Leg Loops Ultra Supreme+ Design Report

3/14/2020

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Executive Summary

With the help of our project partner, Randi, an occupational therapist at Shirley Ryan AbilityLab, who works closely with our client, Jane, we designed a device that would help assist users with spinal cord injuries in lifting up their legs and transferring it to different surfaces such as beds or shower chairs. Our client can move both her arms normally however has no nerve sensations in her right leg.

Jane is a 73-year-old woman, who has a spinal cord injury which results in complete paralysis of her right leg which sometimes could be swollen. Through physical therapy, she has enough upper body strength to physically lift up and transfer her leg on her own, which is mainly her current solution. However, there've been some inconveniences with the current method as there's nothing on her leg to grab hold onto.
We then built 3 alternative mockups. Unfortunately, we didn't have an opportunity to test our mockups directly with our users. However, with the feedback from our project partner and our performance testing with 4 different people, we developed our final prototype for our design.

Our design, Leg Loops Ultra Supreme +, is a modified version of a generic leg loop, consisting of 2 cuffs connected by a fabric strap, where one cuff loops around the thigh and another one loops around the user's calf. Each cuff is secured by 2 magnetic release buckles with an extra layer of Velcro underneath. On each cuff exists 2 handles positioning at 45° away from the user, which corresponds to how our user is used to lifting up her leg.

The Leg Loops Ultra Supreme + satisfies several of our user's requirements:

- **Sense of security to the user's leg:** This is one of the most emphasized user's requirements. We achieved this by using 4 magnetic released buckles. This is because buckles are great fasteners and they also come with a "click" sound providing an audio feedback to our user ensuring her that our product has been secured. To fully optimize the sense of security to the user's leg, a layer of Velcro is also added underneath the buckles as well.
- **Adjustable:** The magnetic buckles come with an adjustable strap that can adjust the diameter of both of the cuffs to fit the user's leg in cases where the leg is swollen.
- **Time Efficient:** With the magnetic released buckles, our design can be put on in approximately 15 seconds and off in 7 seconds (performance testing).
- **Portable:** The main body of the design is made out of nylon sheet which makes the design to be durable, waterproof and most importantly portable. The whole design weights 0.5 kg and can collapse to a 9" × 7" × 4" piece.

Another feature of our design that aids in the ability in assisting our users in lifting her leg is that the handles are made out of nylon fabric with nylon tubing inserted inside. This causes our handles to be rigid which makes it easier for the user to locate and hold on to.

I. Introduction

Following a spinal cord injury, stroke, or other condition that results in decreased leg mobility, individuals often need a device to assist them in transferring their legs during wheelchair transfers between surfaces. The transfers can be grouped into two broad categories: from bed to seat and from set to bed. Individuals may have varying levels of strength or motion. Still, the general paralysis in one or both legs of the users makes it difficult to transfer their paralyzed leg between surfaces without outside assistance.[1]

The user of the device is a woman, Jane, with an L2 spinal cord injury resulting in full paralysis and edema of her right leg. The current products that aim to solve this problem are not considered by Jane to be simple, secure methods of transferring her paralyzed leg. One product, the leg lifter, is a small loop at the end of a rod that is placed around the toe (Figure 1). This product requires users to loop it around their feet. This is problematic because the user cannot lift her toe to aid in the process. An alternative solution to this problem is leg loops. Leg loops are straps that velcro to the user's legs with handles that the user holds onto when lifting their leg (Figure 2). The leg loops are not without issues of their own. They fail to close securely around the leg due to the positioning of the velcro secure on the back of the leg,[2] and are not adjustable enough to accommodate the wide range of sizes that Jane's leg may be due to her edema. Other existing products are not portable and are often mechanized beds or chairs that lift the user to the new surface.[3]

Figure 1: Leg Lifter
Source: Leg Lifter Straps

Figure 2: Leg Loops
Source: Leg Handles

Our design, the Leg Loops Ultra Supreme+, solves the need of the consumer by being a knee brace style device that is portable and easy to put on, while also placing buckles down the front for it to be adjustable and secure on the leg.

[1] See Appendix A for the project definition
[2] See Appendix C for Jane's comments on velcro feeling insecure
[3] See Appendix B for more information on existing products

This report outlines our user and her needs, the design of our device and its use, and addresses the limitations of the product. The report also includes information on competitive products, interview and testing records with the user and project partner, and instructions on the construction and utilization of the device.

II. Users and Requirements

A. Main Users:

Woman with Spinal Cord Injury:

Our main user is a 73-year-old-woman, Jane, who has a spinal cord injury, resulting in the complete paralysis of her right leg, which sometimes becomes swollen, and the partial paralysis of her left leg. As a result, she uses a wheelchair to travel. With physical therapy, she was able to regain some control of her left leg and build strength in her upper body. She is able to use her left leg to aid her when transfering from surface to surface by pivoting off it as well as fix her arms for leverage during her transfers,[4] but she is unable to lift her right leg onto these surfaces. In addition, she is able to bend over and touch the ground while sitting in her wheelchair. She wants to be able to transfer freely from her wheelchair onto any given surface, such as a chair at a restaurant or a couch at her friend's home, without needing to rely on others. At home, she would like to carry out her daily routine independently and would eventually like to cook again. During the user observation, Jane mentioned that she has tried products to help her transfers , such as leg loops. However, she stated that she does not like using them because she hears the velcro ripping when she lifts her leg with them and as a result, feels unsafe using them.[5] In order for her to do these transfers independently, Jane needs a device that is easy to use, sturdy, portable, and adjustable.

Randi Applehans, Occupational Therapist at Shirley Ryan Ability Lab:

Randi Applehans is the user's occupational therapist who helps her regain mobility in her body and will help her learn how to use the device, ensuring that she is able to transfer safely without issue. She wants Jane to have a device that allows her to transfer independently. This means that the device has to be easy to use, sturdy, and portable.

B. Main Requirements:

Easy to Use:

While Jane does have mobility in her arms and left leg and flexibility in her spine, she has not fully recovered from her injury. As a result, she has not regained full strength and mobility. Because of this, the device must be lightweight, as to not add any unnecessary weight to her leg, easy to put on and take off, as to not lengthen the time it takes for her transfers, and must provide ways to securely grab the device, as to better lift her leg.

Sturdy:

During the user observation, Jane mentioned that she feels unsafe using the leg loops and therefore, does not use them at all. In a similar way, if our device were to seem unsafe to Jane, she would cease to use the device, as she did with her leg loops, in fear of it breaking and dropping her leg, which is painful. In order to ensure that Jane will actually use our device, it should support the weight of her leg without showing any signs of excessive strain or breaking. A device that she believes is sturdy would give her confidence that it will keep her leg safe and secure during the transfer process.

[4] See Appendix B for more information on pivot transfers
[5] See Appendix D for Jane's comments about her leg loop

Portable:
Because Jane travels around town, she needs to have a device that can help her with transfers outside the house. For example, she wants to transfer at her friend's house, to a chair at a restaurant, into and out of a car, and in her own home, where she cooks. In order for her to bring the device around and have it with her when she needs it, the device must be portable and able to be stored on her wheelchair.

