Stair Chair

Preliminary Report

BME 200/300 Section 307
October 9, 2024

Client

Mr. Daniel Kutschera

Advisor

Dr. James Trevathan

Team

Matt Sheridan	mjsheridan2@wisc.edu
Cody Kryzer	ckryzer@wisc.edu
Daniel Altschuler	daltschuler2@wisc.edu
Abi Conners	aconners2@wisc.edu
Luke Rosner	lrosner2@wisc.edu

Table of Contents

Abstract

Patients at the Ecompass Rehabilitation Hospital need a means to be discharged from the hospital as quickly as possible, but stair negotiation, especially for older patients, keeps them hospitalized. An electric stair could be purchased, but these devices are bulky and often too expensive to warrant purchase for short 8-10 week non-weight-bearing periods for most patients. No mechanically powered devices exist on the market to combat this problem of short term stair negotiation. To solve this problem, the team decided upon a design with two connected aluminum diamond tread plates held together by hinges that can be lifted up through the use of a winch. These plates will be mounted on aluminum extrusion for stability and act as a freestanding unit that can be used for stair ascension and descension for short periods of time after discharge from Encompass Rehabilitation. Failure tests will be performed on the hinges and the winch system to ensure the desired factor of safety will be determined for the device and to prevent total mechanical failure. Other tests for the mechanical advantage provided by the winch system will be performed to determine the appropriate tuning for all users so that the device works quickly and efficiently. An effective and inexpensive stair negotiation device will provide recovering patients from Encompass Rehabilitation a quicker path to discharge and a safe means to go from in and out of their homes on a daily basis.

Introduction

Motivation

Stair negotiation is a major obstacle for individuals rehabbing temporary wounds to their lower extremities. Over a million Americans each year will be treated in emergency departments for complications from falls during ascension and descension of stairs [1]. Completely healthy older adults are at a greater risk for falls on stairs because of a lack of balance and have a greater risk for tripping [2]. 42.1% of stair related injuries are to lower extremities and older adult patients (>55) are more prone to fractures than their younger counterparts [1]. Most ankle fractures for these patients tend to lead to 6-12 week non weight bearing periods, where stair negotiation becomes even more of a challenge [3]. The motivation for this project is to create a device that allows the user to ascend and descend stairs during this temporary non-weight bearing period.

Competing Designs

While electric stair chairs do exist on the market in great numbers, they accomplish the same goal but for a different problem. A typical electric stair chair will cost at a minimum $2000 USD, a price that many individuals are not willing to pay for stair negotiation over a 6-12 week recovery window [4]. The market for these types of devices is typically arthritic elderly patients who require these lifts for the rest of their lives, making the price a more warranted investment [5]. This is not the market the team is looking to reach. The mechanically powered stair chair is instead targeted towards individuals within a 6-12 week recovery period, who need a temporary, inexpensive solution to stair negotiation, and not a bulky expensive device that is nearly useless after recovery.

Problem Statement

The team is creating a mechanically powered stair climbing device to help temporarily disabled patients at Encompass Rehabilitation Hospital with stair negotiation during their non-weight bearing period of recovery. Crutching up stairs is not feasible for elderly patients, and large electric stair climbing devices are beyond the budget of many patients. The device should be able to fit between 3-5 stairs and withstand average outdoor weather conditions in the state of Wisconsin.

Background

Physiology

To get a better understanding of the mechanical advantage the team would have to tune the track based designs for, research was done on the seated leg press one rep max of women in the 80-85 age group. The team decided to focus on this age group in particular per client's request, as he identified them as likely the weakest of the patients he sees. Tuning the device to the weakest user would ensure the device be usable for a wide range of patients. From a study conducted by Rosalia L. Parrino et al, there was a quantitative measure associated with one rep leg press strength per body mass [6]. A value of 1.72 (load/body mass) was determined and will be the team's initial value for tuning prior to possible testing.

Design Research

Given the novelty of the product, the team was not able to locate any codes or standards that directly related to the device. With this in mind, the team decided to turn its focus to general medical device standards issued by ISO and Wisconsin State Legislature for stair construction code. ISO 13485 is the standard of quality of medical devices throughout their lifecycle, and emphasizes process documentation and risk management for all devices to market [7]. With this in mind, the team will include two points of failure prevention in any design to market to fit within these guidelines, and also keep the LabArchives up to date for all of the design process. Per the Wisconsin State Legislature on stairs, any set of three or more risers must have a handrail. Any set of stairs must also be 91.4 cm wide and each riser may not exceed 20.32 cm in height between top to bottom [8]. With this in mind, the team must design a device that can fit within these sizes so that it is usable on all up to code stairs in the state of Wisconsin.

Client Information

Mr. Daniel Kutschera is a physical therapist at Encompass Rehabilitation Hospital in Fitchburg, Wisconsin. The client hopes to rent out this device to elderly patients with injuries to lower extremities as they recover.

Design Specifications

The device is a mechanically powered stair climbing device that can ascend and descend between 3-5 stairs and be used frequently for up to 26 weeks at a time. The device must also be able to withstand masses of up to 140 kg to account for the many different masses of individuals using the device. The max weight of the product should not exceed 30 kg to make sure it is easily able to be moved between home to home. The device must also have appropriate safety features, such as a seatbelt for users and a system to prevent total mechanical failure or sliding down the track. Given the teams to consider the device as rentable by durable medical equipment (DME), the expected life in service for the device should be around 5 years, like other DME devices (see Appendix A).

Preliminary Designs

Design 1: Ratchet

The first design utilizes a ratchet system to get up the steps. The design includes a seat that rotates 360 degrees to make getting on and off easy and also a lap belt for safety. The user sits down facing down the steps and uses their good leg to ratchet themself up the steps with the seat locking in place along the way. To get down, a handbrake mechanism is in place to control the descent of the user. The seat glides along a continuous track in a clockwise direction.

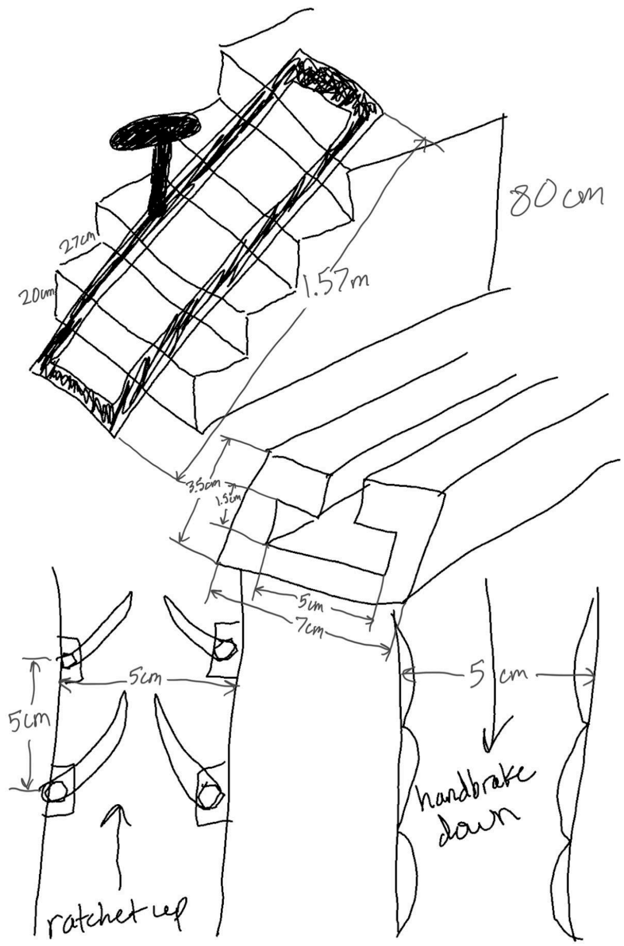


Figure 1: Ratchet Design

Design 2: Counterweight

The second design utilizes a counterweight to aid in both the ascent and descent of the stairs. The design also includes a swiveling seat to allow for easy entry and exit from the device and a lap belt for safety on the ascent and descent. Additionally, the seat is moving up and down on two tracks, with a third in the middle housing the counterweight. The seat and the counterweight are connected via a pulley system, and the counterweight would be adjusted in weight based on the user's weight. On the way up, the counterweight would be lowered, meaning less force would be required to move up the stairs. The user could either push themselves up with their working leg or use the railing to pull themselves up. On the way down, the counterweight would be raised, slowing the descent to make it both safe and quick.

