Portable Elevating and Transfer Seat for Wheelchair Users

BME 300/200

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Abstract

Muscular Dystrophy is a genetic disease that causes progressive weakness and loss of muscle mass. This likely leads to a life in a wheelchair for patients, as they do not have the muscular ability to walk on their own. One aspect of being in a wheelchair that these patients struggle with is transferring onto higher surfaces without the help of others. There are currently no affordable devices on the market that attach to wheelchairs and provide vertical and lateral assistance when transferring. This team's goal is to create a device that effectively raises and laterally moves a wheelchair seat for a patient with muscular dystrophy. The proposed design uses actuators, a lateral track, and a comfortable slick seat to meet the design specifications. The device will be evaluated based on how it works for the patient in situations where transferring tends to be pretty difficult.

I. Introduction

Wheelchairs help those affected with muscular dystrophy and other diseases to get around more easily without putting a large burden on their muscles throughout the day. While they are beneficial, wheelchairs are not perfect for everyone. Often, people who use wheelchairs are limited when they cannot elevate or need assistance to transfer in or out of their chair. While elevating seat lifts exist, they may be expensive, ineffective, or not all people qualify for this feature. Additionally, users often have to manually transfer to and from beds, chairs, toilet sets, and other surfaces which can be difficult especially at varying heights of the surfaces.

The goal for the project is to address this problem by designing an affordable device that can be added to the wheelchair. This product will provide seat elevation and transfer assistance between surfaces.

There are existing products that serve similar purposes to our proposed device. The Uplift Power Seat [1] is an effective device, however it can often be expensive and difficult to add to wheelchair seats. The wheelchair transfer board [2] requires a more manual transfer as it serves as a bridge between surfaces. This device can often be ineffective and difficult to use when transferring between two surfaces of different elevation. Also, it can often be difficult to bring around as it is large and difficult to store.

II. Background

As part of the background research, the team researched muscular dystrophy as the product is intended to be designed for users with muscular dystrophy. This is a group of diseases that cause weakness and loss of muscle mass[3]. Muscular dystrophy contains thirty different genetic disorders. The most common type is called Duchenne muscular dystrophy. Duchenne muscular dystrophy typically affects about one in 5,000 males at birth[3]. While there is no cure for muscular dystrophy, the symptoms can be helped by medications and therapy[4]. Steroids can be used to slow down the muscle degeneration.

Muscular Dystrophy is primarily a genetic disease, but in some cases may still be caused from genetic mutations[4]. Many of the common symptoms of muscular dystrophy include improper balance, progressive inability to walk, and muscular wasting[3]. This progressive inability to walk causes the individual to rely on another means of getting around, typically a wheelchair. Various methods to treat muscular dystrophy are physical therapy, surgery, and medications. Many devices have been developed to make it easier. The team’s product will be one of those devices.

Client Information:

Dan Dorszynski has worked with the UW- Madison BME program for a couple years now and loves the design process. Mr. Dorszynski has muscular dystrophy and looks to the BME program to create devices that make living easier for him. In the past he has had projects to help him play tennis and travel in a airport. This semester, he looks to the team to create a portable elevating and transfer seat that he could use to make the transferring process from his wheelchair much easier.

Design Specifications:

The product should have the ability to elevate 114 kg (250lb) by 6 inches. The product should also add no more than 5.08 cm (2 in) in height to the surface of the chair. In order to provide transfer assistance, the product should allow the user to move laterally, relative to the location of the seat. The part of the device that is in contact with the user should fit properly while causing no pain or discomfort to the user. The device should be constructed with slick, sturdy material allowing for efficient and easy transfer from one object to the other. Ultimately, these features should allow the user to move from the wheelchair to a surface at a higher elevation, without needing help from another person. Additionally, the product must support the weight of the user, and it must not compromise the stability of the wheelchair or the safety of the user.

III. Preliminary Designs

Based upon the culmination of research performed and talking with the client, the three following designs were created. All the designs would use materials that are strong enough to support the weight of the user and give sufficient lateral assistance when transferring surfaces. All designs would also be safe and cause no harm to the user.

Car Jack

Figure 1: Car Jack preliminary design drawing

The purpose of this device is to lift the user to a desired height while supporting the weight of the user and allowing stability for transfer on and off the device. The car jack design is a simple design idea in which a manual crank car jack is placed underneath a wooden baseboard and a more comfortable seat. The wooden baseboard will be connected to the seat piece by tracks, allowing the seat to move laterally. In order for this device to be used, the user will need to turn the crank to lift himself, and turn the crank the opposite way to lower himself. In order to move laterally, the user will need to unlock tracks before use, and lock the tracks back into their resting position when finished in order to provide maximum stability while lowering himself. The car jack will be strong enough to lift the user to the required heights and will provide plenty of stability at higher heights because of the strength of the material.

Gas Spring

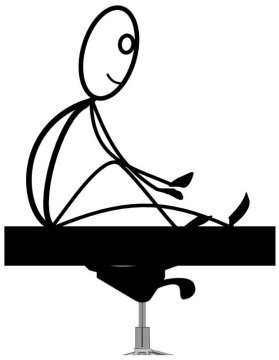

Figure 2: Gas Spring preliminary design drawing

This device would lift the user to a specific height using a pneumatic gas spring. A pneumatic gas spring design is found in many office chairs. The user will apply minimal pressure to the ground with their feet, allowing the gas spring to provide lift. The gas spring can be operated by pressing a lever attached to it. Once the desired height is acquired, the user can release the lever, locking it into place. This secures the seat into position at each height. The gas spring would sit on top of the existing wheelchair, with a platform above it to provide stability as well as a cushion for support.

Scissor Lift

Figure 3: Scissor Lift preliminary design drawing

This designs consists of a scissor lift that is mounted on top of the existing metal platform on the wheelchair. The top of the scissor lift would be connected to another platform, with a metal track mounted on top. A cushioned seat would be mounted within the metal track. The purpose of the scissor lift would be to move the seat vertically, while the metal track would allow the seat to move laterally. A retractable metal bar would be used to lock the seat into place at a specific position. Figure 1 shows an overview of the design, with the cushioned seat connected as it would during use. Figure 2 shows the concept of the slot with the metal track and retractable metal bar.

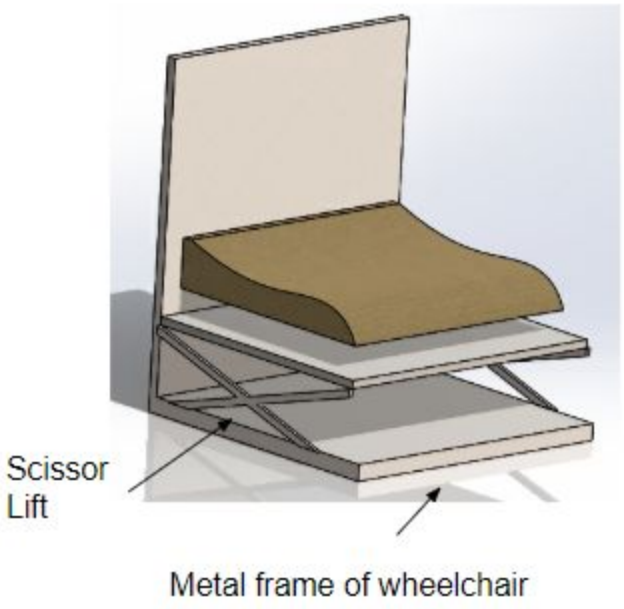

Figure 4. The scissor lift design, with a metal platform attached to the top of the scissor lift. On top of the platform is a metal track, and the base of the cushioned seat moves laterally along the track.

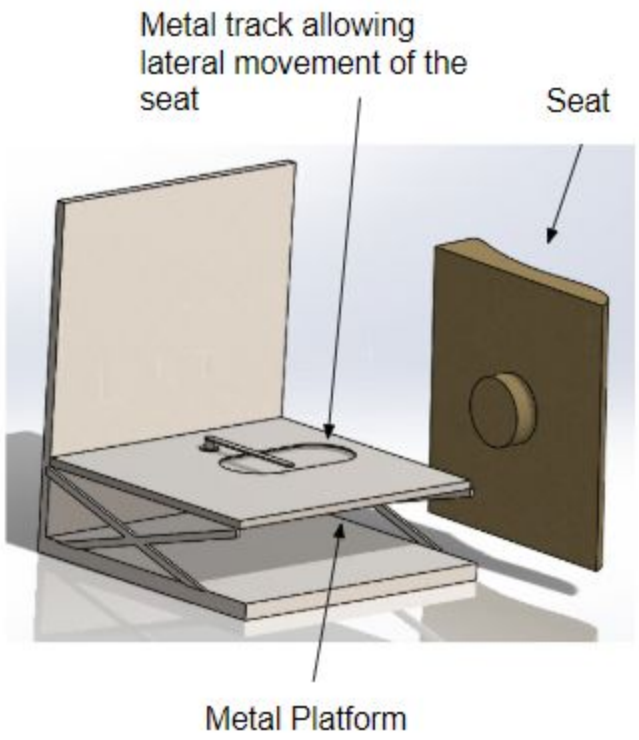

Figure 5. View of secondary metal platform with slot for a metal track. The seat is connected to a piece the can move along the metal track, when the retractable metal bar is turned.

IV. Preliminary Design Evaluation

Design Matrix

Design / Criteria (weight)	Car Jack 		Gas Spring/ The Office Chair 		Scissor Lift 	
Effectiveness(20)	4/5	16	4/5	16	4/5	16
Comfortability (15)	3/5	9	2/5	6	4/5	12
Ease of fabrication (15)	4/5	12	3/5	9	2/5	6
Ease of Use (15)	1/5	3	2/5	6	5/5	15
Durability (15)	4/5	12	3/5	9	3/5	9
Safety (10)	3/5	6	2/5	4	4/5	8
Weight (5)	1/5	1	4/5	4	3/5	3
Cost (5)	3/5	3	4/5	4	2/5	2
Total (100)	**62**			**58**		**71**

* Scores are out of 5. Displayed as score | weighted score

Table 1. The highlighted boxes indicate the highest scoring designs within each of the criteria.

Criteria:

Effectiveness: This category represents how effectively the user can transfer from the wheelchair to another surface. The team believes this category should have the highest weight of 20 because the goal of the device is to make it easier for a user to transfer from a wheelchair to a new surface, which is what this category measures.

Comfortability: This category refers to how comfortable the user finds the surface of the device they sit on. The team decided to give this category a relatively high weight of 15 because the user may be sitting on the device for a long period of time, so having a comfortable surface to sit on is very important.

Ease of Fabrication: Ease of fabrication is defined as the level of knowledge and skill required to fabricate the model as well as replace any needed parts. This category is ranked fairly high because the client has requested that the product be easy to fabricate at home, if possible.

Ease of Use: Ease of use is defined as how easy it is for the user to raise, lower, and laterally move the device. This category is ranked pretty high because if the the operation of the device is difficult or strenuous, users will likely not want to use the device as often.

Durability: Durability is defined as the ability to withstand wear and pressure. The device should be strong enough to raise and lower the patient's body weight whenever needed. The device should also be able to last a significant amount of time if it is durable. This category received a pretty high weight because the device is intended to be used indefinitely.

Safety: Safety is defined as the risk of danger presented to the user by using this device. This includes the risk of the device failing during usage and putting the user in danger. Safety is weighted at a medium level because it is important that the user is safe and does not have any risk of getting injured while using the device. However, it is not higher because the client is not too concerned over safety.

Weight: This category refers to the overall weight of the finished product. The team decided to have this category of not much concern with a weight of 5 as the overall weight of the device will not affect the ability to perform and was not mentioned as an area of much importance by the client.

Cost: This category is referring to the total price of all the materials and production of the device for the finished product. The team decided to place the category as one of the lowest in importance with a weight of 5 because cost is not much of a concern as it is predicted that, by the end of the semester, the budget of the project will not be reached.

Scoring:

Car Jack

The Car Jack design did not end up being the most effective design the team came up with. The design preformed pretty well in effectiveness, but struggled in most of the other categories. This design recieved a low rating of two out of five for comfortability because it would sit quite high on the wheelchair, leading to an uncomfortable sitting arrangement for the user. The design recieved a high rating for ease of fabrication because it is feasible for a user to build themselves if they have the appropriate tools on hand. Next, this design recieved a low rating for ease of use because the user would need to ratchet themselves up with arm strength, which may be pretty difficult to do while sitting in the wheelchair. This design did pretty well in the durability category because car jacks are designed to hoist cars, which weigh much more than 113 kg (250 lbs). Therefore, lifting 113 kg (250 lbs) repeatedly should be of little problem for this design.This design did not perform well in the safety category because operating the lift with the users are muscles can be quite strenuous and possibly cause an injury. This led the team to a three out of five score for the Car Jack design in this category. Finally, Car Jacks tend to be extremely heavy and relatively expensive, which could cause issues for the user with moving the wheelchair and purchasing materials. Overall, the Car Jack design did pretty well in the Effectiveness, Ease of Fabrication, and Durability categories, but struggled to stay on pace in the rest.

Gas Spring

The gas spring is not the most effective design idea that the team came up with. While it has a four out of five for effectiveness, this design falls short for many of the other categories. It would sit fairly high on top of the wheelchair, causing it to be uncomfortable and unsafe. The user would also have to apply some pressure to the ground in order to operate it. This might not be safe for the user's health. The ease of use is ranked low as well due to the user having to apply physical pressure with the floor. The weight and cost of this design ranked better than the other two, but this was overshadowed by the low scores on each of the other categories. Our team will keep this design and its features into consideration.

Scissor Lift (proposed final design)

Overall, the scissor lift rated out as the best design. It graded out as being extremely easy to use, because it will be controlled by a button, and overall comfortable for the user to sit in. The device is expected to be extremely effective in what it does because it starts and stops at a push of a button, allowing more easy transfer positions. Concerns over the durability of the device and the cost of fabrication are issues the team will need to cope with in order to make an effective device. Durability was a concern because of all the moving parts in the design, increasing the chances of failure. Also, the cost of the actuators provides a major fiscal concern due to the fact

that two large scale actuators would cut into the majority of the alloted team budget. Ease of fabrication was also rated lowly because of the multitude of moving parts in the design. If this device were to breakdown, repair would be difficult. Finally, the weight of the device was not considered an issue so the device received a moderate grade, neither helping or hurting its final score. Altogether, the scissor design in the design the team will be moving forward with due its many benefits outweighing its slight inconveniences.

V. Future Work:

As the project continues, the next steps include finalizing the design and beginning to order materials. The design matrix led the team to choose the scissors lifts as the best option to fulfill the clients needs; however, this does not mean the designing process is done. The team needs to decide the number of actuators needed to support the required weight and where the parts will be placed. One extremely strong actuator can be used, or two smaller actuators could be used in an effort to diffuse some of the pressure on the parts. Also, the team must test cushions that allow for sliding as well as comfort. If the user will be on the device, the seat cushion must allow for the user to be comfortable at all times. Research will need to be done into the most effective seat cushion that fits the users needs. The BPAG is responsible for finding the best materials for device as well as the most cost effective due to the budget of 250 dollars. If more money is needed the client has stated that the team could go over the allocated budget if need be or the team could petition the engineering school for more funding.

Currently, the largest issue with the device is the size and its lateral ability. The current wheelchair is already higher than some household devices, including toilets, and some couches. In order to make the device as beneficial as possible, the device should not add any extra height to the current seat as it would make transfering onto the household devices more difficult as it is further away. The team's device must not exceed 5.08 cm (2 in) in height. This short height will be difficult to accomplish as some actuators diameter is greater than this. The lateral ability of the device also calls into question the type of material the team can use so that the seat will not break, as well as the safest way to lock the device from moving laterally once its has reached its full width. Thin material cannot be used as it would break under lots of pressure. Calculations will have to be made to see which material will hold up the best under the weight. Also, in the current design the seat is on a lateral track that has a manual locking mechanism that may not be easily accessible to the user while the device is being used. The safety of the device is important to the team as the team does not want to injure the user is any sort of way. All future designs of the lateral movement of the device will take into account the safety of the user.

The end goal of this device is to provide the user with a more comfortable way to live their life. Through the future work of the team, the team hopes that the device will improve the quality of movement for the user and allow the user to save time while transferring between objects.

References

[1] Carex.com. (2018). *Upeasy Seat Assist Plus*. [online] Available at: http://www.carex.com/item/CCFUPE3/Upeasy-Seat-Assist-Plus/#.W6GhnuhKjIU [Accessed 19 Sep. 2018].
[2] Fairview.org. (2018). *Transferring using a Transfer Board*. [online] Available at: https://www.fairview.org/patient-education/40382.W6GhnuhKjIU [Accessed 19 Sep. 2018].
[3] NINDS. "Muscular Dystrophy Information Page." *National Institute of Neurological Disorders and Stroke*, U.S. Department of Health and Human Services, 2016, www.ninds.nih.gov/Disorders/All-Disorders/Muscular-Dystrophy-Information-Page.
[4] Choices, NHS. "Causes of Muscular Dystrophy ." *NHS Choices*, NHS, 2016, www.nhs.uk/conditions/muscular-dystrophy/causes/.

Appendix

Product Design Specifications

Portable elevating and transfer seat for wheelchair users
September 18, 2018
Advisor: Darilis Suarez-gonzalez
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Function:

People who use wheelchairs are limited when they cannot elevate their seat or need assistance to transfer out of their chair. While elevating seat lifts exist, they may be expensive, and not all people qualify for this feature. Additionally, users often have to manually transfer to and from bed, chairs, and toilet seats.

The goal for this project is to address this problem by designing an affordable aftermarket product that can be added to the wheelchair. This product needs to provide seat elevation and transfer assistance.

Client Requirements:

- Device needs to fit the current wheelchair.
- Device must be able to lift at least 6 inches.
- Device needs to support and raise/lower 250 pounds safely.
- Device must be able to fit through doors and hallways.

Design Requirements:

1. Physical and Operational Characteristics:

a. *Performance requirements:* The product should have the ability to elevate the user by 6 inches. If possible, the product should also be able to lower the user by 2-3 inches. In order to provide transfer assistance, the product should allow the user to move forward or laterally, relative to the location of the seat. Ultimately, these features should allow the user to move from the wheelchair to a surface at a higher elevation, without needing help from another person. Additionally, the product must support the weight of the user, and it must not compromise the stability of the wheelchair or the safety of the user.

b. *Safety:*The device must also allow for safe movement up, down and forward along with laterally on and off of his wheelchair. The material and connections must be strong enough to support 250 lbs of weight while transferring. Finally, the device, if detachable, should be able to be removed and stored without straining or putting the user in danger.

c. *Accuracy and Reliability:* The device should be functional for a user with limited to no lower body movement and limited upper body strength. The device should be reliable and have the ability to withstand everyday use from the user without breaking down. The part of the device that is in contact with the user should fit properly while causing no pain or discomfort to the user. The device should be constructed with slick, sturdy material allowing for efficient and easy transfer from one object to the other.

d. *Life in Service:* The device should last indefinitely

e. *Shelf Life:* The device should be able to withstand multiple uses everyday with some uses coming in short succession of eachother. The device should last indefinitely. Some elements may need to be adjusted if the user's needs change or upgrades for the device are designed. Depending on the design, batteries may need to be replaced along with wiring, and other small pieces of hardware.

f. *Operating Environment:* The model will mostly be used in an outdoor and indoor environment, so it needs to be able to withstand both conditions. The device will also be a part of a moving object, so it needs to be able to withstand bumps and jerks along the way. Finally, the device needs to support the weight of the user at all times when used.

g. *Ergonomics:* This device should support a weight of 250 pounds. It should be comfortable for the user to both sit in and operate.

h. *Size:* The device should be able to fit on the the seat of the wheelchair, while not being too wide or too long where it would impede the user's use of going in and out doorways. The maximum size the device can be is 20in x19in.

i. *Weight:* The device should not be too heavy where it negatively affects the speed of the chair, but it still needs to have enough weight to support the weight of the user while raising or lowering.

j. *Materials:* Components that the user will not be sitting on should be made of a material with minimal friction such as a lightweight metal or finished wood. Cushioned material should be used for any permanent seat to increase the comfort of the user.

k. *Aesthetics, Appearance, and Finish:* The device should look professional and match the rest of the wheelchair in design and comfort. It should be comprised of neutral colors.

2. Production Characteristics:

a. *Quantity: 1*

b. *Target Product Cost:* Less than $250

3. Miscellaneous:

a. *Standards and Specifications*:

FDA Code of Federal Regulations: Title 21, volume 8, sec. 890.3930 Wheelchair elevator:

Code is for: "A permanently mounted wheelchair platform lift is a motorized vertical or inclined platform lift device permanently installed in one location that is intended for use in mitigating mobility impairment caused by injury or other disease by providing a guided platform to move a person from one level to another, with or without a wheelchair."

Key Points:

- Analysis and nonclinical testing needs to show that safety controls are appropriately incorporated in order to prevent free fall of the platform if it fails
- Analysis and nonclinical testing needs to show that the device can handle the intended load with an appropriate factor of safety.
- Analysis and nonclinical testings needs to show that the device provides an adequate enclosure to prevent the user from falling off of the device.
- Analysis and nonclinical testing needs to validate electromagnetic compatibility and electrical safety

b. *Customer:* The client wants a device that can be used to elevate the wheelchair seat approximately six inches in order to help the user more easily transfer to a higher surface. The client also wants this device to be able to move laterally and distally to provide additional help for the user in transferring surfaces.

c. *User-related concerns:* The client wants the device to fit through a door with ease and to avoid any parts behind or above the head.

d. *Competition*: Current equipment on the market are too expensive even with insurance. The user believes the current products are “over designed” . Additionally, there are currently no products that can be added on to a wheelchair in order to provide elevation or transfer assistance; however, there are existing designs that integrate these features directly into wheelchair. Some examples include:

- A wheelchair design that uses cloth bands that are attached to a canvas or plastic seat. These bands are secured around the arm rests and attached to a power shaft that is mounted below the seat; the power shaft is used to shorten or length the cloth straps in order to move the seat up or down [1].
- A wheelchair design that uses an adjustable seat supporting mechanism beneath the seat, that is actuated by a hand crank. The mechanism includes foldable tubular link members that are connected to each other and can pivot in order to raise or lower the seat. The seat supporting link mechanism is directly connected to the rest of the frame of the wheelchair including other metal side supports and the front and back wheels [2].
- Carex Health Brands sells a portable lifting seat that raises and tilts in order to help the user reach a standing position. This seat is self-powered and uses a hydro-pneumatic gas spring, and it can lift up to 340 lbs; however, this product is not designed for attachment to a wheelchair specifically [3].

4. References

[1]. W. R. Griffin, “Elevating wheel chair seat,” 05-Feb-1963.
[2] J. P. Minci, “Portable and adjustable wheel chair,” 02-May-1961.
[3] Carex.com. (2018). *Upeasy Seat Assist Plus*. [online] Available at: http://www.carex.com/item/CCFUPE3/Upeasy-Seat-Assist-Plus/#.W6GhnuhKjIU [Accessed 19 Sep. 2018].