Adjustable:
Due to the user's injury, her leg can become swollen at times, resulting in a varied leg size. In addition, she wears different types of pants with varying thicknesses, adding to the diameter of her leg. Because of the changing total diameter of her leg, the device must be adjustable so that it will fit on her leg without being too tight or too loose regardless of the size.

III. Design Concept and Rationale

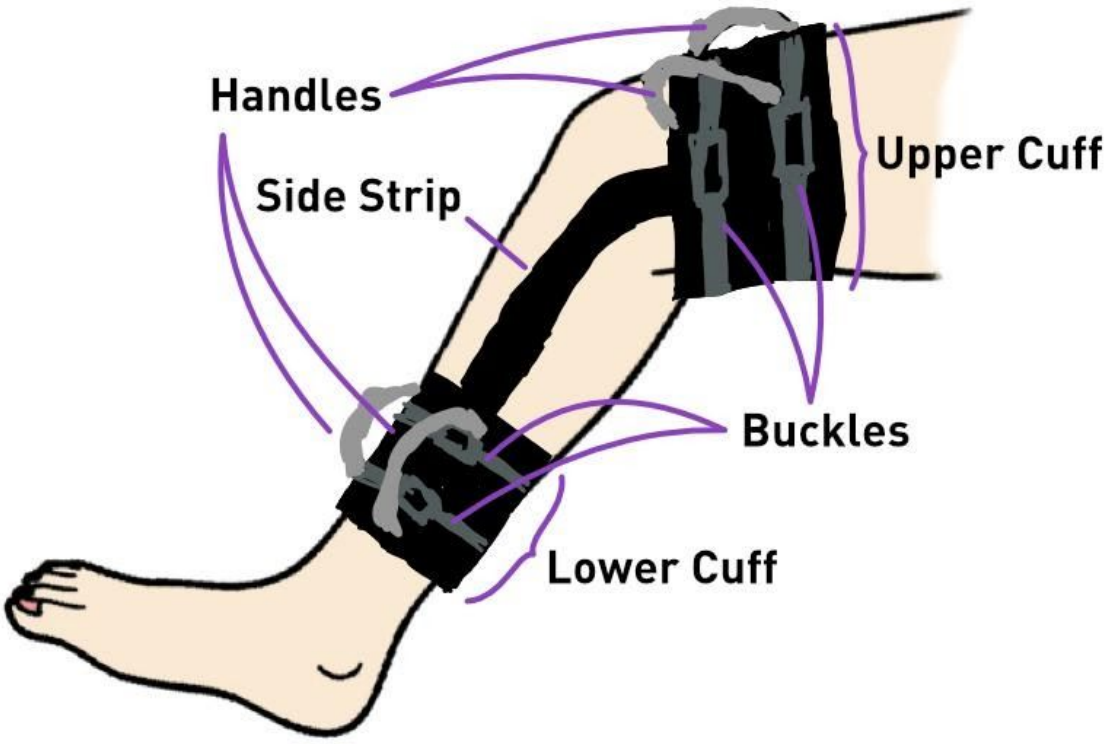

Figure 3: Leg Loops Ultra Supreme+ Diagram

A. Overview:

The Leg Loops Ultra Supreme+ function similarly to generic leg loops with improvements to the securing mechanism, lifting handles, and materials. [6]The device securely buckles to the user's leg and has two sets of handles where the user can grab onto, assisting the user with lifting their leg onto a surface or positioning it.

The Leg Loops Ultra Supreme+ (Figure 3) consists of two nylon fabric cuffs that wrap around the user's leg and are secured with velcro and adjustable buckle fasteners that can be tightened or loosened. The two cuffs are connected by a 2.5" wide strip of nylon. One layer of velcro and two quick release magnetic buckles are attached to each cuff (Figure 4, 5, 6). Each cuff also has a pair of handles, made from nylon with nylon tubing inserted inside.

[6] See Appendix B and C for more information on Leg Loops

Figure 4: Diagram of Closed Cuff

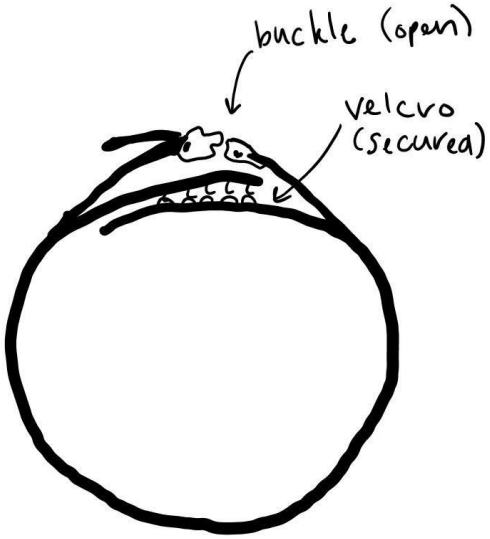

Figure 5: Diagram of Partially Closed Cuff

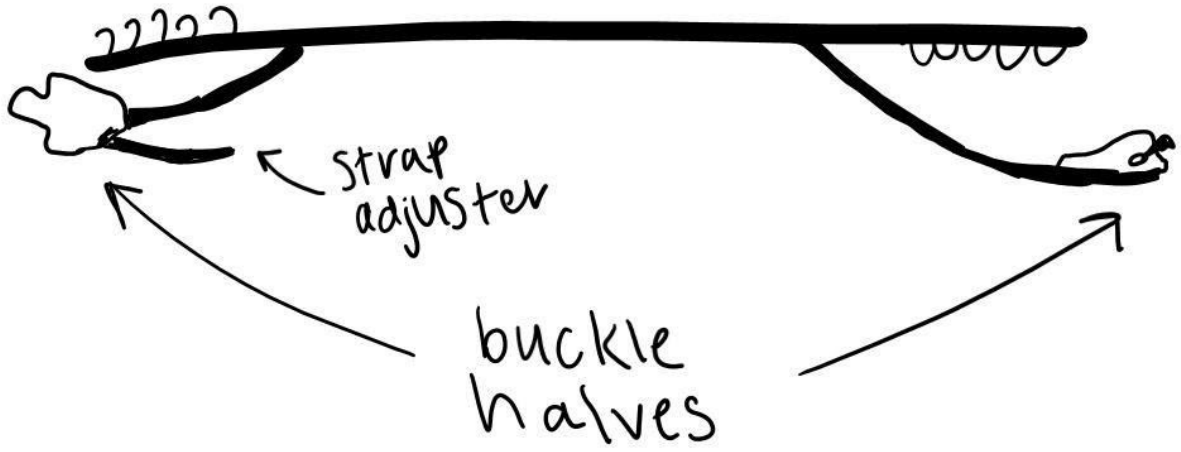

Figure 6: Diagram of Open Cuff

B. How it works:

To put on the Leg Loops Ultra Supreme+, the user slides the device (unbuckled and open faced) under the leg they plan to transfer either onto a surface or into the wheelchair (Figure 7). Then, secure the thigh and calf Velcro (Figure 8), fasten and tighten the four magnetic buckles down the front of the leg (Figure 9). The buckles are secured by moving the top piece (the one with the pull tab) over the

bottom piece, the magnets will pull the buckle together and engage the lock. To tighten the buckle pull on the pull strap. To transfer the leg between surfaces, the user holds onto the two handles on the upper cuff and lifts the leg off the starting surface and, if completing a full transfer, onto the new surface (Figure 10). To complete the transfer, the user moves their hands down to the lower handles and adjusts the positioning of their lower leg (Figure 11). To remove the device, the user pulls the tabs on the front of the buckles (Figure 12), undoes the Velcro (Figure 13), and slides the device out from under their leg.