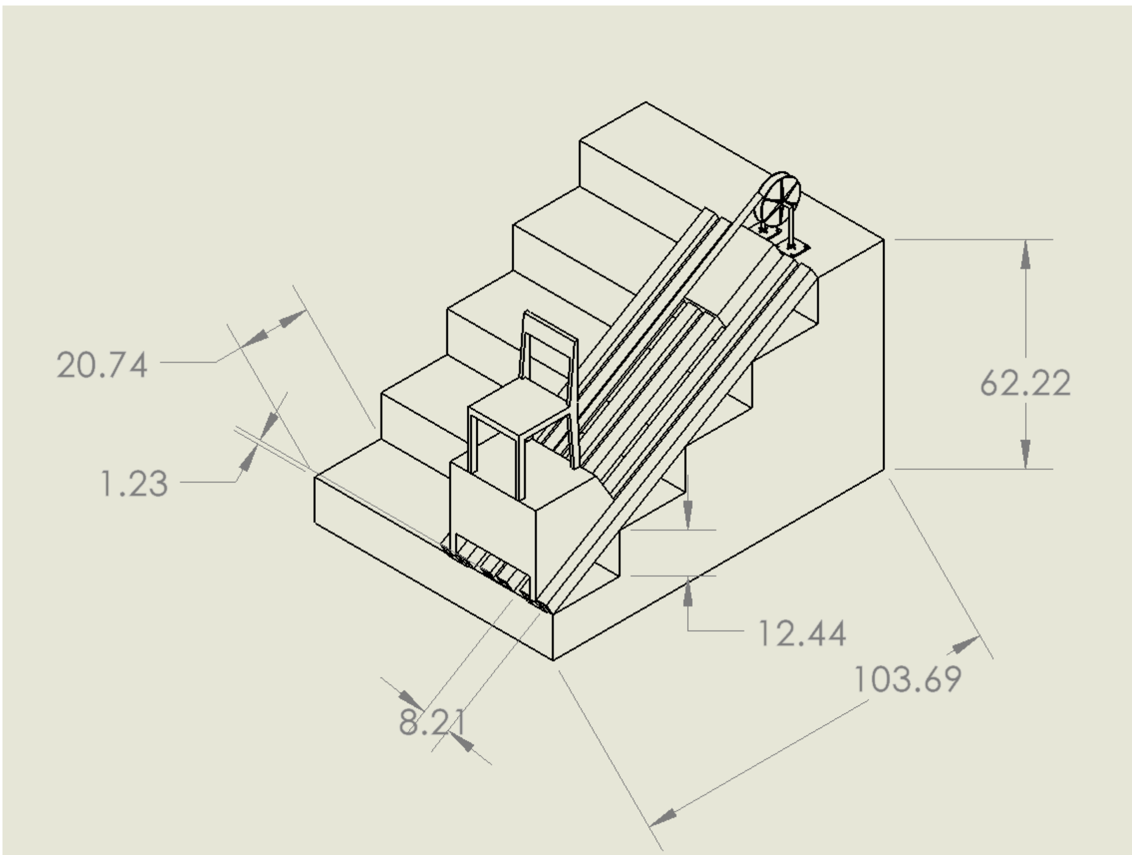


Figure 2: Counterweight Design

Design 3: Hydraulic Pump Design

The third design uses a hydraulic pump mechanism to raise and lower the user up the stairs along two tracks. The user pushes down on a pump similar to that of a barbershop chair, which causes the chair and the pump to slowly raise. The mechanical advantage could be easily adjusted by tweaking the radii of the hydraulic tubes, which would allow for different users of different weights and levels of strengths to all utilize the device. The hydraulic pressure would also slow the descent, keeping the descent safe but relatively quick.

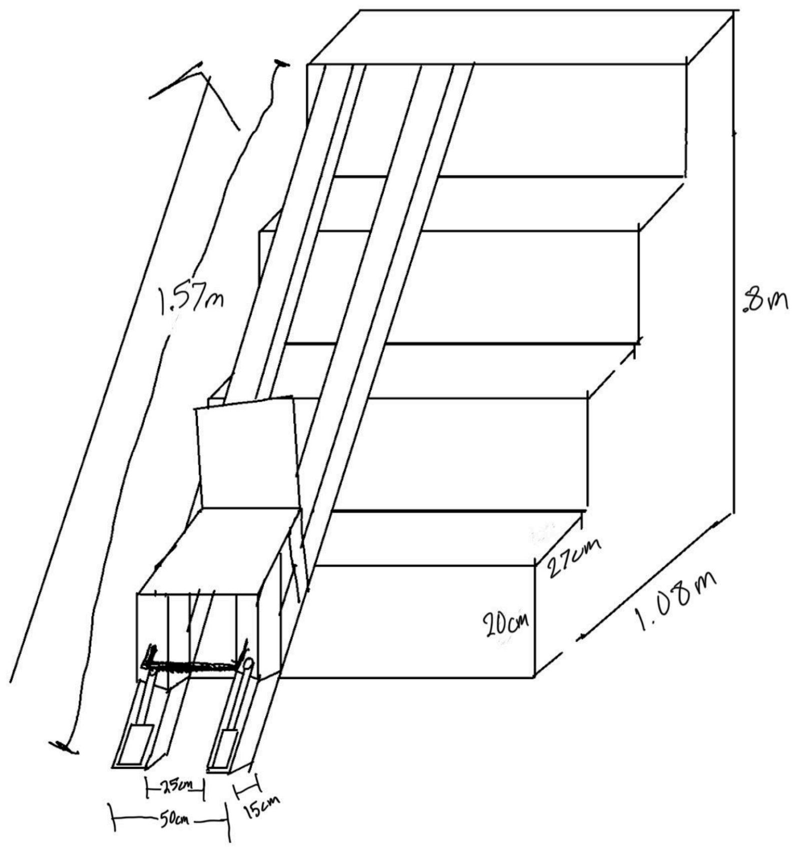


Figure 3: Hydraulic Pump Design

Design 4: Vertical Lift

The fourth design uses a winch system to raise and lower the user on a platform, allowing the user to either walk or wheel across the flat platform to get to the top of the stairs. The flat platform is connected via a hinge to the main platform, and locks into a flat position when the main platform is at the maximum height. The winch system is hand-powered, and can be adjusted to allow for users of different strengths to easily but relatively quickly raise themselves. This design is wheelchair compatible, allowing users to bring their wheelchair up with them, never having to switch between their wheelchair and another chair in the raising process. To descend, the user moves across the flat platform to the main platform, uses the winch to lower the platform, and then rides or walks off.

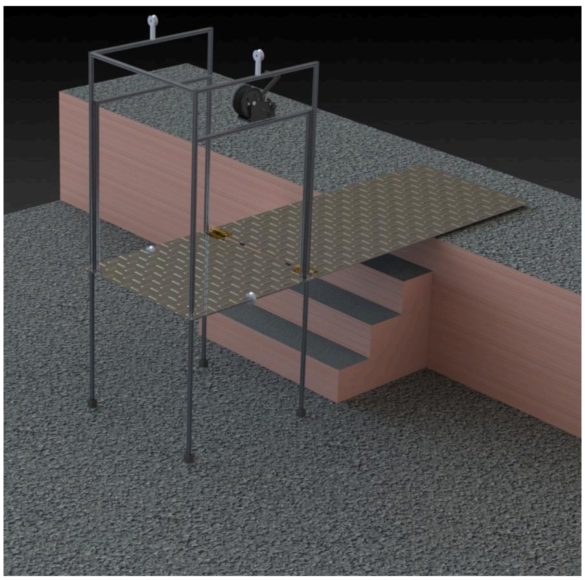


Figure 4: Vertical Lift Design at Lowered Position

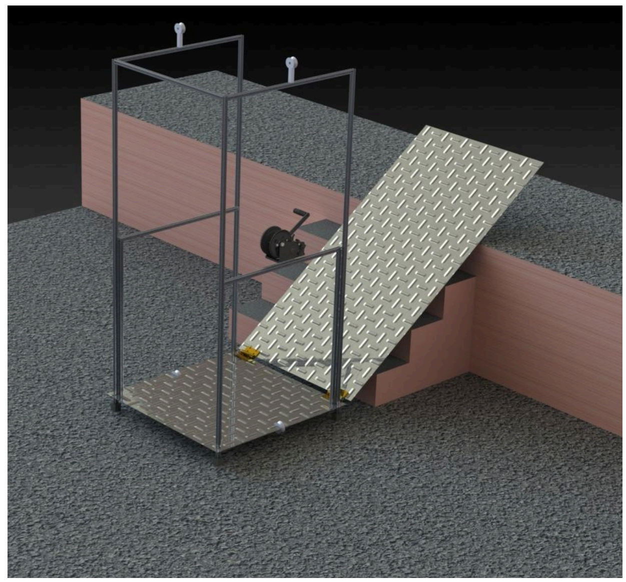


Figure 5: Vertical Lift Design at Raised Position [9]

Preliminary Design Evaluation

Design Matrix

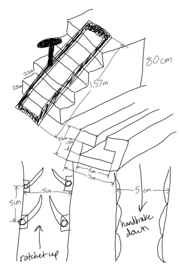
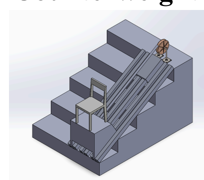
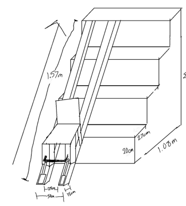
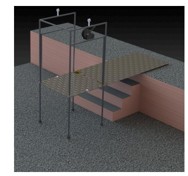
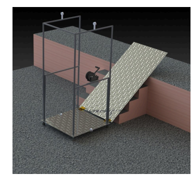
Design Criteria (Weight)	**Design 1: Ratchet** 		**Design 2: Counterweight** 		**Design 3: Hydraulic Pump** 		**Design 4: Vertical Lift**  	
Safety (25)	2/5	10	4/5	20	4/5	20	5/5	25
Efficiency/Ease of Use (25)	4/5	20	5/5	25	3/5	15	3/5	15
Adaptability (15)	3/5	12	2/5	6	2/5	6	5/5	15
Ease of Fabrication (10)	2/5	4	4/5	8	3/5	6	4/5	8
Weather (10)	3/5	6	4/5	8	3/5	6	4/5	8
Cost (10)	4/5	8	3/5	6	3/5	6	2/5	4
Weight (5)	5/5	5	1/5	1	5/5	5	1/5	1
Total Score (100)	**65**		**74**		**64**		**76**	

Table 1: Stair Chair Mechanism Design Matrix

Safety

The safety category refers to the risk of injury for a user while operating the stair chair. This category also considers the risk of worsening injuries through accidental mechanical output from the user's wounded lower extremity, either through slipping while operating the device, or total mechanical failure. Given the wide range of patients that the stair chair is hoped to be usable for, and the risks of mechanical failure, the team decided to weigh the safety category highest at 25. The vertical lift design won the safety category because the user never needs to move up and down an incline, which contributes to user safety. It also will have attached railings so that individuals will not roll off the lift as it raises.

Speed/Efficiency

The efficiency/ease of use category refers to how quickly the user can get from the bottom to the top of the stairs and how easily the chair is mounted and dismounted by the user. The team recognizes that an inefficient and slow device will not be worth using and that a device that involves significant mechanical output could limit the kind of patients who can operate the device. With this in mind, the team decided to weigh this category the second highest at a 20. The counterweight design won this category with a 5/5, earning this score for the ease of tuning the weight. The counterweight would also likely be the fastest of the options, making it much more efficient than slowly ratcheting up a track, or pumping a hydraulic chair.

Adaptability

The adaptability category refers to how much the device can be altered to fit the needs of the user. Whether the rails must be able to telescope to adjust to different amounts of stairs is one of the major considerations of this category. Also, how much tuning the device may need between patients is another consideration of this category. Given this, the team decided to weigh this category at a 10. The boat lift won this category with a 5/5 because the platform could feasibly raise to many different amounts of stairs, making it a lot more adaptable than the other track bound designs.

Ease of Fabrication

The ease of use fabrication category refers to the simplicity of designing and eventually creating a working prototype. One of the major considerations of this category is the amount of time the team has to work on the product, as well as the materials needed to complete the designs. With this in mind, there was a tie in this category between the counterweight and boat lift design, with a score of 4/5. Both designs scored highly in this category due to their large simple parts that can be fabricated by the team, as opposed to the smaller more intricate parts, especially in the ratchet mechanism.

Weather

The weather category refers to how well the design can survive extreme temperatures and severe weather conditions. The device must also be able to withstand general wear and tear from water and sunlight exposure for long periods. Since the device is meant to be usable year-round, and the winters are unpredictable in the Midwestern market, the team decided to weigh this category at a 10. The counterweight and boat lift designs tied in this category with a 4/5 mainly due to their adaptability to the cold weather conditions. The hydraulic design could fail with drastic changes in pressure, and the small ratchet mechanism could corrode after long exposure to rain and heat.

Cost

The cost category refers to how expensive the design is to fabricate and maintain. The major considerations of this category involve the complexity of designs, and also how long those designs can go between major costly repairs. Since keeping the design as inexpensive as possible was a major request from the client, the team decided to weigh this category equally with other client requirements such as the ability to withstand weather and be able to adapt to different amounts of stairs. The ratchet design won this category with a 4/5 in comparison to the larger more expensive mechanisms such as the boat lift, which would have to be purchased by the team, or a large hydraulic mechanism which would be expensive to fabricate.

Weight

The weight category refers to the weight of the device, and therefore how easy it is to set up on the stairs of each user. Since the device is temporary, it must weigh enough to prevent any tipping or sliding, but also be able to be moved between the homes of users with ease. While the weight category is an important factor to consider, the team decided that other categories were more deserving of strong consideration for the final design, and therefore weighed this category at just a 5. The ratchet and hydraulic pump design won this category with a score of 5/5 as their weight can be easily tuned by the types of materials and fluids used for the hydraulic design.

Proposed Final Design

The team has decided to move forward with the vertical lift design. It is the safest of all the designs which is very important since the users are primarily elderly stroke patients or individuals with physical disabilities. The safety comes from the elimination of various failure points such as the transition from wheelchair to an alternative chair, or a rapid descent. It is also the only design that allows the user to remain standing or seated in their wheelchair while getting over the stairs which will help with efficiency and make it easier to carry any cargo up the stairs. Additionally, the vertical lift design is the most adaptable because it only moves vertically and horizontally, and doesn't interact directly with the stairs. This would make it much easier to adjust to different staircase designs, as height is the only notable variable. It also does not require any interaction with a railing, allowing it to be implemented on staircases without railings and those that do not have a stable railing.

Fabrication

Materials

The base plates for the design would be made out of aluminum diamond tread plate. The team decided on this material because of its strength and durability. It also has increased corrosion resistance and is considered to be economical as opposed to alternative materials [10]. To mount the base plates, the team would use 20 mm x 20 mm aluminum extrusion for its resistance to debris buildup. The four open slots on the sides also allow for access in any direction and work well for any type of mounting [11]. For the winch, the team would likely use the Dutton Lainson Brake winch because of its long life and rust resistance. This winch can also lift up to 544 kg which would be perfect for the vertical lifting needed in the team's proposed final design. A built in friction brake will also prevent some user error when operating the device [12].

Methods

The team's full design could be fabricated at the UW Design Innovation Lab. The team does not currently plan on making a full scale prototype due to time and cost constraints. In order to create a model for testing, the team will 3D print parts at a decreased scale factor. Components like the winch would be left out of the scale model as the forces involved would be much smaller. However, these scale forces could be measured and then scaled to the full scale model.

Testing and Results

There are 4 tests that the team will be doing to test the vertical lift design including the hinge maneuver, the force required to to lift the platform, the weight limit, and the stability of the structure. In order to test the hinge maneuver, the hinge will be secured to two boards with scaled down dimensions of the final design. After mounting the scale model to a scale set of stairs, the motion will be carried out to make sure that the hinge works as expected. Additionally, hinge durability will be tested by increasing the load on one side until the hinge fails. This will give information on the load that the hinge can reasonably withstand. Similarly, the lift requires a failure test to determine the maximum weight that the lift can withstand. Once both failure tests are complete, the fatigue of the system can then be tested. With the decided maximum weight limit on the platform, the motion will be repeated until the system starts to malfunction or break. With no weight on the platform the lift will be cranked up attached to a force gauge to measure the force required to lift the platform and the height raise will be noted. This will give information regarding the amount of force that will be required to lift the platform all the way up. Additionally, the same procedure will occur with the maximum weight on the platform to measure how the patient's weight will affect the rate of ascension. Similar tests will be performed for descension. The team will then test the stability of the structure by applying loads in different directions on the structure to make sure that the structure will have enough stability while being used.

Conclusion

The team has been tasked with designing and creating a proof of concept for a device that assists discharged patients from the Encompass Rehabilitation Hospital with stair negotiation. The device is meant for a range of 3-5 risers and must be able to be mechanically powered. To fulfill this request, the team has an adaptable design devised of aluminum diamond tread mounted to aluminum extrusion powered by a winch that lifts the user up and down the stairs outside their home.

Moving forward, the team hopes to create a smaller scale proof of concept model to show that this is a feasible and inexpensive alternative to electric stair chairs on the market. To show efficacy of the product, testing will be conducted to determine the strength of the hypothetical materials, and also the force required to lift the hypothetical design up and down the chosen number of stairs. Through this testing and small scale modeling, the team will be able to determine the next steps forward. Ultimately, the goal of this project is to create a fully functional prototype that can be used by the team's client Mr. Dan Kutschera and his patients at the Encompass Rehabilitation Hospital.

References

[1]D. H. Blazewick, T. Chounthirath, N. L. Hodges, C. L. Collins, and G. A. Smith, “Stair-related injuries treated in United States emergency departments,” The American Journal of Emergency Medicine, vol. 36, no. 4, pp. 608–614, Apr. 2018, doi: https://doi.org/10.1016/j.ajem.2017.09.034.

[2]J. V. Jacobs, “A review of stairway falls and stair negotiation: Lessons learned and future needs to reduce injury,” Gait & Posture, vol. 49, pp. 159–167, Sep. 2016, doi: https://doi.org/10.1016/j.gaitpost.2016.06.030.

[3]N. M. Simske, A. Benedick, M. A. Audet, and H. A. Vallier, “Ankle fractures in patients over age 55 years,” OTA International: The Open Access Journal of Orthopaedic Trauma, vol. 3, no. 3, p. e080, Jul. 2020, doi: https://doi.org/10.1097/oi9.0000000000000080.

[4]“Stair Lifts from $1529.00 | Quick Delivery and Nationwide Installation | USM,” Usmedicalsupplies.com, 2024. https://www.usmedicalsupplies.com/Stair-Lifts.htm (accessed Oct. 06, 2024).

[5]“Stair Lifts and Climbing Devices Market,” www.futuremarketinsights.com. https://www.futuremarketinsights.com/reports/stair-lifts-and-climbing-devices-market

[6] L. Parrino, K. L. Strand, A. C. Hockman, and J. F. Signorile, “Leg press and chest press strength normative values by half-decades in older persons,” Experimental Gerontology, vol. 150, p. 111401, Jul. 2021, doi: https://doi.org/10.1016/j.exger.2021.111401.

[7]ISO, “ISO 13485 Medical devices,” ISO, 2016. https://www.iso.org/iso-13485-medical-devices.html

[8] “Wisconsin Legislature: SPS 321.04(2)(d),” docs.legis.wisconsin.gov. https://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/320_325/321/ii/04/2/d

[9]M. Wade, “2-Speed Reversible Hand Winch (2,500 lb),” grabcad.com. https://grabcad.com/library/2-speed-reversible-hand-winch-2-500-lb-1 (accessed Oct. 09, 2024).

[10]“Aluminum Diamond Plate,” Metalsdepot.com, 2023. https://www.metalsdepot.com/aluminum-products/aluminum-diamond-plate

[11]“20-2020,” 8020.net, 2020. https://8020.net/20-2020.html

[12]“Dutton Lainson Brake Win - 1200 Pound Load Capacity,” Gmesupply.com, 2024. https://www.gmesupply.com/dutton-lainson-brake-winch-1200-lbs-load-capacity?cat_id=12467 .

