson, “Linear actuators 101 - How does an actuator work | FIRGELLI,” *Firgelli Automations*, Nov. 16, 2018. https://www.firgelliauto.com/blogs/actuators/linear-actuators-101?srsltid=AfmBOoqMXQVIUeHzVJbSZV1fcb3tEXPrUMNlxw9g9lX_tkRmmBkhoMO (accessed Dec. 08, 2025).
- [7] VEVOR, “VEVOR Linear Actuator 12V, 20 Inch High Speed 0.55"/s Linear Actuator, 220lbs/1000N Linear Motion Actuator with Mounting Bracket and IP54 Protection,” 2024. https://www.vevor.com/linear-actuators-c_11633/vevor-linear-actuator-12v-20inch-0-55-s-high-speed-220lbs-1000n-ip54-protection-p_010779702477
- [8] Daier Switches, “1000N/220lb 18"/450mm Stroke 14mm/s 12V Linear Actuator Kit,” *DAIER*, 2025. https://www.daier switches.com/products/1000n-450mm-stroke-12v-linear-actuator-kit?variant=48676860756161&country=US¤cy=USD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&srsltid=AfmBOop_xHQA gSGmzRJT_zW9pkCF1_4vcX7UXR0bZau-IT4l-gCdWb-8-sI

Appendix J: Expert Interview with Professor Nicholas Marchuk

Date: November 5, 2025

Time: 6:45 PM – 7:30 PM

Location: Northwestern University Mechatronics Design Lab, Ford Design Center B100

Team members in attendance: Axel Hinz, Alexander Patt, Jixin Yan, Maxwell Kaung

Expert + other key attendees: Prof. Nicholas Marchuk

Prof. Nicholas Marchuk - BS/MS Mechanical Engineering; Senior Lecturer and Mechatronics Design Lab Manager

Prof. Marchuk has a strong academic background in mechanical engineering and assists engineering students with mechanical and electrical design projects in the Northwestern University Mechatronics Design Lab. His knowledge on machinery and circuit design, along with his extensive experience assisting students with design projects, makes him an ideal reference from which to learn how to set up, test, and power our linear actuator. We hoped to learn the following from our interview:

- Appropriate and efficient ways to supply power to our linear actuator
- Necessary components to power linear actuator with a switch
- How to test our linear actuator to gauge what size and kind of battery we will need
- What components are available in the Mechatronics Design Lab

Power source alternatives

Mr. Marchuk presented several options for power sources that we could use to power our linear actuator. These options, along with their strengths and weaknesses, are listed below in Table 1.

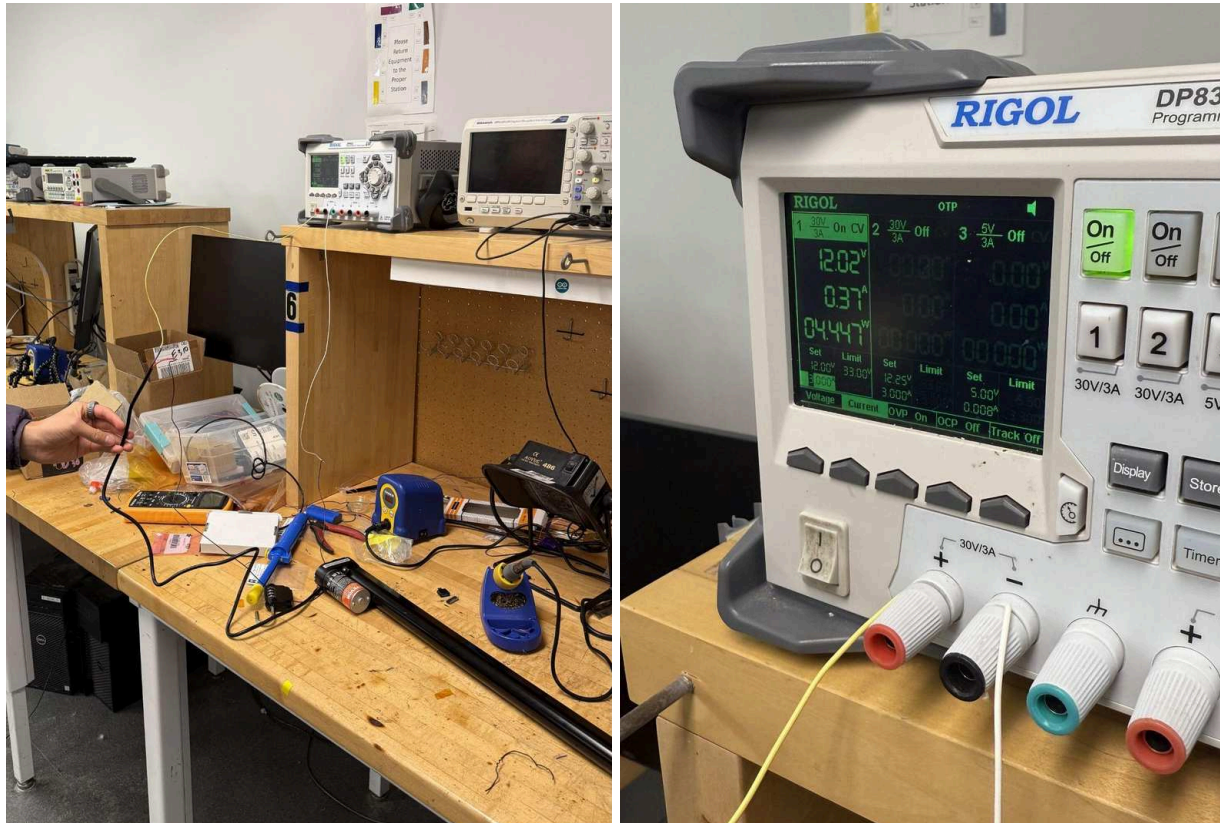
Table 1: Evaluation of various power sources

Power Source	Strengths	Weaknesses
AA battery pack	- Inexpensive - Easily sourced from NU labs - Can be wired together in parallel for more capacity	- Disposable, so needs constant replacement - Takes up lots of space since 8 AA batteries required to reach 12V - May not provide enough capacity
Drill battery	- Can design connection to allow for seamless insertion into walking stick - High capacity 12V options available for purchase - Rechargeable and often comes with charger	- Need to design and print shell with drill battery receptacle - Heavy (reduces portability) - Expensive

Rechargeable LiPo battery	- High capacity 12V options available for purchase - Rechargeable and often comes with charger	- Difficult to design seamless connection with walking stick - Expensive - Heavy
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Testing the linear actuator

Prof. Marchuk assisted in the testing process by helping us connect it to a variable DC power supply and observing the amperage that the linear actuator drew during both up and down movement. Figures 1 and 2 show the linear actuator connected to the power supply and an up-close image of the DC power supply, respectively.



Figures 1-2: Testing the amperage draw of the linear actuator

Photo: Axel Hinz

Through our observation, we were able to determine that the linear actuator had an average amperage draw of 0.5 A. With further calculations, we found that one full extension and retraction with no force applied would take approximately 0.008 Ah of capacity. This means that a 1 Ah battery would ideally allow for over 100 full extensions before needing a recharge. However, our testing showed that applying force to the linear actuator sometimes increased the amp draw up to 0.8 A, which could lower the total number of extensions to as low as 75.

Circuit design with six-pin toggle switch

Prof. Marchuk helped us draw out the full circuit connecting the battery, motor, and six-pin switch to aid in the soldering process once we confirmed our power source.

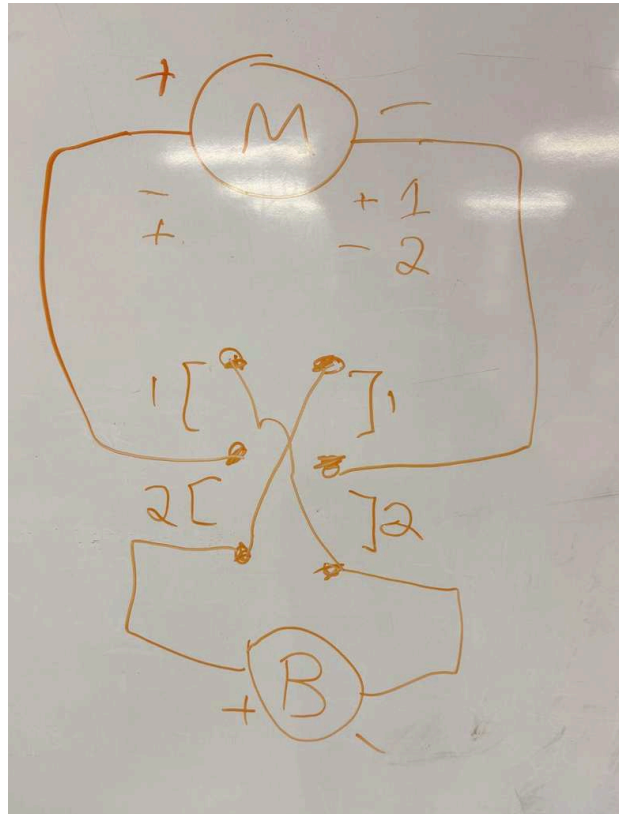


Figure 3: Switch-battery-motor circuit

Photo: Axel Hinz

Miscellaneous

During our conversation with Prof. Marchuk, it was confirmed that we could source our switch, wires, and solder from the Mechatronics Lab. We were also given permission to run further tests in the lab if needed.