Figure 7: Sliding up of Device Under the Leg

Figure 8: Securing of Velcro

Figure 9: Fastening of Magnetic Buckles

Figure 10: Lifting of Upper Leg

Figure 11: Positioning of the Lower Leg

Figure 12: Pulling of Tab to Remove Buckles

Figure 13: Removal of Velcro

C. Components:

Cuffs:

The upper and lower cuffs are made from rectangular nylon fabric with dimensions of 25” by 6” and 18” by 6” respectively (Figure 14). At the endings of each cuff has a layer of velcro and 2 magnetic buckles (Figure 15) with adjustable straps that can be tightened by pulling on the free end of the strap protruding from the magnetic buckle (Figure 4,5,6).

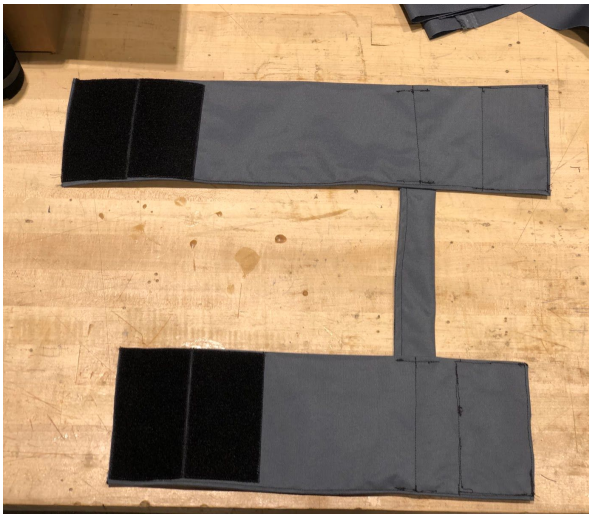

Figure 14: Upper and Lower Cuff

Figure 15: Velcro and Magnetic Buckles on Cuff

Rationale:

The cuffs are made from a strong nylon sheet which makes our device durable and waterproof. As most parts of the device are made from nylon sheets, it allows our device to be able to fully collapse into a 9” by 7” by 4” piece and weigh 0.50kg.

Handles:

The handles are made from a 5” long piece of flexible plastic tubing encased in a 7” long strip of nylon sheet. Figure 16 shows how the nylon strip is folded over and the plastic tubing is sewn into the center. The ends of the handle are sewn down onto the cuff at approximately 45° angle away from the user (see Figure 17).

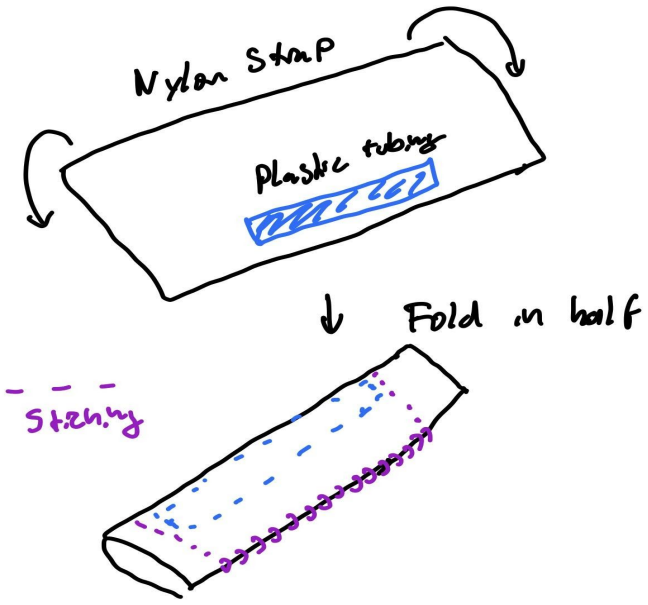

Figure 16: Handle Construction

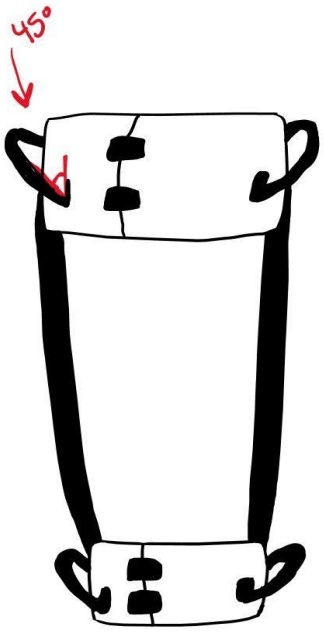

Figure 17: Handle Positioning

Rationale:
The positioning of the handles corresponds to the way our user is used to grabbing and lifting her leg observed during the user observation. The plastic tubing causes our handles to be rigid which causes the loop of the handle to stay open hence makes it easier to locate and grasp easily.

Magnetic Buckles:
We purchased "JASGOOD Tactical Belt with Magnetic Quick Release Buckle" (Figure 18) and used the fabric belt portion for the fabric strips that wrap around the cuff and the magnetic buckles for the fastening mechanism of the cuffs. The magnetic quick release buckle is 1.9" tall and about 3" wide.

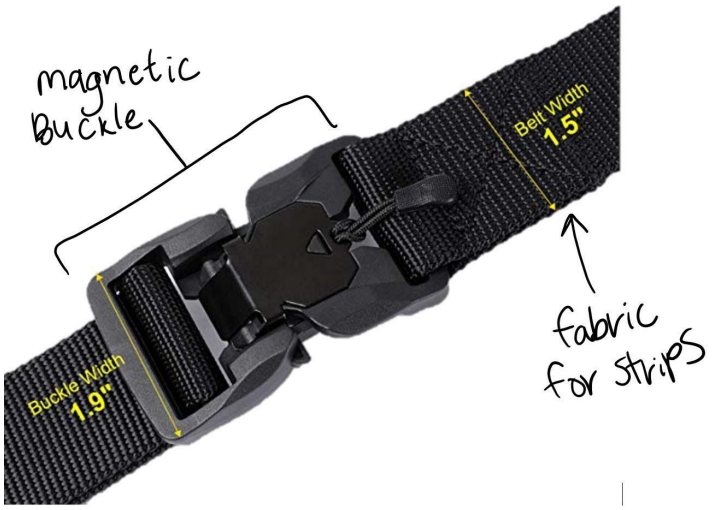

Figure 18: Belt

The buckles are guided into place by magnets (Figure 19) and are released by lifting a pull tab, allowing for the device to be secured and removed with minimal use of the hands. When the buckle is properly secured, the small triangle on the face of the buckle will be completely red (Figure 20).

Figure 19: Magnets on Buckle

Figure 20: Belt Parts

The buckle has latches on one half and catches on the other (Figure 21) that secure the buckle closed. The buckle is opened by pulling the release tab its face (Figure 22), which pulls the face of the buckle up and pushes the latches forward, out of the catches (Figure 22).

Figure 21: Belt Secures

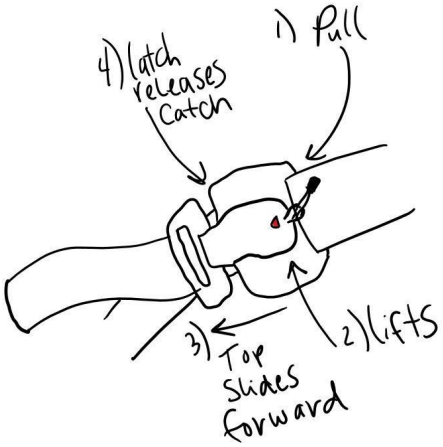

Figure 22: Belt Mechanism

Rationale:
Buckles are used here as they are strong fasteners and they also provide audio feedback which ensures our user that the device has been secured. This fulfills the sense of security as a requirement that our user has been emphasized on. We chose magnetic buckles as they enable the user to quickly and easily put on and take off the device which is time efficient. The device comes with an adjustable strap which allows the device to be adjustable to the size of the user's leg in cases where they're swollen.

IV. Design Limitations and Future Recommendations:

A. Limitations:

One of the limitations of our design is that the lower cuff doesn't loop nicely around the user's leg. This is because the cuff we designed has a circular diameter where a human's calf has more a conical shape, which causes the cuff to slide up and down the lower leg of our user. This could abrade the user's skin and cause a sense of insecurity to our user.

The second limitation is when our user grabs onto the handles on the top cuff and lifts up her leg, she has no control at all over her lower leg. This causes the lower leg to rotate or bend inward attaching itself closely to her body. This again could raise a sense of insecurity to our user.

B. Future Recommendations:

The following steps are recommended to develop the design.

Further Testing:

User Testing: We did not have a user testing, so our final prototype will need to be revised against our user to identify further limitations to our products that we may have missed in order to come up with further design developments.

Improvements to Design:

Fitting of the lower calf: The shape of our lower cuff is currently a rectangle (folded into a cylindrical shape). Therefore, with measurements from future user testings, we can change the shape of our lower cuff such that it can fold into a conical shape so that it could loop around the calf of our user nicely.

Bending of the lower leg: A possible solution to this could be adapted from one of our mockups. We could insert a metal bar on the side of our design where the metal bar is bent at an angle so that it would keep the lower leg of our user secured at an angle when the user lifts up her upper leg.

V. Conclusions

To summarize, our Leg Loops Ultra Supreme+ is designed to help assist our users in lifting and transferring their legs from wheelchairs to other surfaces such as beds or shower chairs. Our product uses a combination of:

- Nylon fabric for both of the cuffs and the strips connecting the cuffs which makes our product to be durable and waterproof
- 4 easy released magnetic buckles with adjustable straps which makes the product adjustable, easy to put on and take off as well as providing an audio feedback to ensure a sense of security for the user
- Nylon fabric with nylon tube inserted inside to provide rigidity in the handles which makes it easier for our user to locate and hold on to.

With this, our design is able to meet several of our user's requirements: sense of security to the leg, adjustability, time efficiency and portability.

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VII. Appendices

Appendix A: Project Definition

Project name: Leg Lifter

Client: Randi Applehans , Shirley Ryan Ability Lab

Team members: Alex Cindric, Daniel Park, Dashiell Slamowitz, Khantey Lim

Date: 1/25/2020

Version: 2

Mission Statement:

Design and manufacture a leg lifter device that is secure, easy to put on and take off and that makes it easier for our project partner to lift her leg onto different surfaces

Project deliverables:

A working prototype of the leg lifter we designed, with a written report including diagrams on the design and construction process as instructions on the use of the product

Constraints:

- 10 weeks to design and manufacture the product - the length of the DTC class
- Spend no more than $100 dollars throughout the quarter - prevents the project from becoming too costly

Users and stakeholders:

- Customised for our user, Jane who has a spinal cord injury and will use the product to lift her left leg from one surface to another (e.g. wheelchair to her bed or showerchair)
- Shirley Ryan Ability Lab (the hospital where our school partners with and our user currently work with)

Table 1: Requirements and Specifications

Requirements	Specifications
Easy to use: - be intuitive to use without much instructions or help needed from other people - take a short time to operate - be easily portable	- the whole process of using the product is less than 30 seconds. - the whole product weighs less than 1 kg and the whole volume to store the product is within a drawstring bag (14" x 18" x 2")
Durable and Secure : - the product has to be able to lift the patient's leg - the product shouldn't come undone when used and should give a sense of security to the user	- be able to lift the patient's leg of approximately 12 kg. - have a visual indicator that it's locked and secured.
Adjustable: - be adjustable so that it could fit the user's leg both when swollen and not swollen	The adjustability should be from diameter of 17" to 21" (allowance of +/- 2")
Safe: - because the user has no sense of nerve in her leg, the product should be adjustable in a way that would not restrict her leg too much - not have any sharp objects involved	The maximum adjustability should have a 2" allowance to prevent her from adjusting it too tight.

Appendix B: Background Research

Introduction:

The purpose of the research conducted by our team was to gain insight into the problem given to us in the project proposal, so that we could ask more targeted questions in our project partner interview and design a better solution to the problem in the long run. The project is to design a product to assist patients—who cannot move one or both of their legs due to a spinal cord injury or a stroke—in transferring their legs from a wheelchair to another surface. We researched (1) basic information regarding strokes and (2) spinal cord injuries, (3) the process of transferring into and out of a wheelchair, and (4) existing products that address the problem.

Strokes:

A stroke occurs when a blood vessel to the brain clots or ruptures. Because that blood vessel is no longer able to carry oxygen and nutrient rich blood to the brain, brain cells begin to die. This damage to the brain can result in motor function impairments, such as the inability to control movements in the arms and legs. Depending on the severity of the stroke, the individual could lose partial functionality in some of their limbs, or potentially experience full paralysis ("Stroke", n.d.).

Spinal Cord Injuries:

Damage to the spinal cord can lead to the loss of sensation and or loss of motor control below the site of the injury. Spinal cord injuries are classified as either complete or incomplete . If all feeling and motor control below the site of the injury are lost the injury is a complete spinal injury, conversely if any amount of sensory or motor functions remain the injury is incomplete ("Spinal Cord Injury", 2019). The location of the injury along the spinal cord determines the region affected by the injury. The user has an L2 spinal cord injury, which is located in the lumbal spinal segment (Figure 23). The nerves in the lumbar segment facilitate leg control and damage to the L2 region can cause paraplegia and numbness in the legs (“Lumbar (L1-L5) Spinal Cord Injuries”, n.d.).

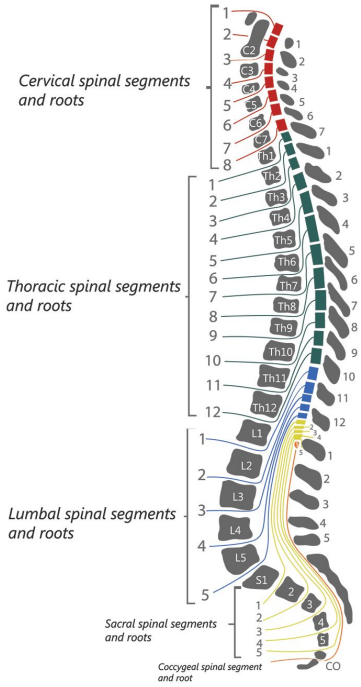

Figure 23: Spine Anatomy

Wheelchair Transfers:

The execution of wheelchair transfers is dependent on the level of paralysis and muscular function. The use of slide boards, either assisted or unassisted, or slide sheets allows individuals to transfer their torso from their wheelchair to the secondary surface. Individuals may also perform wheelchair transfers without the assistance of devices to move their upper bodies between surfaces. Sit-pivot and stand-pivot transfers can be executed by individuals who do not require transfer boards, but they require both balance and the ability to hold up one's own body weight using their lower limbs. After the transfer of the upper torso, the individual must also be able to move their legs onto the new surface (Watanabe, 2016). This may not be possible for individuals with paralysis, and instead may require assistive devices to aid in the movement. There are three major types of products used to transfer legs: leg lifter straps, leg loop straps, and automated leg lifters.

Existing Products:

Leg Lifter Straps:

The leg lifter consists of a long aluminum rod with a loop on both ends, allowing for a handhold and a foothold (Figure 24). This allows the user to secure their foot in the foothold and lift their leg using upper arm strength, controlling the leg transfer through arm movements.

This product allows for a lightweight, easily portable and affordable option; however, it is difficult for users to place their foot in the hold and offers little control of the leg during the transfer, especially for users with little upper body strength ("Leg Lifter Strap", n.d.). The user had experience with using this product for transfers and found it difficult to loop the end around her toe.

Figure 24: Leg Lifter

Leg Loop Straps:
The leg loop is designed similarly to a leg brace with the addition of a set of nylon handles at the thigh and ankle (Figure 25). The product allows users to wear it on top of normal trousers and functions through the lifting of either the upper or lower handle. The multiple handles allow for users to complete the transfer in multiple steps, providing more security and control to users.
The design of this product requires less upper body strength than the leg lifter, is able to be used by individuals without hand control, and provides users with more accuracy in their transfers. The product can be difficult for users to put on and take off, and is cumbersome to leave on for extended periods of time ("Leg Handle-Cast Handle Leg Lifter ", n.d.). The user has experience with this product; however its design places the velcro secures on the back of the leg, creating a feeling of insecurity during use.

Figure 25: Leg Loop Straps

Multifit Leg Lifter:
The Multifit Leg Lifter is an automated device with a self-raising platform, controlled by a remote button (Figure 26). The device directly attaches to the side of the bed and allows for the transfer of the user's legs without the requirement of upper body strength. The high cost of the product and the lack of portability make it inaccessible to many potential users ("Leg Lifter (MK3L)", n.d.).

Figure 26: Multifit Leg Lifter

Conclusion:
The five main categories of research, stokes, spinal cord injuries, transferring into and out of a wheelchair, and existing products that address the problem, are all key components to defining the user of the design problem and competing designs.

Appendix C: Project Partner Interview Summary

We conducted our initial project partner interview with Ms. Randi Applehans from the Shirley Ryan Ability Lab at 6:00 pm on January 14th in DTC classroom G211 in the Ford Motor Company Engineering Design Center on the Northwestern University Campus. The interview was conducted to gain a more thorough understanding of the project that our project partner had presented to us. This appendix summarizes and categorizes the information that we collected in the interview.

Client:

We obtained detailed information regarding the client that we are designing the leg lifter product for and the specifics of her spinal cord injury.

- 73 year old woman
- Incomplete spinal cord injury
    - Injury at L2 vertebra (Figure 27)
- Weak upper body
    - 3 mos. in upper body brace, could not bend over
- Right leg:
    - Complete paralysis
    - No sensation
    - Nerve pain
    - impaired spatial awareness - when her eyes are closed she cannot determine the location of her leg
    - Edema (swelling, heavy, requires larger shoe)
- Left leg:
    - Partial sensation
    - Partial paralysis
    - Some movement (weak)
- Difficulty with bending and lifting

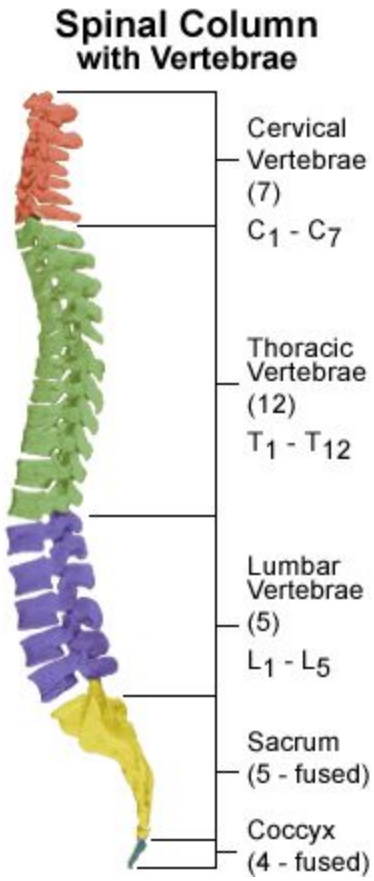

Figure 27: Spine Diagram

Competitive Products:

Our project partner emphasized that the woman that we are designing a new leg lifter for is not satisfied with any of the current competitive products on the market.

- Leg lifter (Figure 28):
    - Pros:
        - Cheap, Lightweight, Portable
    - Cons:
        - The client has difficulty getting the loop around their food because they cannot lift their toes. The leg lifter is also difficult to use to finely control and place the leg. For some the foot loop is too small for their shoes, but this is not an issue for our project partner.

