Optimal Design Report:

Stair Lift System and Walker

By

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Team 2

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1. Optimal Design Project for Stairlift and Walker

1.1 Introduction, Statement of Need

Heidi Almeida is the mother of a single child, Thalia Almeida. Thalia is a seven-year-old female with Spina Bifida on Lumbar (L4) and (L5). The disease is caused by the incompletion of neurotube closure as well as the vertebrae being opened and not fully formed [2]. The disease progresses with exposure of the spinal cord, and in extreme cases, the spinal cord protrudes through the bone of the spinal column [1]. The debilitating effects of Spina Bifida can range from weakness in the legs to deficiencies in cognitive skills, planning, organizing as well as working memory skills. Thalia is mainly affected by weakness in the legs while presenting with relatively normal cognitive skills.

With Thalia growing older, it is becoming exceedingly difficult for her Mother and Father to carry her up a winding set of stairs in their two-story house. As Thalia grows older, she is also learning to be more independent, especially in terms of mobility around the house. With that said, two devices have been designed to assist Thalia and her growing needs. These two devices consist of a walker to suit Thalia’s height and mobility needs, as well as a stair lift system that can bring Thalia up and down her winding staircase. Each of these projects have taken into account Thalia’s size as well as her mobility, mostly consisting of strong arms and limited leg strength.

1.2 Product Development

The purpose of this project is to develop a stairlift for the split-level staircase in Thalia’s home as well as a walker. The stairlift will utilize a single-track design, which will allow for continuous movement as it winds around the staircase. The single track will be composed of two parallel railings that remain a set distance apart. Utilization of two rails will decrease load on the
attachment points at the wall as well as individual bearings and shafts that the pulleys are mounted to. The chair will be attached to the tracks via two pulley assemblies, ensuring the chair will not rock back and forth as it travels up the track. The use of a single stairlift will be more convenient and safe for Thalia, as she will not have to walk in between staircases (as in a setup with one stairlift per staircase). In addition, a continuous stairlift will be more cost effective as there will be no need to duplicate parts for each set of stairs. A 400-pound winch will be utilized to pull the chair up the track via a steel cable. A remote operated winch control will ensure that wiring into the wall is avoided. Thalia is 45” tall and 65 pounds, so the system will be designed to accommodate her height and weight. The weight capacity will also be kept at a factor of three times her current weight to ensure her safety as well continued usability as she grows older. An expandable side-loading chair will be implemented to ensure that Thalia can use the stairlift system as she grows. Through design and initial testing in Solidworks, there is a clear indication that the parts will work successfully in the device.

The walker designed for Thalia will be designed to specifically match her height. As most of the force she can provide to move the walker is from her upper body, careful consideration was taken in finding the optimal height for the walker. The walker will be based on the Medline Standard and Junior Rollator/Walker. Steel piping will be removed from all four tubes to reduce the height by one foot to Thalia’s height. The brake wires will be re-threaded through the handgrips and attached to the rear handles. This will allow for reversal of the current brake setup and provide a default brake condition. Utilizing a reverse braking setup is a novel approach that will ensure that the walker will only move when a handle is pressed. As soon as the brake handle is released, the walker will stop moving, ensuring that any loss of balance she has will be contained before a fall can occur.
1.3 Optimal Design Selection

Multiple alternative designs for both the stairlift and walker were considered before the optimal design was selected. For the stairlift, the first alternative design included using a track system with a motor mounted to the back of the chair (climbing a toothed track up the staircase). This setup would require individual setups for each staircase and did not seem feasible with the budget provided. In addition, Thalia would have to cross from one staircase to another increasing her risk of injury. The second alternative design was to simply use a current market offering as a solution in Thalia’s home. The current market offerings are not only thousands of dollars over what our budget provides, but also the majority required a two-stairlift system similar to alternative design one. The safety issues and budgetary constraints indicated that a new continuous track design was necessary. As such, a winch-based system was developed by our team that utilized a continuous track to ensure safety as well as to remain within the budget.

For the walker, there were two other alternative designs which seemed viable initially. The first alternative design for the walker was to modify a play chair similar to one Thalia currently uses to get around. The issues with this design include a lack of maneuverability as well as a large amount of force required for movement. The second alternative design was a standard walker, which requires lifting the walker for each step to be taken. This type of motion proved difficult for Thalia after her parent’s tried currently available devices similar to this design. Both of these alternative designs required a large amount of force and did not provide the maneuverability Thalia needs around her home. The shortcomings of these alternative designs were overcome by utilizing a wheel-based walker for maneuverability and reverse-braking
system for safety. Our team implemented these ideas in our optimal design through modifications to the Medline Standard walker.