In addition, Prof. Marchuk gave Team 13.3 a brief soldering tutorial in the Mechatronics Lab so we can independently put together our circuit once we decide on our power source.

Conclusions and Next Steps

The information and experience we gathered from our interview with Prof. Marchuk helped lead us to the decision to select a 12V, 4Ah drill battery to power our product. It will also be crucial as we move into the construction phase of our project in the upcoming weeks and need to build the circuit ourselves.

- Place order for a 12V, 4Ah drill battery on Amazon
- Solder wires to six-pin switch and motor while we wait for the battery to arrive
- Begin modeling the plastic shell which will house the drill battery in SolidWorks

Appendix K: Walking Stick Construction Materials

Introduction

This appendix explores the materials and components typically used in the construction of walking sticks. This research is intended to aid in the selection of construction materials and components for an extending walking stick. Some research questions this appendix will address include:

- What materials are used in typical walking sticks and canes, and how do they compare?
- What materials are typically used to manufacture cane handles and bases, and how do they compare?
- What walking stick components should be included in our design?
- What are the best materials to use in our product's design that balance strength, weight, and cost?

Methods

- Databases and Search Engines: Google Search, Google Scholar, Science Direct
- Keywords: “walking stick”, “cane handle”, “cane foot”, “materials”, “strength”, “weight”, “aluminum”, “wood”, “carbon fiber”, “properties”, “hiking stick”
- Number of sources: 13

Results

Walking stick materials

According to Fashionable Canes and The Stick and Cane Shop, one of three materials is typically used to make the body of a walking stick: wood, aluminum, and carbon fiber [9][12]. Though beech is listed as the most common wood for walking sticks, the available wood in the Ford Design Institute is primarily pine. For this purpose, it will be the focus of our research on wood. In addition to these materials, Team 13.3 has identified PVC and PLA as construction materials worth researching due to their abundance in the Ford Design Institute. These materials, their densities, and some other of their miscellaneous properties are listed in Table 1 below.

Table 1: Typical walking stick materials and their properties

Material	Density (g/cm³)	Properties	Source
Aluminum	2.6-3.0	- Resists progressive oxidization - Resists corrosion from water, salt, and other compounds - Easily fabricated into many forms - Surface can be made dark using anodization process - High tensile and compressive strength - High ductility allows for bending without brittle breakage	[5], [6]
Wood (Pine)	0.4-0.6	- Readily available in Ford Design Institute - Considered classic material for walking sticks - Known for natural beauty and easily paintable - Prone to warping over extended periods - Moderate tensile strength parallel to grain, but very weak perpendicular to grain - Sustainable - Lightweight and easily fabricated into many forms	[1], [13]
Carbon fiber	1.8	- Exceptionally high tensile and compressive strength, especially for its low density - Sleek and minimal profile - Prone to cracking and shattering - More difficult to fabricate into different forms	[3]
PVC	1.44	- Readily available in Ford Design Institute - Resists oxidation - Comes in cylindrical forms so minimal fabrication required, and can be telescoped - High tensile strength - Flame retardant - 78D on Shore D hardness scale (1-100), resists indentation	[7], [8]
PLA	1.24	- Readily available in Ford Design Institute - Moderate tensile and compressive strength - Low impact resistance, prone to breaking - Easily fabricated into any form using 3D-printer	[2], [10]

Walking stick components

Fashionable Canes and Mayo Clinic both list a rubber base as a necessity when choosing a walking stick. This added security is especially important in a medical context where a user may have weakness or instability. According to Mayo Clinic, “the tip of a cane can help provide traction on most surfaces [11].”



Figure 1: Cane handles. Cane handles provide a comfortable way to grip a walking stick [11].

Additionally, Mayo Clinic recommends a foam or fitted handle to ensure a comfortable grip on a walking stick. Additionally, “choosing a good cane grip eases stress on joints and may help prevent other joint problems [11].” REI also lists cork and rubber as potential grip materials, though these are more intended for active hiking purposes. REI notes that cork “decreases vibration and best conforms to the shape of your hands [4].” The ability of cork to be easily shaped to the contours of a hand makes it a valuable consideration for the construction of our handle. Because we intend for our walking stick to be used frequently, and our user will need to place their body weight on the stick, it is crucial that we design a comfortable grip.



Figure 2: Rubber cane tip. A rubber tip is attached to the bottom of the cane or walking stick to ensure traction and prevent slippage on a variety of surfaces [11].

REI and Fashionable Canes listed a cane/stick wrist strap as a useful addition to walking sticks. REI reports that a properly-fitted wrist strap “supports your wrist and heel of the hand and allows you to keep your hand relaxed on the grip [4].” Additionally, Fashionable Canes writes, “for convenience or added flair, a cane strap ensures that you can let go of your cane without having to lean it up against something and having it drop to the floor [9].” These two benefits give the wrist strap ample reason to be considered during the design process.



Figure 3: Handle wrist strap use. A wrist strap can reduce the stress and strain on hand muscles for long periods of use [4].

Analysis, conclusions and recommendations

Analysis

This exploration of the various materials and components used in the design of functional and medical walking sticks is vital to our extending walking stick design. Based on our research, we can support our decision to switch from a screw jack to an aluminum alloy linear actuator because it more than satisfies the necessary strength requirements to pass as the body of our walking stick. In addition, we have identified PVC and PLA as potential materials for a cover or casing for the linear actuator’s motor and electrical components due to their availability and strength profiles. While PVC is stronger and more resistant to indentation, PLA is easier to fabricate into any necessary shape and still performs relatively well under tension and compression.

This research also identifies three additional components to add to our current design: a foam handle, a rubber base, and a wrist strap. Sources like Mayo Clinic and Fashionable Canes gave recommendations for specific kinds of bases and handles that we can select from to ensure we are making well-grounded design decisions.

Conclusions and next steps

In the coming weeks, Team 13.3 will:

- Purchase a foam handle and rubber base from a recommended supplier
- Inquire about wrist straps in a future Project Partner observation
- Decide on the optimal material to design a protective casing for the motor and electrical components
- Investigate potential designs for a protective casing for the motor and electrical components
- Investigate how to securely attach the handle and rubber base to the linear actuator

References

- [1] “Pine Wood: Properties, Characteristics, and Uses.” Accessed: Dec. 08, 2025. [Online]. Available: <https://k-timbers.com/pine-wood-properties-characteristics-and-uses/>
- [2] L. Ranakoti *et al.*, “Critical Review on Polylactic Acid: Properties, Structure, Processing, Biocomposites, and Nanocomposites,” *Materials (Basel)*, vol. 15, no. 12, p. 4312, June 2022, doi: [10.3390/ma15124312](https://doi.org/10.3390/ma15124312).
- [3] “Fiber properties guide,” Texonic. Accessed: Dec. 08, 2025. [Online]. Available: <https://texonic.net/en/tableau/technical/>
- [4] “How to Choose Trekking Poles and Hiking Staffs | REI Co-op,” REI. Accessed: Dec. 08, 2025. [Online]. Available: <https://www.rei.com/learn/expert-advice/trekking-poles-hiking-staffs.html>
- [5] J. R. Davis, “Aluminum and aluminum alloys,” ASM International, 2001. doi: 10.1361/autb2001p351.
- [6] “Properties: What Are the Properties of Aluminum?,” AZoM. Accessed: Dec. 08, 2025. [Online]. Available: <https://www.azom.com/properties.aspx?ArticleID=1446>
- [7] “PVC,” Xometry Pro. Accessed: Dec. 08, 2025. [Online]. Available: <https://xometry.pro/en-eu/materials/pvc/>
- [8] “PVC’s physical properties,” ECVm. Accessed: Dec. 08, 2025. [Online]. Available: <https://pvc.org/about-pvc-old/pvcs-physical-properties/>
- [9] “Selecting the Best Walking Cane: A Buyers Guide to Walking Canes,” Fashionable Canes. Accessed: Dec. 08, 2025. [Online]. Available: <https://fashionablecanes.com/pages/buyers-guide-walking-caness>
- [10] J. L. Núñez, “The densities of all 3D printing materials,” Bitfab. Accessed: Dec. 08, 2025. [Online]. Available: <https://bitfab.io/blog/3d-printing-materials-densities/>

[11] “Tips for choosing and using canes,” Mayo Clinic. Accessed: Dec. 08, 2025. [Online]. Available:

<https://www.mayoclinic.org/healthy-lifestyle/healthy-aging/in-depth/canes/art-20548206>

[12] “Walking Stick Material Guide - What Material for your Cane - Stick and Cane Shop | Stick & Cane Shop.” Accessed: Dec. 08, 2025. [Online]. Available:

https://www.stickandcaneshop.co.uk/walking-stick-material-guide?srsltid=AfmBOor5ydidD-gSKDiMtn0ujkZI8U-4EjZRBL7NWO1qN6McVuD_Thy