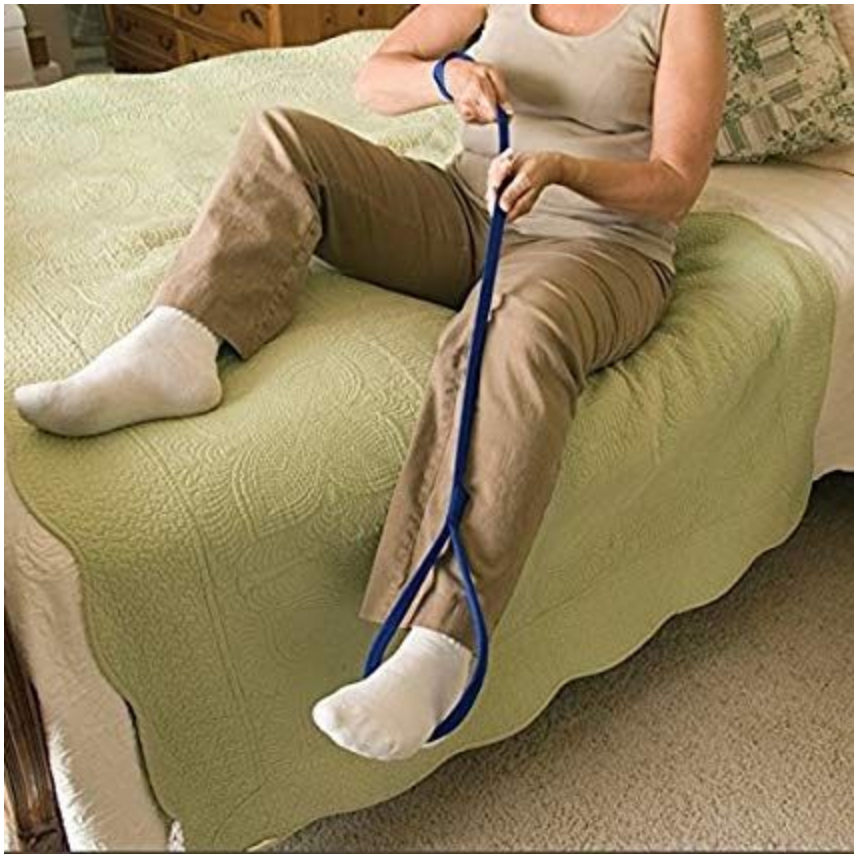

Figure 28: Leg Lifter

- **Leg loops (Figure 29):**
  - Pros:
    - User can grab any loop between thigh and ankle
    - Allows for both small and large movements
    - Good control of leg
    - Upper body strength is less of a concern due to ability to make incremental movements
    - Able to be used with just wrists*

      *useful for individuals with loss of hand control
  - Cons:
    - The client does not like to leave the legs loops on all the time due to their unattractive appearance and because she views them as a tool in the recovery process rather than a permanent solution. Because the client is putting the device on and taking it off every time she does a transfer the don/doff time of the device is particularly important and a shortcoming of the leg loops.
    - Customized sizing required*

      *made by rehab engineer at SRAL
    - Difficult to put lower section on

Figure 29: Leg Loops

Must Haves:

Our project partner detailed these requirements for our design:

- Quick and easy to use
- Nothing too sharp or tight that could cause injury to an individual who lacks leg sensation
- Able to be carried in a wheelchair (portable)
- Allows for independent transfers

Product Functions:

The product will ideally address all of these functions:

- Allows for transfers from wheelchair to bed, shower bench, couch, car
    - Most surfaces are within 6 inches of the wheelchair height
    - Uphill transfer into shower bench
    - Transfers out of both sides of the wheelchair
- Wants to drive in the future, facilitating entering/exiting driver's side of car
- Potential Function:
    - Assisting in putting on shoes*

*client currently has to put on shoes while sitting in bed with both legs forward

Miscellaneous:

- The client is capable of pop/pivot transfer putting weight on her left leg
- Does not use a transfer board

Appendix D: User Observation Summary

On Monday, January 20, 2020, our team went to the Shirley Ryan Ability Lab in Chicago in order to observe the project partner, Jane, throughout her rehabilitation exercises and to ask her questions regarding what she found difficult and any constraints that we would have to adhere to when designing our product. The purpose of the observation was to understand her daily routine better, the transfers she goes through, and any difficulty she has with them. This appendix summarizes the what was observed, her daily routine, and her requests when it comes to the design of the product

Methodology:

The entirety of the observation took place in the room where Occupational Therapist Randi Applehans guides Jane through physical therapy exercises. She was asked to transfer from her wheelchair to various surfaces and then back to her wheelchair. She was also asked about previous products that she has used in the past. At the end of the user observation, Randi took various measurements of her wheelchair and leg.

Overall Mobility

Because Jane suffered a spinal cord injury, she was originally in a brace. However, after she recovered, she no longer needed it. She now has limited mobility in her back. In addition, she maintained full use of her arms despite the injury. The list below shows the extent of her current mobility:

- Her right leg is paralyzed and swollen.
- Her left leg is mobile and she is able to use it to assist her during transfers.
- She has spinal cord flexibility and is able to bend down to a position where she is able to touch the ground with her hands.
- She does have slight toe movement and was able to lift her knee once, showing promise that she may be able to regain control over her leg again with continued therapy.

Daily Routine and Transfers

Jane is currently an outpatient at the Shirley Ryan Ability Lab, which means that she can stay in the comfort of her own home and does not have to stay at the lab. Instead, she comes in for her physical therapy. Her daily routine is listed below:

1. When she wakes up, she first uses a catheter, which is used to remove urine from the bladder.
2. She gets dressed in her bed and proceeds to transfer to her wheelchair.
3. She then goes to the bathroom and showers, transfering from her wheelchair to the toilet and shower bench during that time.
4. On Mondays, Wednesdays, and Fridays, she has to transfer from her wheelchair into a car in order to go to physical therapy at the Shirley Ryan Ability Lab.
5. Occasionally, she does have to transfer from her wheelchair to a chair or couch.

In terms of transfers we observed during physical therapy:

- She would use an unassisted "pop over" technique, where she would use her arms and left leg as leverage from transferring from one surface to another.
- After the transfer, she would use her arms to lift her right leg onto the surface.
- One problem with this was when she had to transfer to a soft surface, such as a bed.
- The soft surface of the bed made it difficult for her to use her arm as leverage because the surface was not hard.
- In some cases, she would use a wooden slide board to get from one surface to another.
- The leg lifter velcro would audibly start to unhook

User Requirements

Jane made several requests regarding the overall design of the product:

- It has to be sturdy and be able to securely carry the weight of her leg.
- It has to be intuitive and easy to use.
- It has to be transportable so she can bring it to the variety of places she goes to.
- It has to be adjustable to account for different types of pants she wears and her current swollen leg.
- It cannot be a stay-on device.
- It should be quick to use.

Problems with Current Devices

- She didn't like that the leg loop didn't feel secure because she would hear the velcro ripping as she lifted her leg.
- She also didn't like that it took around a minute to put it on and take it off.
- She did not like that the leg lifter was hard to use because it was difficult for her to get the loop under her foot.
- Oftentimes, the loop would go through her foot, forcing her to start over again.

Dimensions:

Wheelchair Measurements

- 22" from top of seat to ground (front)
- 21" from top of seat to ground (back)

Body Measurements

- WO size 8 shoe (left), WO size 9 ½ shoe (right)
- Mid thigh: 19"
- Lower calf: 13-14"
- Hip to foot: 45"
- Hip to knee: 21"

Misc. Measurements

- 26" from ground to bed
- 23" from ground to shower seat
- 15" from ground to top of tub
- 14" from inside of tub to top of tub

- 5” tub lip width

Photos:

Figure 30, 31, 32: Photos from User Observation

The user observation allowed us to see the areas of the transfer that Jane struggled with the most. We can then use that information when designing our product to ensure that it will make those aspects of the transfer easier to do. In addition, we now know what she is and is not looking for in a product, which helps to narrow down our ideas.

Appendix E: User Testing Report

Purpose:

The purpose of this user testing was to check if our product could provide the sense of security the user's looking for, whether the placement of the handles are in the right location and to get feedback on the usefulness of the metal bar on our product. To proceed with user testing, the user will need to use our product and try to transfer her leg to different surfaces: her bed and shower chair.

Test Methodology:

Our final mockup is approximately the complete look of our product. The mockup consists of 2 cuffs, one top and one bottom connected by a fabric strap. There are 2 buckles on top and 2 at the bottom. The strap of the buckle is sewn onto the fabric cuffs. There are 2 handles on the top and 2 handles at the bottom. The 2 handles are made up of nylon webbing with nylon tubes inserted inside. The handles on the top are placed at a 45-degree angle as instructed by our user during the first user observation (Figure 33). Our second mockup consists of the above descriptions with an addition of a bent metal bar inserted on the side of our product (refer to figure 34).

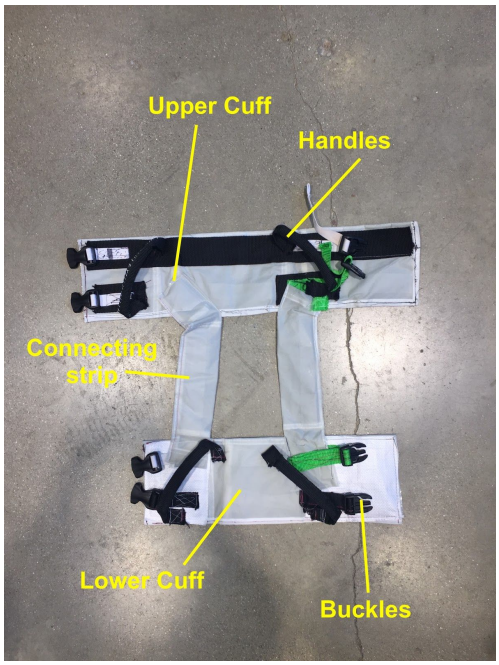

Figure 33: Diagram of Mockup Design

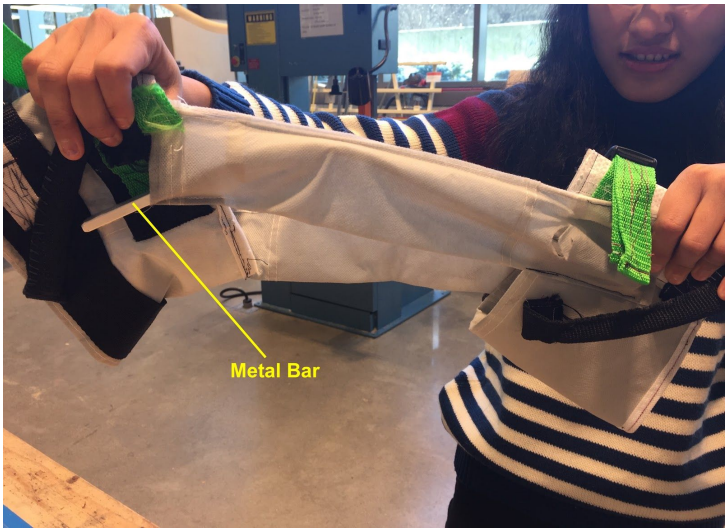

Figure 34: Positioning of Metal Bar

The user first leans onto her left side and slides the product under her right leg, where one of the cuffs loops around her thigh and another cuff loops around her calf. The user then secures the 2 buckles on top and the 2 buckles at the bottom. Finally, the user will grab onto the top handle and lift up her leg and go on to grab the handles at the bottom and transfer her leg onto a different surface.

The user will first try to lift up and transfer her leg using our product without the metal bar onto different surfaces: (1) bed and (2) into a shower chair. Secondly, the user will then try to lift up and transfer her leg to the mentioned surfaces using our product however with the addition of the metal bar.

Results:

Unfortunately, our user was not present on the user testing day, therefore we did not manage to undergo our testing methodology with our user and get her feedback on it. However, we did have a conversation with our project partner. With her expertise in working with our user before, she provided some guidance and feedback to our product.

According to our project partner, the top half of our product should be complete meaning that the handles placements on the upper half are in the right position. However, the metal bar should be covered and also secured to our device for safety purposes if the metal is going to be used as our final product.
Moreover, our project partner feels that we could improve our bottom half of the product. The lower half of the product is too loose which makes it not loop nicely around the user's ankle.

Conclusion and Limitation:

We got quite limited feedback directly from our user. Hence, most of the testing that we've done there is similar to our performance testing. However, what's something useful that we got out of the user testing is the feedback from our project partner who still has more knowledge on this than us, as she works closely with our user.

From the discussion with our projection partner, the top half of the product is complete. This would also mean that the placements of the handles, the dimensions of the fabric looping around the user's leg could be used in our final product design.

We still need to work on the lower half of our product, determining where the handles should be placed as well as the right dimensions to fit the lower leg perfectly. Our project partner doesn't really give many opinions on whether or not to have the metal bar inserted on the side. However, if the metal bar was to be used in our final product design, it has to be attached and covered completely onto our product.

Since the results we get are quite limited, we will need to combine this result with our performance testing and our design reviews to determine our final product design.

Appendix F: Performance Testing Summary

Purpose

Two of the most important aspects of the design is that the product needs to be secure and needs to be put on and taken off quickly. Because the product was going to be made from nylon webbing, as it is strong, yet flexible, there are a multitude of methods for fastening this material together. The method we chose to go with was the side release buckles. In addition, we added handles, to grab onto, on the side of the device so the user would feel safer holding unto the handles rather than their leg itself. The objective of the performance testing was to determine how quickly the device could be put on and taken off, how secure the buckles felt, and how secure the handles felt.

Methodology

In order to determine how quickly the product can be put on and taken off, each of the four project members were asked to put the product on, and then take it off. The time it took for each member to do so was recorded using a stopwatch. Once this was done, each of the members was then asked to use the product to lift their leg and rate how safe that process felt on a scale from 1-10, providing any feedback they had regarding the safety of the product.

Results

Table 2 shows the time it took each individual to put on and take off the device.

Table 2: Time Spent Putting On and Taking Off the Device

User	**Time Putting On** (seconds)	**Time Taking Off** (seconds)
User 1	14	5
User 2	14	4
User 3	16	7
User 4	15	7

Table 3 shows the 1-10 rating each individual gave the device after they lifted their leg using it and any feedback they had to provide.

Table 3: Safety Rating of the Device

User	**Safety Rating (1-10)**	**Feedback**
User 1	6	The rigidity of the handles makes them easier to grab but they still felt too loose, which made it harder to lift my leg and made it feel less safe. But

		overall, it didn't feel like it was going to break.
User 2	5	The handles of the modified leg loop had too much give in them, which made it feel like they might come off.
User 3	6	The strap on my calf wasn't tight enough so it was able to slide up my lower leg a little bit making it feel unsafe.
User 4	7	The device felt safe overall and I would trust it to carry the weight of my leg without breaking, but it was a bit loose.

Conclusion

Based on the data and feedback collected from the performance testing, it can be concluded that:

- The device is able to be put on and fastened quickly and is able to be taken off quickly, which indicates that the side release buckle is a sufficient fastening method in terms of speed
- The handles were too loosely attached to the device, which made them give too much and made the device feel unsafe.
- The plastic tubing in the handles makes them easier to hold onto
- The loops themselves were not able to be adjusted small enough for certain individuals.

Overall, the product was successful in the sense that all of the four testers were able to lift their leg without the product breaking or dropping their leg. However, there are changes that need to be made in order to improve the device's safety, especially in regards to the handles and the adjustability. This will be worked on in the future so that the product feels more safe for users.

Appendix G: Instructions for Construction

Required Tools and Materials

Materials used for Construction

Table 4: Materials used for Construction
Table 4[7]

Material	Specifications	Quantity
Nylon Fabric	13"× 23"	1
	13" × 14"	1
	4" × 22"	1
	3" × 10"	4
Plastic Tubing	⌀ 0.5", 6" long	4
Velcro	5.8" × 3"	2 hook 4 loop
Tactical Belt	XL	4
Nylon Thread	3-ply	N/A

Tools used for Construction

- Sewing Machine
- Scissors
- Needles
- Pins
- Measuring and marking tools (ruler/straight edge and sharpie)

[7] See Appendix I for details on cost and part numbers

Instructions:

Measure and cut the nylon fabric into the sizes specified in Table 1.

Fold the 13”× 23”, 13”× 14”, and 4” × 22” sheets in half and sew 0.5” from the edge where the two ends meet.

Turn the sewn sheets inside out. These two large ones will become the upper and lower cuffs. The smallest one will be the side connector

Sew 2 of the loop velcro pieces side by side to the front of the left side (seam edge down) of each of the cuffs

Sew 1 of the hook velcro pieces on the back of the right side of each of the cuffs

Figure 35: Nylon Fabric

Sew the side connector to the back side of the upper and lower cuffs according to Figure 36.

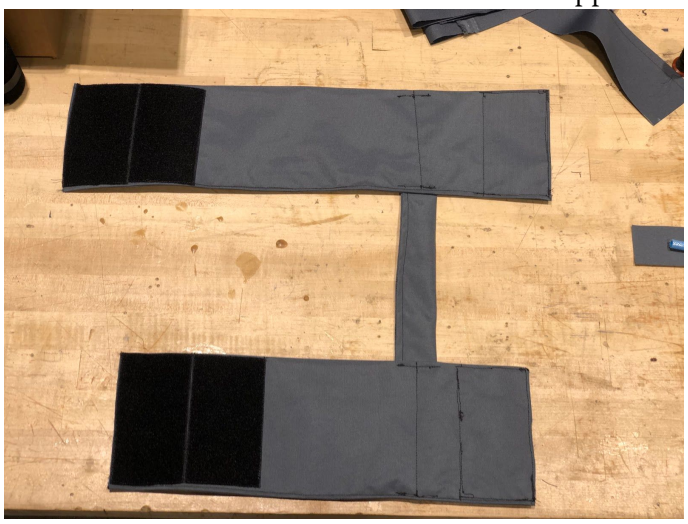

Figure 36: Constructions of Upper and Lower Cuff

The four 3” × 10” pieces of fabric will become the handles. Place a piece of plastic tubing in the center of each of the pieces of fabric and hand sew the long edges together using a whip stitch.

Sew two magnetic quick release belts onto both the upper and lower cuffs approximately 0.5” in on each side

Figure 37: Magnetic Buckles

Figure 38: Fabric for Handles

Figure 39: Construction of Handles

Trin the loose ends of the belts so that 4-5” remain when tightened on the users leg

Use a blowtorch to melt the ends of the loose ends to prevent fraying

Figure 40: Melting the Ends of Loose Ends

Figure 41: Painting of Visual Indicator

Paint the triangle indicators on the magnetic quick release buckles red.

Sew the handles onto the belts at about a 45° angle onto the belts behind the loose ends

The product is complete.

Appendix H: Instructions for Use

Putting on the Product:

Set Up:

1. Release the buckles on the front of the product and unfasten the velcro closure. The product should be able to be completely opened.
2. Optional: Loosen the buckles using the pull straps connected to them.

From a wheelchair or seat:

1. Take the top cuff and position it against the back-side of your knee.
2. If possible: Lean to the side opposite of the leg being transferred, lifting your upper thigh off the seat. You may also raise your thigh using your arms or may slide the product under your thigh by slowly feeding it under your leg (Figure 42).
3. If you are not able to lift your thigh, the product can be positioned under the thigh by gradually pulling the cuff towards your body from the back of your knee.
4. Fasten the velcro on the front of the cuff, then buckle the two buckles.
5. Take the lower cuff and position it behind your lower calf.
6. Wrap it around your leg and fasten the velcro on the front, then buckle the two buckles (Figure 43).
7. Adjust the tightness of the cuffs using the pull straps attached to the buckles.

Figure 42: Putting on Upper Cuff

Figure 43: Fasten Velcro and Buckles

From a bed:

1. Place the product buckle side down on the bed next to your leg.
2. If possible: Use your arms to lift your thigh off the bed.
3. Holding your thigh with one arm, use the other to slide the product under your thigh.

4. Put down your leg and wrap the cuff around your thigh, securing the velcro and two buckles.
5. If not able to lift your thigh: Slide the top cuff under your thigh by slowly feeding it under their leg. Once the product is under the leg, wrap the cuff around your thigh, securing the velcro and two buckles
6. Repeat one of the two options for the lower cuff as well, positioning it at the lower calf.
7. Secure the lower calf velcro and buckle the two buckles.
8. Adjust the tightness of the cuffs using the pull straps attached to the buckles.

Transferring the Leg:

1. With one hand on each thigh handle, grab onto the device (Figure 44).
2. Lift your leg off the starting surface, guiding your leg to the secondary surface.
3. Transfer grip to lower handles by either:
    a. Letting go of one thigh handle and grabbing one lower handle, then transferring the other hand to the lower handle
    b. Setting your leg down on the second surface, then taking hold of lower handles
4. Use lower handles to make adjustments to your leg position (Figure 45).

Figure 44: Holding Upper Handles

Figure 45: Holding Lower Handles

Removing the Product:

1. Disengage the buckles on the upper and lower cuffs by pulling the small loop on the front of the calf (Figure 46).
2. Unfasten the velcro on the upper and lower cuffs (Figure 47).
3. Slip the product out from under the leg by using side-to-side rocking motions, pulling the cuff away from the body. You may also lift your leg by leaning or picking it up slightly with your arms in order to pull the product out from under your body.

Figure 46: Disengaging the Buckles

Figure 47: Removing the Velcro

Appendix I: Bill of Materials

Table 5: Bill of materials

Item	Description	Quantity	Vendor	Unit Cost	Total Cost ($)
Tactical Belt with Magnetic Quick Release Buckles	Black nylon web strap with black plastic buckle: - strap width: 1.5” - buckle length: 3” - buckle width: 1.9”	4	Amazon	12.99	51.96
Upholstery Nylon Thread	Black, 150 yard	2	Amazon	3.86	7.72
Waterproof Nylon sheet	Colour: Coal Width: 56”	1 yard	Amazon	10.99	10.99
Sew-On Velcro	Black, Nylon	2 yards	Amazon	8.99	8.99
Total:					79.69