### 1.4 Subunits

**Chair Lift Subunits:**

Many small parts will be necessary for the optimal chair design. Consisting of frames, pulleys, and pivot systems, these pieces are created in order to perform several tasks at once. Consideration with long-term use, each part will be designed out of non-corrosive material. The pulley and backings of the chair will be fabricated out of Aluminum, and the chair will be highly durable plastic, both capable of withstanding years of high amounts of usage. As safety is a main concern as well in this project, duplicate pieces will be used on the chair backing in order to carry a maximum capacity much greater than necessary for our patient.
Beginning with the smallest yet most significant design of the chair, the swiveling pulley system is a major component of the stairlift design. From left to right a piece-by-piece process is constructed above into the final swiveling pulley system design. Starting with the far left, this piece will be attached to the chair backing by the square base, and is designed to allow for 360 degree rotation of the pulley system on the chair backing. This will allow for the rotation of the chair to take place, keeping it in horizontal, upright position as the chair ascends the staircase along the two-rail system. Once the chair reaches the flat midway stage of the staircase, the swivel system will allow for the chair to remain level throughout the slanted and level sections of the multi dimensional staircase.

The block is the framework for the pulley system and will be the housing for the swivel attachment system along with the two sets of pulleys (side and top) on this device.

With a side pulley’s contour shape to snuggly follow the top of each of the two tracks along the stairs, as well as a cylindrical bottom pulley to disperse the weight from the moment produced by the sitting patient, this system will allow for a smooth, practically frictionless, and upright ride, up and down the stairs.

Fashioned together with cylindrical inserts, each pulley will be able to rotate at 360 degrees, allowing for a frictionless roll along the tracks. Much like normal pulley systems, the outside will be free to move, while the inside, cylindrical insert will be fixed using a large bolt. The far right of fig. 1 is a depiction of an inside view of the workings of this pulley system device.
Displayed above in fig. 2 is the complete design of the Swiveling Chair Pulley system. Depicted in the center of Fig. 2 is a display of how the Swiveling Pulley system will be installed into the chair. Using two Swiveling Pulley Systems to disperse the weight will allow for a safe and secure ride time and time again. An “F” shaped frame is introduced to the Chair’s back in order to maintain extra stability of the Pulley systems.

As seen from the two profile views, this chair is designed with a middle attachment piece, connecting the back and bottom of the chair. This design will allow for a collapsible design, capable of folding in while not in use to allow for stair access of the non-users of this device.

Also seen in the profile view are the two sets of swiveling pulley systems, which will sit on the two separate tracks aligned against the stair wall. In between the two tracks will be a winch cable that will attach to the “F” frame, giving the chair remote mobility up and down the staircase.
A final depiction of the design is given below in fig. 3, this shows the final solid display of our optimal design.

Allowing for a more realistic view of the design, this solid view is a very close representation to how the final product should look. Depictions of both our small part Swiveling Pulley system, as well as our Swiveling Chair Pulley Design are shown in fig. 3. Fig. 1, 2 and 3 have been designed in SolidWorks, and will either be constructed in a Machine shop for customization, or bought off the shelf and fine-tuned for our design. With a 3-D construction of this device, it will be easier to construct these pieces, or find them specified to purchase for our design.

**Walker Subunits:**
Fortunately, after much research, our team has discovered a frame for the walker that meets all our specifications but one. Figure 4 is the off the shelf device, which we will fine tune to meet all of our specifications for our walker.

![Walker Model](image)

Although this model meets all the size and shape requirements for our walker, there is one issue with its design.
This walker is equipped with a braking system, which locks when its handles are squeezed, and moves freely when the handles are released. Due to specifications created from the physical characteristics of our patient, the braking system must be customized for her use.

Since Thalia’s leg mobility is very limited, yet her upper body is good, she requires a walker which can remain locked until she specifies otherwise. For this reason, our braking system will be reversed from the design already in use.

That being said, we will create a design such that when the handles are released, the braking system is used, and the wheels lock. When our patient is ready to move, she must squeeze the handles to unlock the wheels so she can move freely.
This will allow for Thalia to move safely through her how, and will keep her from loosing control of the walker as she moves. If she were to begin to lose control of the walker, it would be much easier for her to release the handles than to squeeze them to brake the wheels.

Our design will be accomplished by extending the wired breaking system through the handle, and down the front side of the trigger grips. It can be seen by fig. 4 that a release of the handles will extend the wire, therefore braking the wheels and locking them into place. Once the handles are squeezed, the wire will relax, allowing for the locked wheels to become free.