Appendix

Appendix A: Product Design Specifications

Function

The main function of this device is to transport non-weight-bearing patients both up and down an outdoor staircase consisting of 3 to 5 stairs. It should also allow for easy access into and out of the device for the patient. The device should be an inexpensive alternative to electric stair lift systems, as well as being resistant to conditions that come with Wisconsin winters. Additionally, the device should be light, but sturdy enough to withstand frequent use across eight to ten-week windows when patients are non-weight bearing.

Client requirements

- The client requests a proof of concept for a mobile stair chair that non-weight bearing patients of his can use to travel up and down between 3 to 5 stairs
- The device should be free-standing to make the device accessible for patients that do not have sturdy rails leading up to their residences
- The device must be durable enough to withstand heavy use during eight to ten-week windows
- The device must be reusable once a patient no longer needs to use it to travel up and down stairs
- The chair must be able to swivel and support up to 140 kilograms
- Given the old age of some of the patients, the ratchet system should not require more mechanical power than an 80-year-old could output with one leg
- The chair must have a seat belt attachment to keep patients secure as they use the device

Design requirements

1. **Physical and Operational Characteristics**
    a. *Performance requirements*

The device will be used frequently during largely eight to ten-week spurts, but should also be able to withstand up to twenty-six weeks of frequent use for patients that remain non-weight-bearing for longer. The device should also be capable of holding up to 140 kg.

b. *Safety*

The chair should have an attached seat belt to keep patients from falling off during use. The device should also have stable legs that keep it from tipping over, as it will be a freestanding unit. A ratchet system will be used on the rails to prevent patients from accidentally sliding down five steps while attached to the device. The chair will also be able to be sanitized easily as it will be made from plastic. Given the originality of the idea, there are limited standards to be concerned with beyond ISO 13485, the standard of quality for medical devices [1].

c. *Accuracy and Reliability*

The device should be able to ratchet up the stairs without enduring significant wear and tear that could render it unusable. The attached seat should swivel without much force, allowing a patient to twist the seat and get off of the chair once they have reached the top of the stairs.

d. Life in Service

The assisted stair chair is built with the assumption that it will be rented out by DME (durable medical equipment) rental companies. That being said, it will deteriorate from transport, installation, patient use, removal, and cleanings. Altogether the assisted stair chair can expect a lifetime of 5 years as compared with other DME [2].

e. Shelf Life

Due to the metal component of the assisted stair chair, the device should be stored in a dry, climate-controlled environment to prevent corrosion. Additionally, the device should be protected from high pH conditions, salt, and other corrosive materials.

f. Operating Environment

The assisted stair chair should be able to withstand routine weather conditions as well as tougher conditions. It should be able to withstand temperatures between -18°-52°C and should be able to function within the normal atmospheric pressure range between 751-767 mmHg [3]. Additionally, the assisted stair chair should be able to handle outdoor conditions such as dirt, snow, rain, humidity, and other common conditions.

g. Ergonomics

The stair chair should be accessible to a wide range of individuals, specifically those with limited strength in one leg. The force required to raise the chair should be feasible for all, meaning a force of 20 kg should be able to cause upward motion [4]. Additionally, the plate should be reachable for all users from a seated position, and getting onto and off of the chair should be seamless regardless of height.

h. Size

Staircases in Wisconsin must be at least 91.44 cm wide [5], so the stair chair should be able to accommodate staircases of that width and greater. This means that the product should be able to be installed and function within that 91.44 cm range without causing discomfort for the user. With a wider staircase, room should be made to the side of the product to allow for walking.

i. Weight

Because the individual will be propelling both themselves and the product up the staircase, the weight of the product should be minimized, with a maximum product weight being 30 kg. This maximum weight is adjustable if added weight allows for more mechanical advantage. An ideal weight is from 10-15 kg, and there is no concern with a minimum weight, as long as the product can withstand the performance requirements stated earlier. The track portion of the product does not have weight requirements.

j. Materials

The material for the chair portion should be a strong and durable yet relatively lightweight plastic, with metal included where needed to strengthen the product. The rails for the device will likely be made out of some aluminum alloy, given the material's high strength-to-weight ratio, excellent corrosion resistance, and high ductility that allows them to be shaped without damage to the material [6]. Additionally, a fabric cover could be included to keep the product out of the elements.

k. Aesthetics, Appearance, and Finish

The finish on the product should be a texture that is not overly slippery to prevent injuries. As far as color, many stair lifts come in a cream, beige, or light gray color [7] to not draw attention to the product. A neutral color such as those will be the initial goal for the product but can be expanded on with additional time.

2. **Production Characteristics**

a. Quantity

Client is seeking a proof of concept item.

b. Target Product Cost

Production cost will be determined once the feasibility of the product is determined through proof of concept.

3. **Miscellaneous**

a. Standards and Specifications

Standards are limited due to the novelty of the product. Related standards include:

i. ADA §405 - ADA Standards for ramps. [8]
ii. S. Hrg. 111-1138 - Hearing before the Senate Subcommittee on Employment and Workplace Safety of the Committee on Health, Education, Labor and Pensions - discusses patient lifting standards. [9]
iii. FDA CFR Title 21, Volume 8 §850.5150 - FDA standard on powered chair lifts. [10]
iv. ASME A18.1-2017 - American Society of Mechanical Engineers standard on safety for powered chair lifts. [11]
v. ISO 13485 - international standard on quality and safety of medical devices. [2]
vi. Premarket Notification 510(k) - "A 510(K) is a premarket submission made to FDA to demonstrate that the device to be marketed is as safe and effective, that is, substantially equivalent, to a legally marketed device." Premarket Notifications can only be used for Class I and II devices. There is no classification for the proposed device, however the powered chair lift is classified as a class II device. [12]

b. Customer

The client intends to rent out the apparatus to patients at the Encompass Health Rehabilitation Hospital of Fitchburg. Patients are typically older people with short term mobility issues, most often with one usable leg.

c. Patient-related concerns

Since the device is intended for short term use, comfort is not necessarily prioritized. Safety is important to address since patients are already dealing with injuries. The device should require little effort to use.

d. Competition

Current solutions for ascending and descending stairs with a mobility issue include electric stair lifts, wheelchair lifts, wheelchair ramps, and elevators. The goal of this project is to provide a cheaper, temporary, and more practical solution than these alternatives. Few stair assist devices exist that are portable, lightweight, and safe. One dubbed the "Step by Step" is another UW Madison BME design project that Daniel Kutschera was involved in [13].

References

[1] ISO, "ISO 13485 Medical devices," ISO, 2016. https://www.iso.org/iso-13485-medical-devices.html

[2] "Social Security Act §1834." https://www.ssa.gov/OP_Home/ssact/title18/1834.htm

[3] "Calibration & barometric pressure | | Wisconsin DNR." https://dnr.wisconsin.gov/topic/labCert/BODCalibration2.html

[4] Diogo Luís Marques, Henrique Pereira Neiva, Daniel Almeida Marinho, Ivan Miguel Pires, C. Nunes, and Mário Cardoso Marques, "Load-power relationship in older adults: The influence of maximal mean and peak power values and their associations with lower and upper-limb functional capacity," Frontiers in Physiology, vol. 13, Sep. 2022, doi: https://doi.org/10.3389/fphys.2022.1007772.

[5] "Wisconsin Legislature: SPS 321.04(2)(d)," docs.legis.wisconsin.gov. https://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/320_325/321/ii/04/2/d

[6] "Aluminum Alloy: Definition, Characteristics, Types, Properties, and Applications," www.xometry.com. https://www.xometry.com/resources/materials/what-is-aluminum-alloy/#:~:text=Aluminum%20alloy%20has%20a%20high

[7] "Stairlift Features," Silver Cross, Jun. 13, 2024. https://silvercross.com/stair-lifts/stair-lift-features/#:~:text=Seat%20styles%20and%20colors (accessed Sep. 18, 2024).

[8] "U.S. Access Board - Chapter 4: Ramps and Curb Ramps," www.access-board.gov. https://www.access-board.gov/ada/guides/chapter-4-ramps-and-curb-ramps/

[9] "- SAFE PATIENT HANDLING AND LIFTING STANDARDS FOR A SAFER AMERICAN WORKFORCE," www.govinfo.gov. https://www.govinfo.gov/content/pkg/CHRG-111shrg76035/html/CHRG-111shrg76035.htm

[10] "CFR - Code of Federal Regulations Title 21," www.accessdata.fda.gov. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=890.5150

[11] "A18.1 Safety Standard for Platform Lifts & Stairway Chairlifts - ASME," www.asme.org. https://www.asme.org/codes-standards/find-codes-standards/a18-1-safety-standard-platform-lifts-stairway-chairlifts

[12] FDA, “Premarket Notification 510(k),” FDA, Nov. 30, 2021. https://www.fda.gov/medical-devices/premarket-submissions-selecting-and-preparing-correct-submission/premarket-notification-510k
[13] “Step by Step: A comprehensive approach to stair climbing assistance,” Wisc.edu, 2023. https://bmedesign.engr.wisc.edu/projects/f23/stair_assist_bench (accessed Sep. 18, 2024).

Appendix B: Finance Table

Item	**Description**	**Manufacturer**	**Mft Pt#**	**Vendor**	**Vendor Cat#**	**Date**	**QTY**	**Cost Each**	**Total**	**Link**
Category 1										
									$0.00	
									$0.00	
Category 2										
									$0.00	
									$0.00	
								TOTAL:	**$0.00**	