[13] “What are the properties of wood?” Accessed: Dec. 08, 2025. [Online]. Available:

<https://www.garnica.one/en-us/blog/properties-of-wood.html>

Appendix L: Methods of Construction

Overview of the Extend-a-Stick

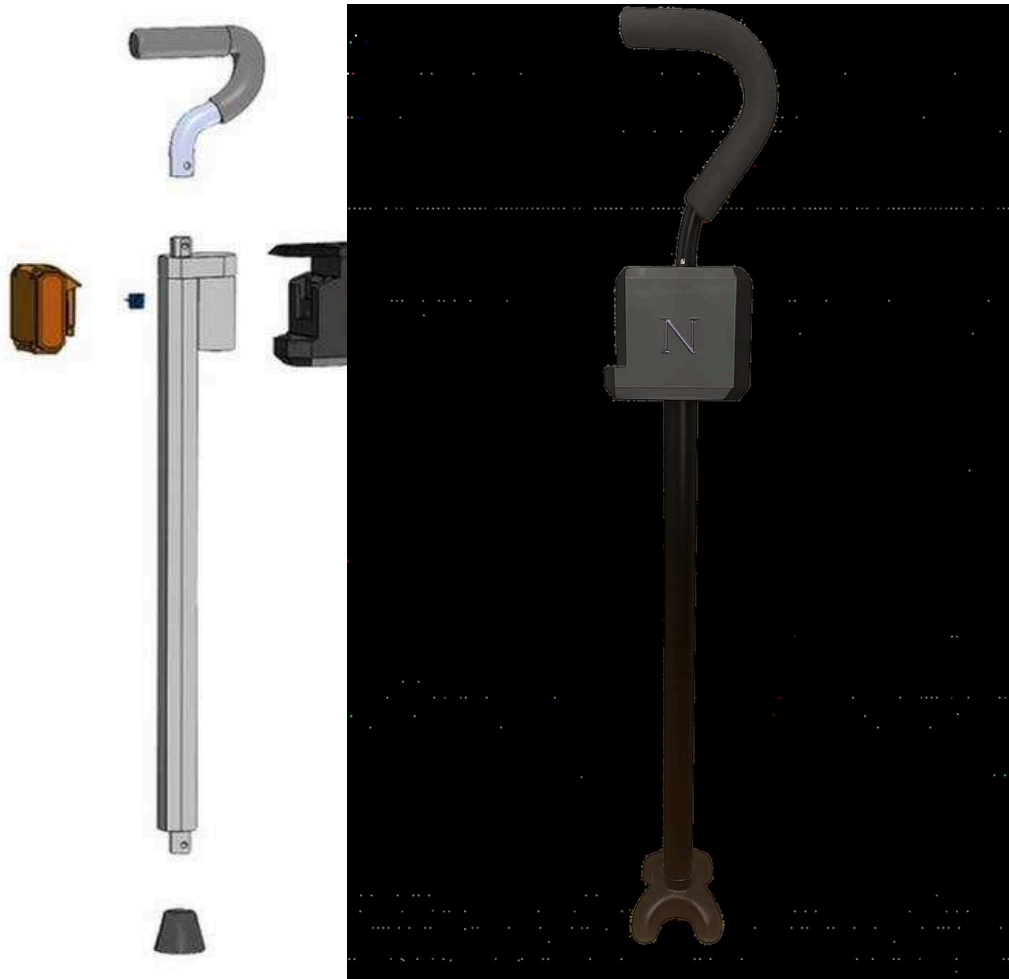


Figure 1: Explosive and front view of Extend-a-Stick.

Graphic created by Maxwell Kaung with SolidWorks

The explosive view at left shows the composition of the whole design, which include an ergonomic cushioned handle on the top, a linear actuator as the body, a rubber base at the bottom, a 3D printed case, a switch inside the shell, and a drill battery. The front view at right shows Extend-a-Stick when fully composed.

Theory of Operation

By composing the right components and following the step-by-step instructions below, the user should be able to construct an extendable, reusable, and controllable walking stick. If constructed properly, the 3D printed protective shell should fit perfectly on the walking stick and the drill battery should be able to insert on it perfectly and power the linear actuator. In addition, the user

should be able to control the motion of the linear actuator with three modes: up, down, and off. Last, the user should be able to install the rubber bases at the bottom of the linear actuator and exchange one easily.

List of Parts Required:

Table 1: Materials used for Construction

Item(s)	Specifications*	Qty
Linear Actuator	220 lbs/1000 N lifting force, 20 inch stroke length, 24.6 inch resting length, 12 volts motor, with dimensions specified in Figure 2	1
Cane Handle	Cushioned $\frac{3}{4}$ elliptical handle	1
Rubber Bases	One four-foot base and one single-foot base, both with 18 mm diameter	2
Black PLA Filament	0.2 or 0.08 mm diameter filaments compatible with the 3D printer used	1
Drill Batteries	Two 12 volts Li-ion batteries with 4000 mAh	2
Battery Charger	Charger for drill batteries	1
Solid wire	~4 ft of solid wire needed	1
Three-Mode Switch	With dimensions specified in Figure 6	1
Screws	Two screws used for closing the 3D printed case with body and the bottom. One screw used for fixing the cane handle with the top of the linear actuator	3
5052 Aluminum Alloy Sheets	Two pieces with width of 0.71 mm, height of 9.93mm, and approximate length of 15 mm	2
Solder	.5 mm aluminum solder	

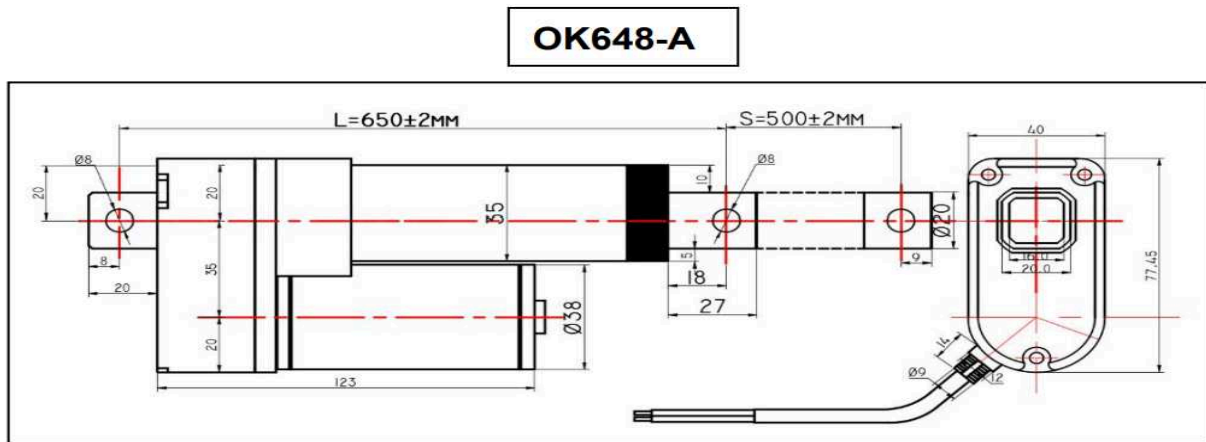


Figure 2: Dimensions of linear actuator used in Extend-a-Stick
Image by Vevor

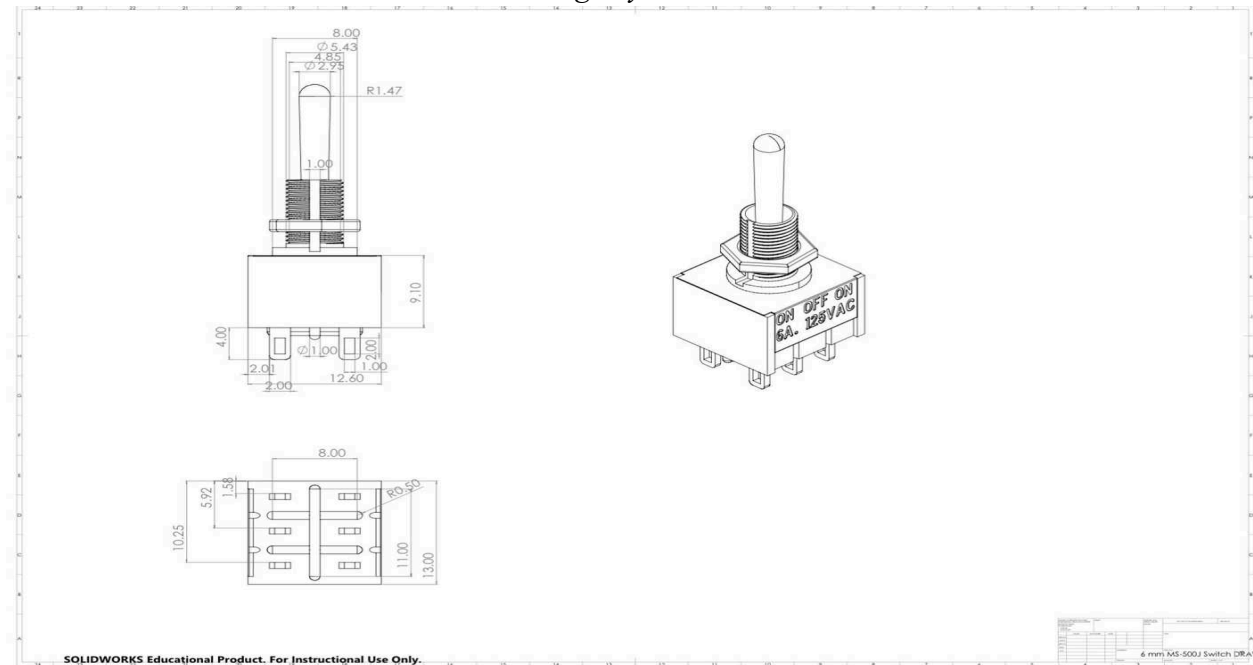


Figure 3: Dimensions of the three-mode switch
Graphic created by Maxwell Kaung with SolidWorks

Tools:

- 3D printer for printing the CAD model
- CAD for modeling the prototype and case
- Soldering station for connecting wires on switch and metal pieces
- Flat file for filing down the diameter of the linear actuator base in case the rubber bases don't fit perfectly

- Screw driver
- Tin snip used to cut metal sheet
- Measuring caliper
- Drill
- Pliers
- Wire-cutter Pliers

Step-by-Step Instructions

Case Modeling

1. Use calipers to carefully measure the dimensions of the motor section of the linear actuator and the dimensions of the drill battery
2. Open a 3D CAD program such as SolidWorks and model 3 parts, a shell top, shell bottom, and battery cover, with dimensions as shown in figures 4, 5, and 6, respectively

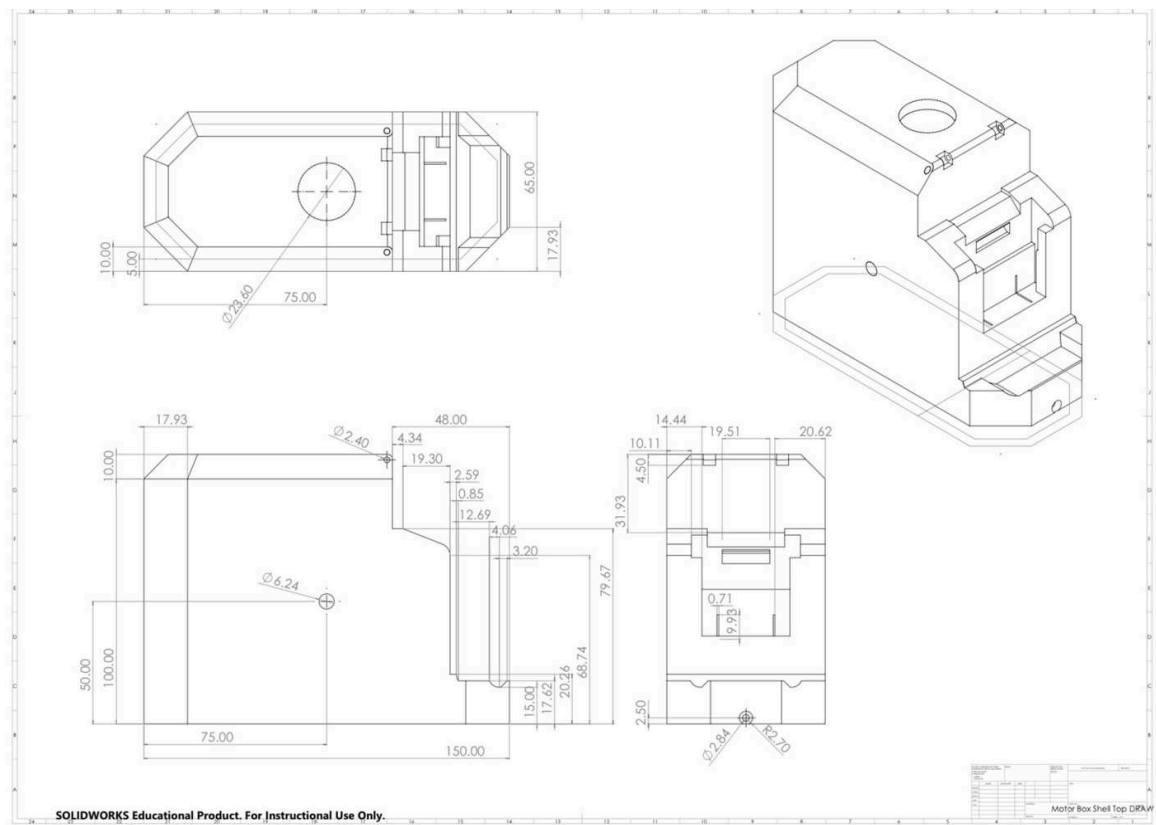


Figure 4: Dimensions of the top of the 3D printed case.

Graphic created by Maxwell Kaung with SolidWorks

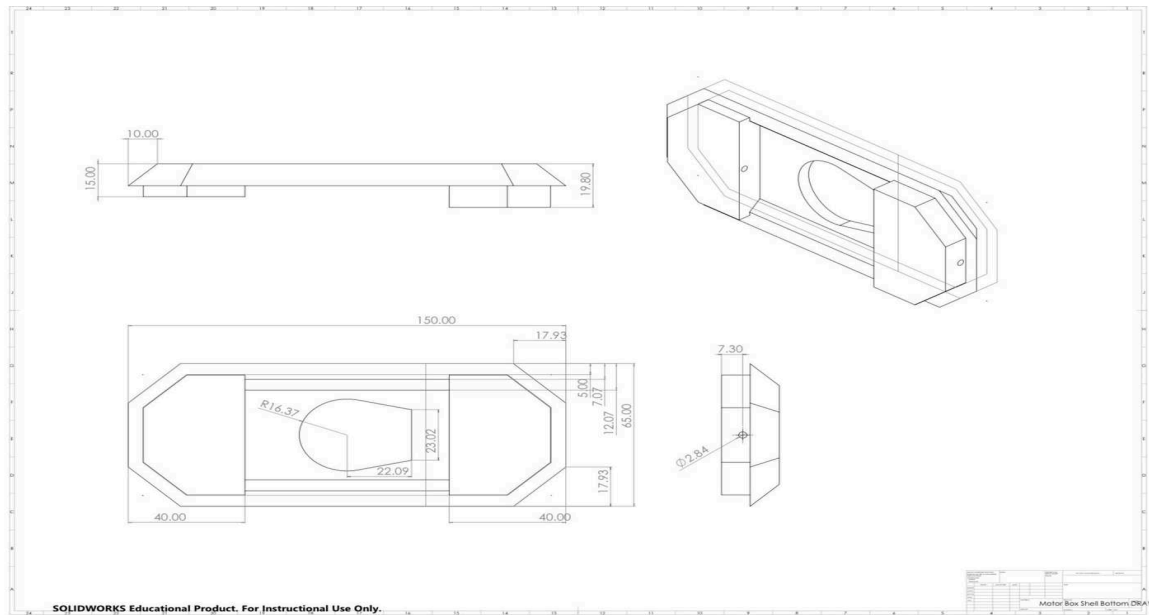


Figure 5: Dimensions of the bottom of the 3D printed case.

Graphic created by Maxwell Kaung with SolidWorks

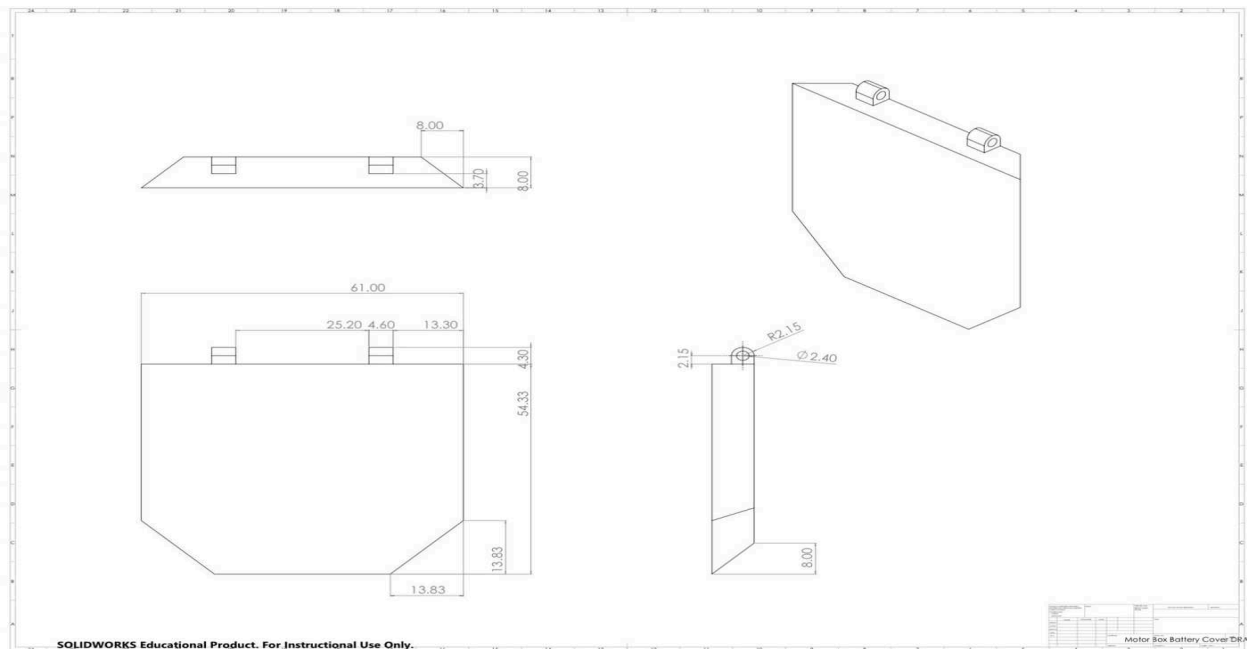


Figure 6: Dimensions of the battery cover in the 3D printed case

Graphic created by Maxwell Kaung with SolidWorks

Case Printing

1. In the CAD program, press save as and download the CAD files for the shell top, bottom, and cover as STL files
2. Open BambuStudio or a similar program to slice STL files for 3D printing
3. Open the files for the shell top, bottom, and cover onto three different plates
4. Orient the shell top so that the opening for the handle is facing upward, orient the shell bottom so that the large flat surface lies on the plate, and orient the cover so that the hinges overhang
5. Select 3 wall layers, 5% infill, and enable tree supports
6. Insert a black filament spool into the 3D printer and send the print request
7. Once the print has finished, wait for the heat bed to cool below 40 degrees Celsius before removing the parts from the bed
8. Use pliers to carefully remove tree support material from the prints

Handle Drilling

1. Place handle on its side under the drill press.
2. Line up drill head 4 mm above the bottom of the handle in the center.
3. Clamp handle.
4. Turn on the drill press.
5. Drill through handle to the other side.



Figure 7: Drilling through the handle

Photo by Alexander Patt

Switch Mechanism Engineering: Soldering

Soldering wires to switch, linear actuator, and metal plates (see Figure 8)

1. Cut six 6 in. wires from the 4 ft of wire using pliers. Strip ends of wire $\frac{1}{4}$ in. in.
2. Strip wires from linear actuator

Repeat the following process for soldering linear actuator wires to wire, those two wires to middle tips of switch, and for soldering other four wires to opposing corners of switch, and those wires to the aluminum plates. When soldering wire to wire, wrap wires around each other before soldering. When soldering wire to switch, feed wire through holes in switch and wrap around before soldering. When soldering wire to aluminum plate, press wire down on aluminum plate. (See Figure 3 in Appendix K for a specific wiring circuit.)

3. Turn on solder power source
4. Touch soldering iron to desired connection points.
5. Dangling solder over contact point, touch soldering iron to solder
6. Press soldering iron onto contact point
7. Release
8. Wait for metal to harden
9. Apply hot glue to soldered contact points (see Figure 9 for quantity)

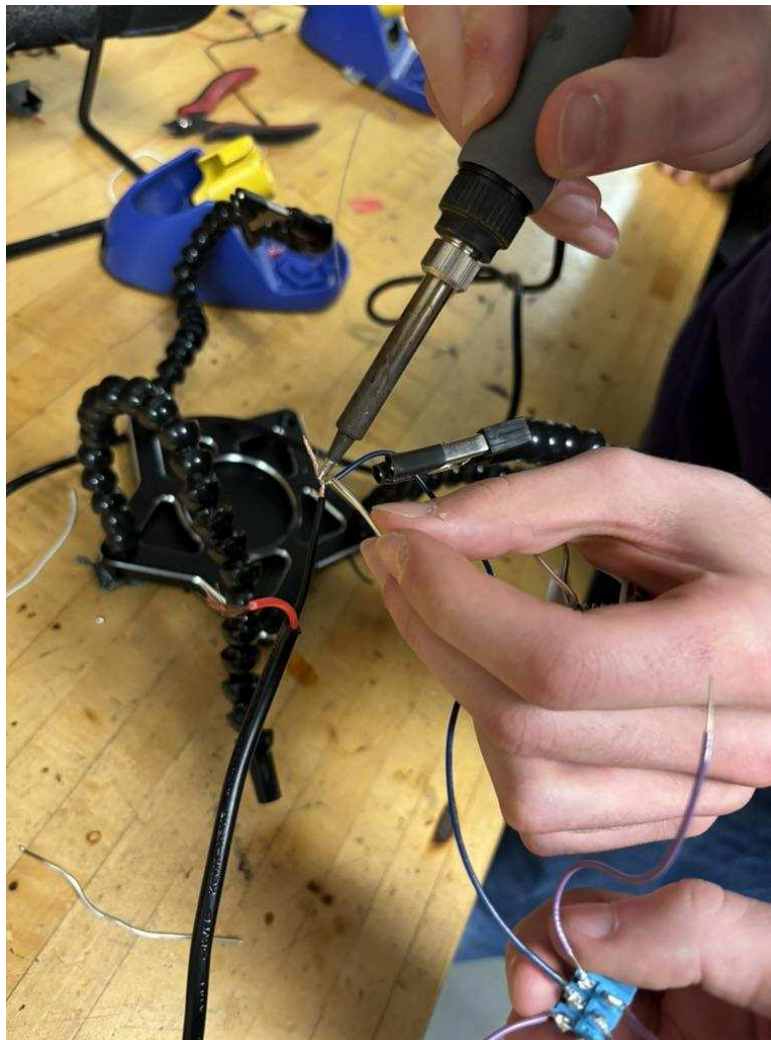


Figure 8: Soldering

Photo by Alexander Patt

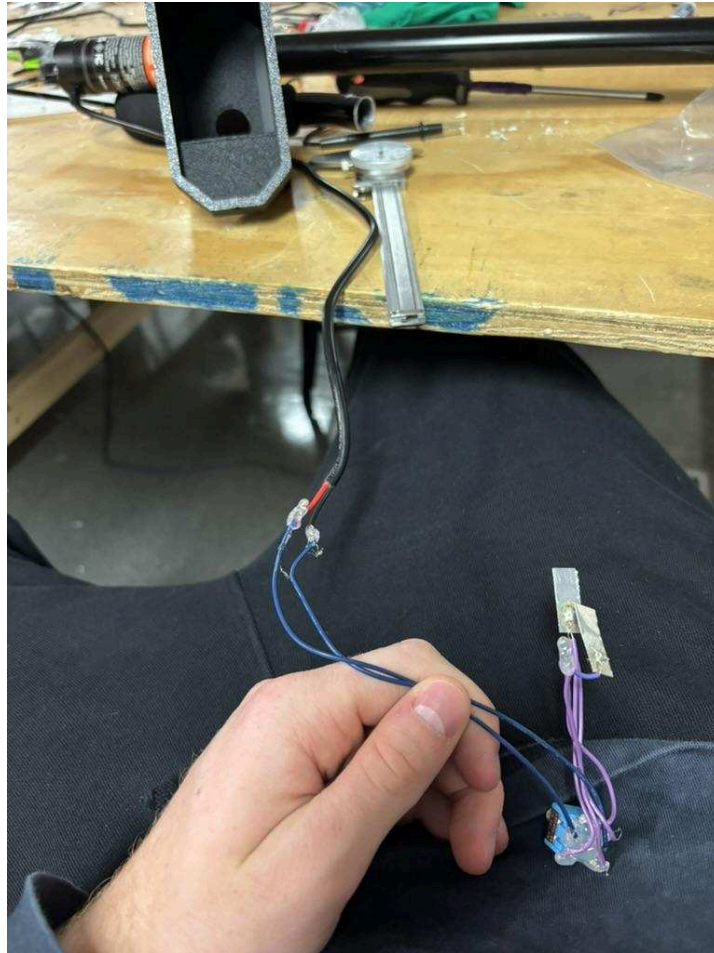


Figure 9: Finished soldered switch system

Photo by Alexander Patt

Bottom of Linear Actuator and Handle Filing

The handle bottom comes too narrow and the linear actuator bottom comes too wide. To solve this problem, file down the inner circumference of the handle bottom and the outer circumference of the linear actuator bottom until they fit into their respective positions.

1. Grab file with strong hand, push object against a table with other hand
2. Make contact with filing surface
3. Push forward, wrapping around circumference
4. Retract without making contact with surface (as this backwards contact weakens the file)
5. Repeat steps 2-4 until bottom of linear actuator fits into rubber bases and handle fits atop linear actuator; check fit after every 10 filing motions



Figure 10: Filing linear actuator bottom

Photo by Alexander Patt



Figure 11: Filing inside of handle

Photo by Alexander Patt

Unit Testing

After gathering all required components of building the Extend-a-Stick, the user should first test the functionalities of each unit and connections between them before the final assembly.

1. Case Testing

1.1. If modeled and printed correctly, the drill battery should fit securely in the case with no risk of falling out, even when shaken vigorously. If the fit is not ideal, measure the battery's dimensions and revise the model to ensure the case is properly sized.

1.2. Then, test whether the two metal pieces can pass through the places reserved in the case. Since the metal pieces have already been soldered to the wires connected to the switch, verify the fit from the inside of the enclosure to the outside. If trimmed correctly, the metal pieces should slide smoothly through the opening and have an appropriate length for the battery to make a reliable connection.

1.3. Next, check whether the bottom part of the case can pass through the bottom of the linear actuator. If it does, test the enclosure of the bottom case and the upper section. The clearance should be negligible. If the dimensions align, test the closure of the case by inserting the screws and verifying the overall stability. If modeled and printed correctly, the case should close securely.

1.4. After that, check whether the top of the linear actuator can pass through the opening at the top of the case. If it does, then verify that the amount passed through the opening is sufficient to install the handle with the proper screw. If not, measure the relevant dimensions and adjust the model accordingly.

1.5. Last, attach the battery cover with a wire. It should be able to swing if modeled correctly.

2. Linear Actuator Testing

2.1. First, connect the linear actuator with the battery or any 12 volts power source. If connected correctly, the linear actuator should be able to extend and retract at a constant speed.

2.2. Second, test the operation of the linear actuator with different levels of workload. If the linear actuator is properly powered, it should be able to function normally with less than or equal to 1000N exerted on it.

3. Switch Testing

3.1. If soldered properly, the connection between the wires and the metal pieces should be stable and effective. Test the connection and working mechanism of the switch by connecting the battery or any other 12 volts power source and the linear actuator. If working properly, the three mode switch should be able extend the linear actuator by flipping upward the switch, retract the linear actuator by flipping downward the switch, and stop the motion of the linear actuator by flipping back the switch into the middle position. If the motion and flip direction of the switch is reversed, it's better to make a new switch system by adjusting the circuit accordingly. However, this doesn't affect the functionality of the product but only the user experience.

3.2. After testing the functionality of the switch system, test whether it fits properly inside the case. First, check whether the switch flip can pass through the opening on the side of the case. Next, verify that the switch system has sufficient space inside the enclosure when the linear actuator is also inserted through the case. If it does not, measure the relevant dimensions and adjust the model accordingly.

4. Base Testing

4.1. After filing the bottom of the linear actuator, the base should fit perfectly on it with stability. Additionally, the base should not be difficult to remove and replace.

5. Handle Testing

5.1. If drilled properly, the handle can attach to the top of the linear actuator with a proper size screw. When secured with the screw, the connection should be stable so that the linear actuator will not come off even when lifted by the handle.

Final Assembly

1. Prepare all required components: the handle, the linear actuator, two screws, one wire, a drill battery, the switch system, the 3D-printed case, and a rubber base.
2. First, pass the linear actuator through the opening of the upper section of the 3D-printed case
3. Second, implement the switch system inside the case, make sure the switch passes through the opening at the side of the case, and the metal pieces can pass through their slits. (Figure 12)
4. Third, close the case by attaching the lower section of the case with 2 screws on each side to stabilize the closure.
5. Fourth, install the base at the bottom of the linear actuator and the handle at the top of the linear actuator with a screw stabilizing.
6. Fifth, slide a battery into the case with correct connection with the metal pieces.
7. Last, install the battery cover with a wire through the holes on either side of the cover atop the battery slop.

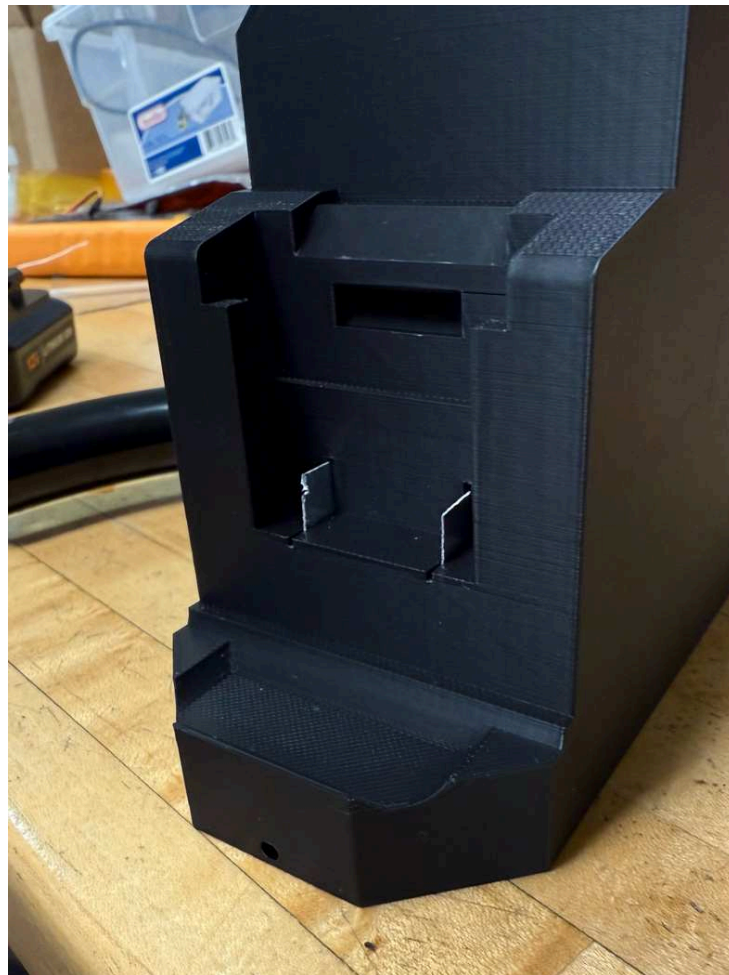


Figure 12: Aluminum plates fed through 3D-printed case.

Photo by Axel Hinz

Appendix M: Bill of Materials

Table 1: Bill of Materials

Item	Description	Qty	Source	Part #	Unit Cost	Total Cost
Linear Actuator	1000N/220lb linear actuator with 20in stroke length and 0.55in/s extension rate, powered by 12V DC motor	1	Vevor	OK648/OK648-A	33.99	36.79
Drill Battery	Electrical power supply for motor, chargeable	1	Amazon	DCB120	49.99	55.11
Handle Foam	Current carrying	1	Amazon	512-1303-0200	9.99	10.21
Bases	A four legged base and a single foot	2	Fashionable Canes	460B LK*16 1621*16	19.95 (for four legged) 2.0 (for single foot)	32.01
Horizontal handle	A walking stick handle with horizontal beam	1	Segal Workshop	N/A	0	0
Switch	Electrical component controlling the motion of linear actuator	1	Mechantronics Lab	N/A	0	0
					Total	134.12

Appendix N: Project Definition

Project Name: Sit-to-Stand Assist for Muscular Dystrophy: The Extend-a-Stick

Project Partner: Monil Gandhi

Team members: Alexander Patt, Maxwell Kaung, Jixin Yan, Axel Hinz

Date: 11/03/2025

Version: 3.1

Mission Statement

To design a discreet and portable support device that reduces the strain on the user's upper and lower body muscles during sit-to-stand movements from various heights and environments.

Project Deliverables

- Final report (digital copy)
- Presentation and poster during the DTC Project Exposition
- Final prototype

Design Constraints

- Budget (\$150)
- Materials
- Time (12 weeks)
- State/Federal Regulations

Users and Stakeholders

- Monil Gandhi - project partner (has muscular dystrophy, which causes gradual muscle weakness and loss over time)
- Patients with any physiological condition that impacts muscular strength/muscle mass
- Anyone with difficulty completing sit-to-stand movements

User(s) Profile

Monil Gandhi is a man with muscular dystrophy who has difficulty on sit to stand movement due to the weakened lower body and upper body muscle groups. He uses trekking poles for daily standing support. Sitting at different heights would require varying amounts of effort to stand up.

Illustrative User Scenario

M.G. wakes in his bedroom to the sound of his alarm. His wife helps him out of bed and he gets ready for his day. He is meeting with a client at a coffee shop a few blocks down the street, so he makes sure to grab his walking stick before leaving. While walking to the cafe, he is careful not to step on any rocks or in any divots or holes that could cause him to lose balance and fall. He has enough strength to walk with his knees locked, but rough surfaces and loose items could cause his knees to buckle. When he arrives at the cafe, he shakes his client's hand and sits down across from them. The weakness in his legs means he has to fall into his seat rather than lowering himself into it. When the client meeting is over, he has to stand up, but the seat is rather low and this movement puts significant strain on both his lower and upper body. Luckily, there is enough room around the seat to achieve a wide stance to support the movement. He has to lean all his weight on the coffee table and push himself up with both hands to get up. He realizes his wallet had fallen out of his pocket when he was getting up, so he must sit down to grab it from the floor. He then must stand up again using the same method, but his muscles are fatigued and he finds it more challenging to get up the second time. He wishes he were able to stand up from lower chairs with less physical effort. He is also self-conscious about how much attention this movement may draw to him in public spaces, and he wishes that he could sit down and stand up more discreetly.

Project Requirements - Needs Identification, Metrics, and Specifications

Table 1: Project Requirements

Needs	Metrics	Units	Ideal Value (See Appendices I and L)	Allowable Value	As-Built
Easily transported	Weight	lb	1 Based on the project partner's personal walking stick	8 Estimated weight based on current components	5 lb

	Shape	N/A	Walking stick/Hiking stick		Horizontal handle walking stick
	Max diameter	in	1 Based on the average diameter of a walking stick	3 Estimated rod width based on current linear actuator	3 in
	Max height	in	50 Based on the project partner's current walking stick height	42 Estimated height based on current linear actuator	52 in
Discreet	Color	N/A	Black or Gray	N/A	black
	Noise	dB	50 dB	70 dB	50 dB
Stable Base	Base radius	in	3	1	18 mm or 72 mm (depending on base choice)

	Base material	N/A	Rubber	N/A	Rubber
Can safely lift the project partner's weight	Force, material	N, lbs	1000 N, 220 lbs Based on the project partner's full weight, to ensure no failure	Greater than 800 N, 180 lbs	1000 N
Ergonomic and comfortable handle	Material /shape	N/A	Enough cushion on the handle to place full upper body weight on it for up to 30s	N/A	Foam handle cover around metal handle

Appendix O: Instructions for Use

DTC 1 - Team 13.3

Alexander Patt, Axel Hinz, Jixin Yan, Maxwell Kaung

Introduction

These instructions will cover the following sections:

- (1) Setting the Extend-a-Stick for use
- (2) Using the Extend-a-Stick for sit-to-stand assistance
- (3) Removing, charging, and replacing the Extend-a-Stick's rechargeable battery
- (4) Replacing the Extend-a-Stick's piston foot

The use of Extend-a-Stick does not require any experience or background knowledge. The user should be able to complete the setup of the product independently within 1-2 minutes.

Parts List

- Extend-a-Stick
- Extend-a-Stick fitted rechargeable 12V drill battery
- 12V drill battery charger

Safety Information

CAUTION — Potentially Hazardous Mechanical Movement

Refrain from putting hands, fingers, or loose clothes near the interface between the piston and the outer shell of the Extend-a-Stick.

WARNING— Electricity

Use the supplied 12V drill battery. Check battery conditions before use. Do not expose the Extend-a-Stick motor box, battery, or battery charger to water or extreme conditions.

CAUTION — Operation

Ensure the environment is free of excessive moisture or slippery surfaces that may cause the Extend-a-Stick to slip. Use with caution and ensure a steady base during use to prevent a fall.

Carefully follow each step and consider all recommendations in the following instructions to minimize risk of injury or damage to the Extend-a-Stick.

Setting Up Your Extend-a-Stick

Parts required: Extend-a-Stick, Extend-a-Stick-fitted rechargeable 12V drill battery, 12V drill battery charger

1. Place the Extend-a-Stick horizontally on a flat, open surface
2. Move the switch on the side of the Extend-a-Stick's motor box to the "centered" position if it is not already centered
3. Slide a fully charged, fitted, 12V drill battery into the battery port on the side of the Extend-a-Stick's motor box

- a. Ensure the metal spades on the battery port slide into the outer slots of the drill battery
4. Flick the switch on the motor box so that it is pointing towards the handle of the Extend-a-Stick
 - a. The piston of the Extend-a-Stick will start to extend. Ensure that there are no obstacles in the way of the piston as it extends, and wait for the piston to completely stop extending before proceeding to the next step
5. Place the Extend-a-Stick upright on its piston foot and firmly grip the handle to use as a walking stick

Using Your Extend-a-Stick for Sit-to-Stand Assistance

Parts required: Extend-a-Stick

1. Flick the switch on the Extend-a-Stick's motor box so that it is pointing down, towards the foot of the stick
2. Move the switch to a "centered" position when the top of the Extend-a-Stick handle has reached the hip height of a seated position
3. Move the switch between the "up", "centered", and "down" positions to adjust the stick to the preferred height
 - a. It is highly recommended that the Extend-a-Stick be lowered to below chest height
4. Move the base of the Extend-a-Stick so that it is centered between the legs and approximately 6" away from the feet
5. Shift forward as far as possible to the edge of the chair/seat
6. Widen stance as far as possible in seated position
7. Lean forward over the Extend-a-Stick so that the sternum/lower chest is directly over the stick's handle
 - a. Ensure that the stick is completely upright to prevent risk of damaging the Extend-a-Stick or falling
8. Grab the horizontal handle with one hand
9. Place the entire bodyweight on the handle of the Extend-a-Stick
10. Flip the switch on the motor box "up" and quickly grip the handle bar or handle base with the other hand
 - a. The Extend-a-Stick will begin to extend upwards at a constant pace
11. Move the switch to a "centered" position when the Extend-a-Stick reaches the preferred height, or wait for the Extend-a-Stick to reach full height

Charging Your Extend-a-Stick

Parts required: Extend-a-Stick, Extend-a-Stick-fitted rechargeable 12V drill battery, 12V drill battery charger

1. Hold the clip on the drill battery attached to the Extend-a-Stick and slide it upwards to remove it
2. Examine the condition of the drill battery and drill battery charger for damaged components

- a. Do not use a damaged battery or battery charger. Use the replacement provided or purchase an identical drill battery
3. Plug the battery charger into an electrical outlet
4. Carefully slide the drill battery into the battery charger
 - a. The spades of the battery charger should slide into all four slots of the battery
 - b. The LED on the battery charger should light up, signifying that the battery is charging
 - c. Wait until the battery is sufficiently charged
5. Removed the drill battery from the battery charger
6. Check that the switch on the side of the Extend-a-Stick's motor box is in the "centered" position
7. Slide a fully charged, fitted, 12V drill battery into the battery port on the side of the Extend-a-Stick's motor box
 - a. Ensure the metal spades on the battery port slide into the outer slots of the drill battery

Replacing Your Extend-a-Stick's Piston Foot

Parts required: Extend-a-Stick, 2 cm inner diameter rubber base

1. Flick the switch on the motor box to the "down" position to fully retract the Extend-a-Stick
2. Place the Extend-a-Stick horizontally on a flat surface
3. Remove the current rubber foot from the bottom of the piston
4. Slide a replacement rubber foot onto the base of the Extend-a-Stick
5. Place the Extend-a-Stick on the ground and carefully apply weight to make sure the base is stable and has sufficient traction

Troubleshooting

Problem	Probable Cause	Solution
The Extend-a-Stick will not turn on, even though the battery is attached	The drill battery is not charged, or the metal spades are not inserted into the correct slots	Check the charge of the battery and make sure that the spades are inserted into the outer two slots on the battery.

List of Figures

Figure 1: Design Approach

Created by Axel Hinz

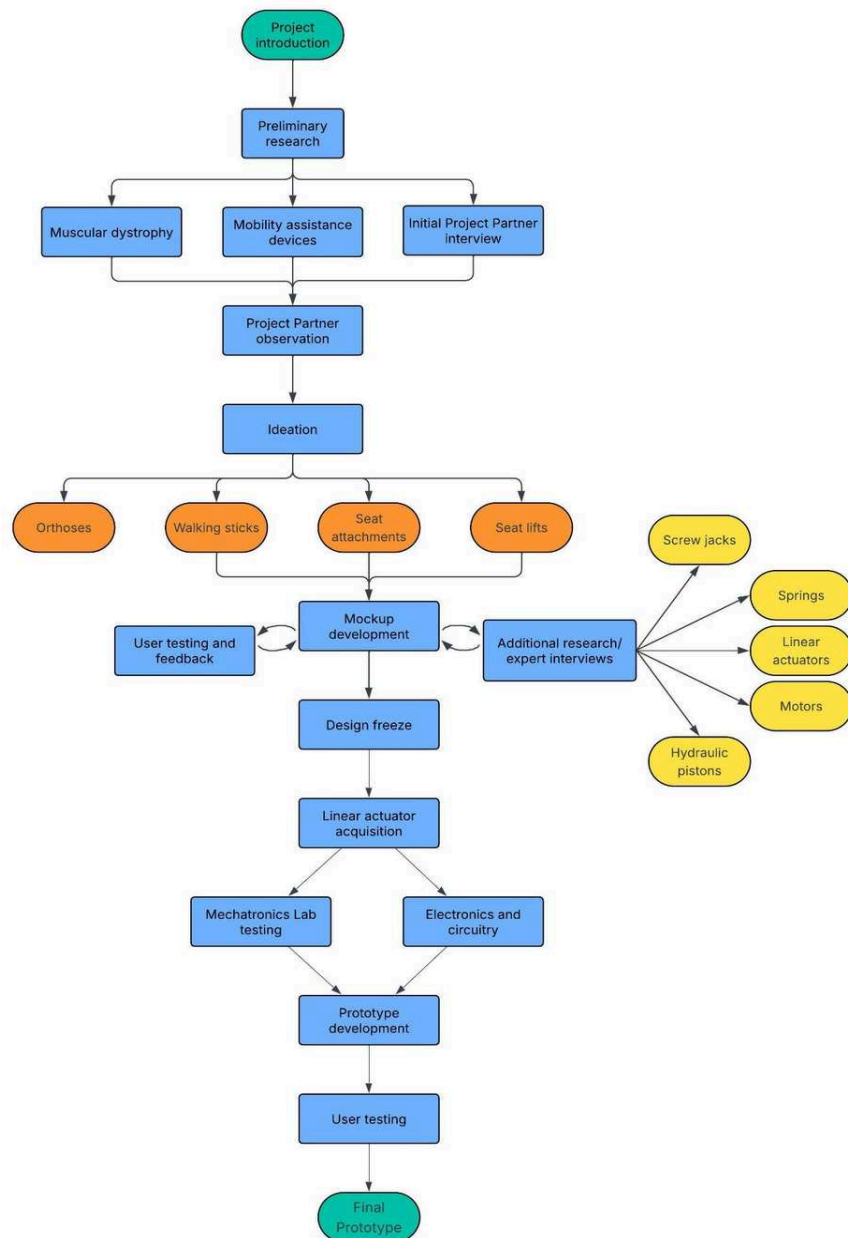


Figure 2: Concept drawing of the Extend-a-Stick.

Graphic by Maxwell Kaung.

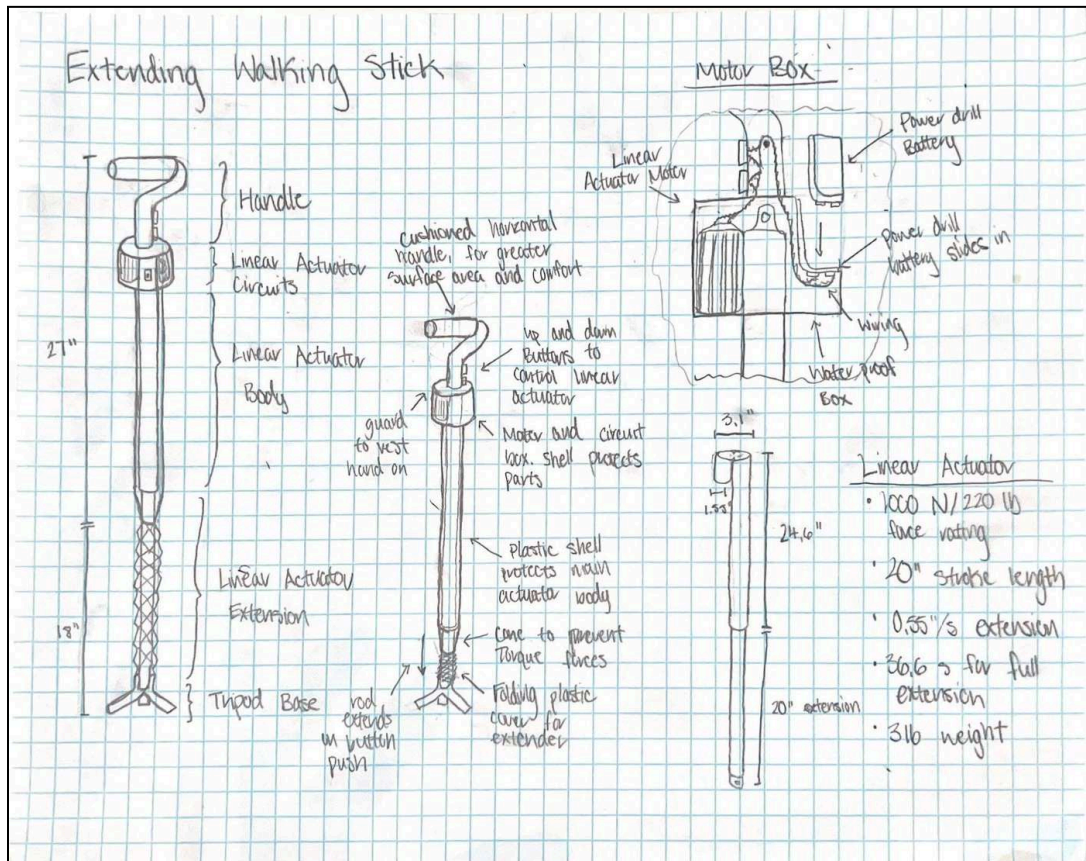


Figure 3: Linear Actuator Fully Extended and Fully Retracted

Graphic by Maxwell Kaung

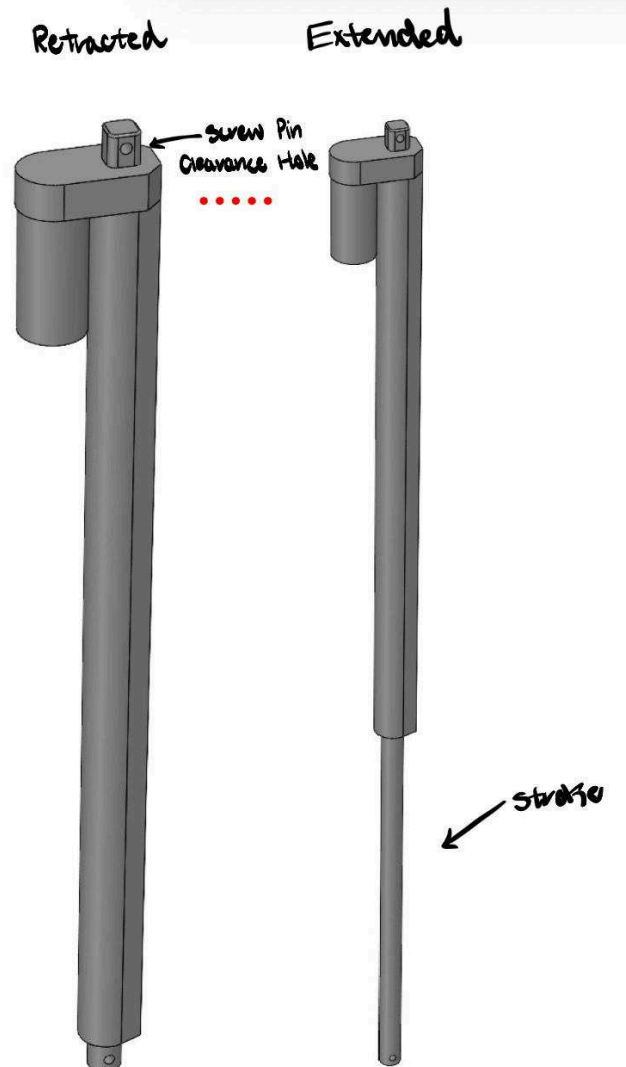


Figure 4: The Cushioned Horizontal Handle

Graphic by Maxwell Kaung

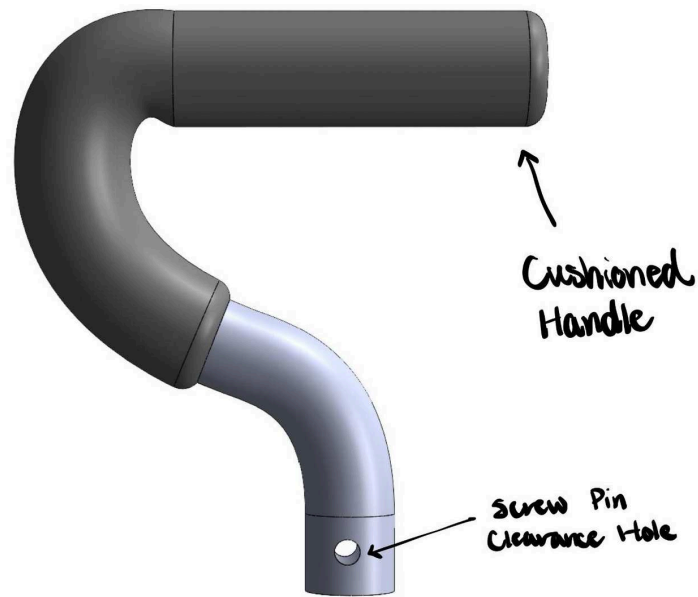


Figure 5: The Battery Case and Shell

Graphic by Maxwell Kaung using SolidWorks

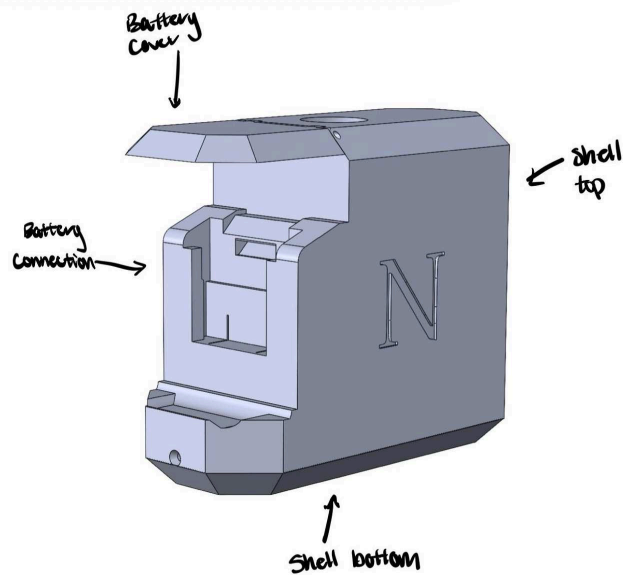


Figure 6: 12 V Lithium Ion Drill Battery.

Graphic by Maxwell Kaung



Figure 7: One-legged Rubber Base

Photo taken by Alexander Patt



Figure 8: Four-legged Rubber Base

Photo taken by Alexander Patt