2. Realistic Constraints

2.1 Engineering Standards

All engineering standards will be met in the development and production of the stairlift and walker. Through use of the Solidworks design software, all parts have been constructed and analyzed for the device prior to actual fabrication. Many safety issues have been addressed already and improved upon with the optimal designs dictated in this report. The stairlift and walker designs developed do not appear to infringe upon any patents or intellectual property currently available.

2.2 Realistic Constraints

Economic: With a budget of 1000 dollars, the parts for both the chairlift and walker were chosen very carefully.

Environmental: The materials chosen were recyclable and environmentally friendly.

Sustainability: Stainless steel or other types of non-corrosive material are being used in the design to ensure longevity of the devices.

Manufacturability: The designs are easily reproducible, in order for easier manufacturability on a
large scale.

Social/Ethical: The designs created are our own, and we are not infringing on someone’s idea.

Safety/ Health: A huge component of this project is Thalia’s safety. Many fail-safes have been implemented to ensure that the device ceases to operate in a predictable manner if any sort of failure were to occur. In addition, the other family member’s safety will be kept in account. The chairlift design implemented is foldable and compact so it does not interfere with their ability to traverse up and down the stairs.

3. Safety Issues

A huge component of this project is Thalia’s safety. Many fail-safes will be implemented to ensure that the stairlift device ceases to operate in a predictable manner if any sort of failure were to occur. If only one track were used, there would be potential for the chair to rock backwards in the direction opposite the chair is being pulled. To remedy this, a two-track design was implemented to ensure stability of the chair as it moves up the staircase. A continuous track design will also ensure that Thalia does not need to move from one staircase to another, which decreases the likelihood of injury. The remote control for the winch that can be operated by the user of the chair will ensure that it can be stopped at any time the user deems it necessary. In addition, the other family member’s safety will be taken into account. The chair for the stairlift is foldable and compact so it does not interfere with their ability to traverse up and down the stairs.

The walker contains multiple features that ensure Thalia’s safety. The use of a wide based walker such as the Medline Standard walker will decrease the likelihood of tipping during use. The reduction in height will further lower the center of gravity to ensure the walker remains
upright. The main safety feature implemented for this device is the reverse braking system.

Without modification, the Medline walker can only be stopped when the user presses the handles. This is not ideal for Thalia, as with her limited leg mobility, she needs precise control of when the walker moves to ensure that she can remain stable. The walker will therefore be modified with a reverse brake setup, in which the walker can only move if the handles are depressed. Clearly, multiple safety measures have been taken into account in the designs of both the stairlift and walker.

4. Impact of Engineering Solutions

Creating, testing and designing both a walker and a stair lift for the needs of an individual with Spina Bifida will allow for a standard model for not just individuals with this specific disorder, but also an entire community of people who lack mobility in lower extremities. Injuries to the spinal cord, stroke victims and paraplegics can all benefit from one or both of these devices. There are a variety of related products on the market for both the stairlift and the walker. Many of the stairlift products available are both very high in price (over 10,000 dollars) and not suited for a split-level home. The increased cost of taking care of a person with a disability often puts many families in a position where they cannot afford the devices they need. Our stairlift has a much more reasonable cost, increasing accessibility to many families who may need it. The idea implements different methods than traditional stair lifts, as it uses a compact design along with a winch based system. This method drives down cost and uses a proven device to ensure longevity and reliability of the product.
The walkers currently available provide a viable starting point, however they will need to be modified to accommodate Thalia’s size. The brake type will be reversed to ensure Thalia is able to move safely, and at her own pace. A walker like this has yet to be designed, and with its relaxed breaking system, can be used for patients suffering from various ailments that result in decreased leg mobility. Modification of a current walker would decrease environmental impact, as a new factory would not need to be developed for parts production. A much smaller operation could satisfy the changes that need to be made during modification and assembly. The impact of the optimal designs has the potential to improve the quality of lives of many at a reasonable cost and with little harm to the environment.

5. Life-Long Learning

There was a vast amount of new material learned through this design process. Firstly, working with an end user first hand was an eye-opening experience as it allowed us as engineers to fully address the needs of the consumer. Through meeting with the end user, additional factors in the design process came into play including cost, safety, as well as reproducibility. These considerations were not really made when designing smaller devices in previous engineering courses. An additional challenge was also introduced when having to actually implement the design. The amount of testing that needs to be done before fabrication can occur to ensure safety and viability of the design was another learning experience. The ability to design and model in the software Solidworks was a newly acquired skill, which proved very useful in preliminary testing and 3-D modeling of the designs. Testing through this method also allowed us to correct any potential design flaws before building of the actual device commenced.
6. References:
