Portable Recliner

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Abstract

Our client, due to several physiological ailments, encounters difficulty with sitting up from a reclined position or standing from a seated position. However, he can still walk with a walker for short periods of time and finds himself well enough to travel. This is not uncommon, and could also be the case for individuals with multiple sclerosis, muscular dystrophy, and stroke victims. Though many reclining chairs exist, they are large, heavy, and not suited for portability, which can be problematic for individuals who need to sleep in an assistive device but still would like to travel. In order to meet this need, our team aimed to create a reclining chair that is portable enough to take on overnight trips away from home and can assist the client in sitting and standing. The device created is able to be carried by one person and is small enough to fit in the trunk of a vehicle. Our prototype uses a wood frame and a lift seat, as well as a back support for the reclined chair. The device is able to support 159 kg on each weight-bearing surface with 0.6 cm of deformation or less, and costs less than $250 to build. Future work will implement this design in a more portable material and will implement more features for greater comfort and ease of use.

Introduction

Client Background

Stan Fox, one of our clients, underwent knee surgery in 2007. Due to several complications, he experienced a heart attack and suffered kidney failure. He now undergoes dialysis treatments three times per week. These treatments, along with residual effects from his other complications, leave Stan feeling very weak, and he, thus, needs assistance in sitting up and standing. However, Stan, along with his wife, Connie, are still very active. Stan can walk for short distances with the assistance of a walker, and the clients enjoy traveling if possible.

At home, Stan receives the assistance he needs for sitting up and standing from a mechanized recliner that he sleeps in. An example of this type of recliner can be seen in figure 1 below. This recliner, however, is too heavy and cumbersome to allow Stan and Connie to travel on overnight trips. The clients are seeking a more portable version of the mechanized recliner that Stan sleeps in at home. This recliner needs to be light enough for Connie to carry and assemble (<18kg) but also needs to be strong enough to support Stan's weight for up to 16 hours.

Figure 1: Mechanized power recliner (1)

Problem Statement

Many individuals may require the use of a mechanical reclining chair for sleeping, but devices available are large and heavy, and therefore, not portable. The team aims to create a portable reclining chair that also features a lift mechanism to assist the user in going from a prone to a seated position, and from a seated position to a standing position. This device should be able to be carried and stored in a vehicle, and should be comfortable enough to sit or sleep in.

Motivation

Existing Products

Currently there are no true assistive portable reclining products designed for sleeping or sitting in available in market. However, there are products that are currently available that assist consumers in standing from a sitting or lying position. The most notable of these products are the mechanical recliners commercially available from many retailers. This product, pictured in figure 1 above, often uses a hand-held remote to go from a reclining position, to a seated position, to a standing position. These chairs can support an individual of up to 181kg and are electronically operated, however, they weigh over 45kg, and therefore are not portable (1).

Another commercially available product that is similar to this design project is the sleeper chair series from La-Z-Boy contract furniture. These chairs and couches can be found in many hospital settings and can easily convert from a chair to a bed. The chairs, pictured in figure 2 below, have a pullout footrest and a backrest that folds back to a prone position in order to convert the chair to a sleeper. This chair can support an individual of up to 225kg, but weighs 90kg and would not be considered portable (2).

Figure 2: Collapsible Sleeper Chair (2)

Figure 3: Mangar CAMEL emergency inflatable lift chair (3)

Other portable standing assist products are also available, but many are specially designed for emergency use. The Mangar CAMEL, which is an example of a portable emergency lift, uses inflation to lift a person weighing up to 315kg from the floor to a seated position. When not inflated, this product rolls up to 76 cm (length) by 20 cm (diameter), allowing it to be easily carried and transported. This product, shown in figure 3 above, uses a portable battery to inflate the system, and, while doing so, lifts a fallen person to a seated position. The product takes 2 minutes to inflate and only weighs 6kg, but is designed for use for fallen individuals and has a limited lifetime (3).

Portable lifting assists are also available commercially for everyday use. The Up-Lift portable lifting cushions, pictured in figure 4 below, are devices that are able to be used with any seat, and assist an individual who weighs up to 135 kg in standing from a seated position. These systems use either pneumatic or electrically operated control systems to lift the seat to a standing position. While the pneumatic system is designed as an assist and only supports 70% of a users' body weight, the electric system is a true lift system and is able to support 100% of a users' body weight upon standing. These products are also lightweight, weighing only 6kg, and portable, as they are only the size of a seat cushion (4).

Figure 4: UpEasy power lifting seat (4)

Broad Scope Motivation

There are several medical conditions that could create a need for a portable recliner. In order for this product to be useful to an individual, the user must be well enough to travel but also need assistance in sitting up or standing. Therefore, this device may be useful to individuals with degenerative muscle diseases or partial loss of muscle function. In particular, this product could be useful to individuals with early to middle stages of multiple sclerosis and muscular dystrophy (5,6). In each of these diseases, there are wide variations of the physical abilities of the individual, but all are characterized by muscle weakness and loss of muscle function, which can lead to a need for assistance in standing or sitting up. However, in many cases, individuals with these diseases, especially in their early to middle stages, can still walk for short periods of time, and are often well enough to travel (5,6). This may also be the case for some stroke victims. While stroke can lead to a partial or complete loss of balance and motor function, oftentimes stroke victims are also well enough to travel after recovery (7). Therefore, the product designed could be adapted for use by individuals with any one of these diseases, but it is extremely important to note that, because of the range of strength and ability, it would be extremely difficult to design one product that suits all needs.

<u>Design Specifications</u>

Client Specifications

In order to make the recliner portable but still strong, several requirements need to be met for the design. Since the client plans on sleeping in the chair, it must recline all of the way to a prone position and it should be long enough when fully extended to allow a man who is 175 cm tall to lay flat. The product should also allow a person of this height to sit up in it comfortably. The chair should be comfortable, as it is meant to be sat or slept in for up to 16 hours at a time. Additionally, the chair must be able to support a load of 135 kg for this length of time. Finally, the product must be able to assist the user in sitting or standing.

In order to be portable, the recliner must be able to fit in the trunk of a car. Thus, it must take up less than 0.35 cubic meters of space. The client also needs to be able to easily carry the product, and thus, it must weigh less than 18 kg. This product is also meant to be assembled by one person, and therefore must be easy to assemble and disassemble. Finally, the seat must cost less than $300.

Ergonomics

Stan is also slightly dissatisfied with his current reclining chair because it is slightly too big for him. His hip to knee length is slightly shorter than the depth of the chair, and, therefore, he currently requires pillows to support him when he sits. Therefore, it is crucial that this design be customized to Stan's measurements.

Additionally, Stan experiences back pain, and this is one of the reasons that he sleeps in a recliner. Knowing this, it is important that the product has back support and will not further Stan's back pain. Therefore, the product must have lumbar support for Stan's lower back and must have no juts or raised portions in this back support.

Ethics

As with any engineering design, it is paramount to ensure the safety and well-being of the users of the product. Therefore, the design should be tested very vigorously before it is to be used by the client. It must be ensured that the product will not fail while in use. The product should be designed so that it will not, under any foreseeable circumstances, tip, slide, or greatly deform while in use. Additionally, this product should not be presented as anything except a portable recliner designed for assistance in seating or standing. This product will not be designed for sleeping or sitting in for many days in a row and should not be advertised as such. Finally, if, in the future, the client, design team member, or any other person finds a noticeable flaw in the design that could compromise the safety or health of the user of the product, that person should immediately notify the team members so that the product may be altered to remove this flaw.

Design Alternatives for Chair

Design Option #1: Slider

This design, as seen in figure 5 below, has a frame with legs that fold up into the main frame when the prototype is collapsed. The seat rests on a platform, with the backrest held up by a torsional spring and support bars that lock into place. The footrest is connected to the seat and hangs straight down when in the seated position. The cushions are removable and connect to the frame with Velcro straps and strips. The entire seat, footrest, and backrest part of the chair are connected and are on a movable track on the main support platform. The track consists of a number of bearings and support bars across the main frame.

When the individual moves to a leaning back position or down to a sleeping position, the whole seat unit moves along the track. As the seat moves back, it slides along the bearings and pulls the legs up and over the front edge of the platform. The platform also has features that increase portability, and can be removed when the seat is not reclined. The backrest also has pegs to lock it into a reclined or prone position, which can be unlocked by the caretaker. The torsional springs in the hip help lift most of the weight up in a controlled ascent as the person slides the seat forward and the legs rotate down. The bottom of the footrest has an edge for the feet to rest upon. When this design is collapsed, the seat, footrest, and backrest unit will pull away from the main support platform. The seat unit will then collapse up into a suitcase like piece, while the platform's legs fold up and the platform telescopes into itself.

This design has many features that allow it to have the most user-friendly and safe reclining mechanism. Because of the locks and torsional spring, the user will be very well assisted in going from a prone position to a seated position, and this spring will not activate when it should not activate. However, the sliding mechanism causes the user to need assistance from a caretaker when reclining, resulting in a relatively low ease of use for this design. Additionally, while this design needs a greater amount of space for it to be set up and used, it collapses into small, lightweight, and portable components. Though, due to the large number of components, this design is also the most difficult to assemble. Finally, this design is what most resembles what was described by the client for her ideal design.

Figure 5: Slider chair design option

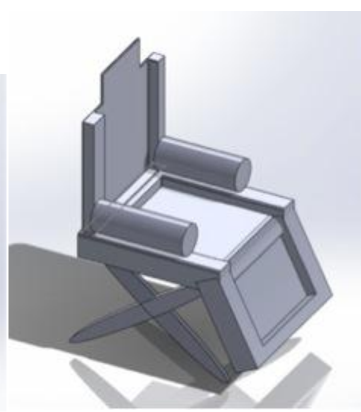


Figure 6: Directors' chair design option

Design Option #2: Directors Chair

This design option, as seen in figure 6 above, features a rectangular seat with indentations of 5cm deep, 5cm away from the sides. Removable cushions will be placed in these indentations to improve the portability of the seat. Removable, cylindrical armrests were also built into this design for increased user comfort as well as for pulling on or holding onto when the user goes from a laying position to a seated position or from a seated position to a standing position. The back of the chair also features a headrest for increased user comfort in the seated position. The footrest in this design consists of a rectangular slab with an indentation, which will be filled with another removable cushion.

The back of the seat connects to the seat through a metal rod that runs through the sides of the seat and the bottom of the back, allowing the back of the seat to be rotated relative to the seat bottom. This back reclines by using torsional springs that can be locked in a compressed position for when the user is lying down or an extended position for when the user is sitting up. The footrest is attached to the seat in a similar manner and can be raised to a laying position through a similar mechanism. The torsional springs can be unfastened from the footrest and back of the chair to allow the seat to fold on top of and the footrest to fold under the chair seat to increase portability. The locks specified in this description will be of the push knob with latch variety for ease of use.

The legs of this design option consist of two bars connected by a metal rod going through the center of both sets in order to increase stability. These bars are attached to the bottom of the seat but are removable in order to increase portability. Additionally, this model will have the pneumatic UpEasy portable seat attached to the base to assist the user in going form a seated to a standing position.

Because of the removable parts of this chair and the fact that the chair can fold up like a suitcase, this design option is the most portable and compact out of the three. It is also for this reason that this design option is the lightest. However, this minimalist design raises concerns about the stability of this design, as well as its ability to be sat in or laid in over long periods of time. Finally, because this chair does not have a great deal of support, it will also be the least comfortable to lie in

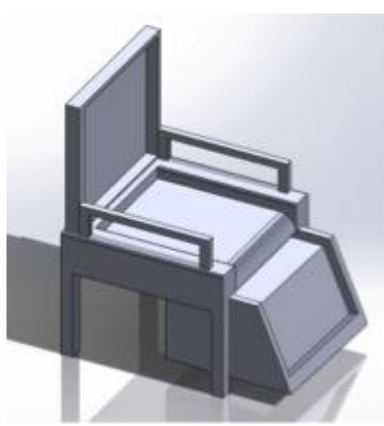


Figure 7: Lazyboy design option

Design Option #3: Lazyboy

This design option, as seen in figure 7 above, also features a traditional seat bottom and back. Similarly to the other designs, these two parts also have indentations in which removable cushions will be placed. This design features armrests that are not removable and are rectangular. They will be padded, but their primary use will be to aid the user in going form a laying position to a seated position, allowing him to grab onto the armrests and use them as assists in pulling himself up. These will also be useful in assisting the user in going from a sitting to a standing position, as he can use the armrests as bases of support to help him up.

The legs of this seat are rectangular in shape and, if needed will have crossbars spanning the sides of the chair on the legs for extra support. Additionally, these legs are non-removable in order to increase stability. The footrest on this model slides out from under the chair to become the portion of the bed needed for the legs and feet. When it is completely slid under the chair, it can be locked in this position and acts as a footrest. When completely pulled out from underneath the chair, the footrest portion measures 45 cm and the structure can be used as a bed when a cushion is placed in the built-in indentation. The footrest can also be locked in this extended position so that the structure does not slide back in during the night. The locks specified in this description will be of the push knob with latch variety for ease of use.

The back of this chair reclines in a manner similar to a beach chair. That is, the seat is regularly locked in a seated position, and when unlocked can be tipped back to a prone position and locked again. Supports for this portion of the recliner can be folded out of the back of the chair. Additionally, this model will have the pneumatic UpEasy portable seat described in the standing mechanism section attached to the base to assist the user in going form a seated to a standing position.

Because this design option does not have any torsional springs or other complex mechanisms it will be relatively easy to use. Additionally, the large base of support and the bulky footrest make this model very durable and stable as well as being very well suited to be sat in for a long period of time. However, because of this increased support, this model is rather bulky, which raises concerns about its portability and weight. This model also does not have an assist (besides the aforementioned armrests) to help the user go from a prone position to a laying position, which could potentially problematic for our client.

Design Alternatives for Standing Assist Mechanism

The team decided that purchasing a portable lifting cushion or lift assist would be a very good option for the portable recliner because lifting cushions available on the market suit the needs of the project well, that is, they are inexpensive, portable, able to be used in a variety of situations, reliable, and suit the client’s needs. There are two main options of portable lifting cushions available on the market, which includes power control and pneumatic lifting mechanisms.

The power control option, shown in figure 4 (located on page 5), uses an electronic control. The user presses a button on a hand-held control and two support beams slowly raise the cushioned portion of the seat to help the user into a standing position. The pneumatic seat, shown in figure 8, uses a pneumatic lift to assist the user into a standing position. The user shifts forward in the seat and the gas spring automatically activates to help lift them.

The power control option supports 100% of an individual's weight in going from a sitting to standing position, however, this model can only support 135kgs and costs $130-200 (depending on the width of the seat and the type of material desired for the cushion). This model is also restrained in terms of space, as it must be plugged into an outlet in order to be used. By contrast the pneumatic model does not need electricity to lift the user, and can support up to 160kgs. This model also costs between $75-150 (depending on the width of the seat and the type of material desired for the cushion), however, it only is an assist, and only supports 70% of the user's weight to obtain a standing position (4).

Figure 8: UpEasy pneumatic seat assist (4)

It was decided that the pneumatic option will be used in the portable recliner. The pneumatic option is more affordable, more portable, and alleviates the need for electric mechanisms in the chair. This simplifies it for client use as well as improves portability of the entire device. It was also discussed that, for the needs of the client, the fact that this option only supports 70% of the users' weight would not be an issue, as the client can, at this time, play an active role in standing, and truly just needs assistance.

<u>Design Matrix</u>

Design Requirement	**Slider**	**Directors**	**Lazyboy**
Comfort	12	12	14
Ease of Use	7.5	10.5	9
Compactness	7	7	5
Client Satisfaction	12	4.5	7.5
Weight	7	7	4
Feasibility of Construction	7	7	6
Ease of user assembly	4	7	6
Durability	3	1.5	3.5

Cost	2.5	2.5	2.5
Total	62	59	57.5

Table 1: Design Matrix ranks each design on its ability to fulfill each requirement

For the design matrix, the following were used as definitions of the design requirements. Comfort is defined as the ability of the design to be slept in for two nights straight, and is the highest weighted category (20%) because it is the clients' top priority. Ease of use implies that the design allows the user to be able to recline, raise and lower the footrest, and have an assist in standing with ease. This was rated second highest (15%), along with client satisfaction, since this is what separates this product from an ordinary lawn chair, and the product is being specially designed with this client in mind. Ability to compact is based on how small the structure can become and how few pieces will be involved in collapsing the structure. The recliner is going to be used for traveling and is being transported by car, so the recliner must be compactible. Thus this was also given a weight of 10%. Weight, feasibility of construction, and ease of user assembly were also given weights of 10%. Cost and durability were determined to be the least important and were given weights of 5% each. The durability was decided to be of little importance because the recliner would be used only 1-3 times a year for a max of 3 days.

The final scores were calculated and, as can be seen in table 1 above, the slider design was determined to be the best of the three. However, each of the designs had high scores in several categories due to the qualities articulated in the design descriptions. Because of these similar scores, the final design is a combination of elements of all three designs.

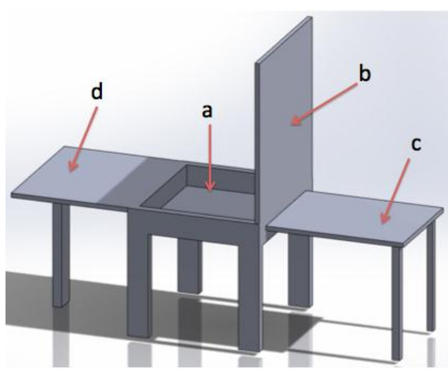


Figure 9: Solidworks model of final design where a is seat, b is seat back, c is back support, d is footrest

<u>Final Design</u>

The final design of the prototype has three main components: a seat, a footrest, and a backrest. These components are described below and their dimensions are listed in table 2 (also below). Additionally, a schematic of the final design is included in appendix

B. The final design is shown in figure 9 above and specific components are denoted in the figure above by the letters in parenthesis in their descriptions:

Seat

The final seat design features a box-shaped seat (a). This portion of the design is consistent with that in both the directors' chair and the lazyboy design. The use of a box shape will allow us to insert a removable back support for the reclined seat (see below). This seat is supported by four legs that can be unscrewed to allow portability. Legs that unscrew are similar to the fold-up legs found in the slider design. It is thought that this design will allow the greatest portability (over fixed legs) and will also not present a pinching safety hazard (as the scissor legs or foldable legs do) (8). Within the seat box, there is a cushioned base and an UpEasy pneumatic lift seat to assist the user in standing.

Backrest

The backrest (b) of the final design is rectangular in shape and is attached to the seat base with two hinges. These hinges allow the backrest to fold on top of the seat to allow portability. The hinges also allow the seat back to be propped up vertically for use of the product as a chair or to recline for use of the product as a bed. The backrest is attached to the back support (c) with a torsional spring, which assists the user in going from a prone position to a seated position. The backrest is also cushioned to increase comfort. While all three of the design options feature a hinged backrest, this design is most similar to the directors' chair design because it features a torsional spring. The torsional spring will provide assistance in lifting the user from a prone position to a seated position. However, the inclusion of the torsional spring also could be problematic if the user is not strong enough to recline against the spring. Therefore, in the final product, it will be noted that, if necessary, the caregiver should assist in reclining the seat, and a locking mechanism will be included to keep the back reclined when in a prone position.

When in a prone position, the backrest is supported by a back support (c). This support is removable and fits snuggly into a hole cut into the seat box. This support also has two legs to increase the stability of the structure. This is a very similar feature to the back included in the slider design. The inclusion of the extra legs will provide more stability, and will decrease the probability of a failure in comparison to a support that is fastened directly to the back. This is because, since the support exists as a separate component and is wedged into the seat back, it is not dependent on a hinge or another fastener but rather on the strength of the wood, which will decrease the probability of a failure (8).

Footrest

The footrest (d) of the final design is rectangular in shape and is attached to the seat base with two hinges. These hinges allow the footrest to be raised from a vertical position to a horizontal position when the product is used as a bed. The footrest has one hinged leg that can swing out to prop it up when in a horizontal position. Finally, the pins can be removed from hinges of the footrest using a small hammer and any nail, increasing the portability of the design. In the future, a different type of hinge will be used that will eliminate the need to remove the pins in order to transport that chair. This footrest design is most similar to the footrest in the directors' chair and the slider design alternatives. This design alleviates the problem of the footrest not being level with the chair created by the pull-out footrest featured in the lazyboy design.

Cushions and Construction Materials

The cushions are made out of high-density foam covered with fabric. This allows them to be comfortable but also washable. The cushions will also be fitted with Velcro. The cushions, then, will be able to attach and detach, making the design more portable.

Wood was chosen as the material for the prototype. This material was chosen over aluminum because it is easier to work with and does have the strength needed to support the user (see the modeling section below). In the future, however, the prototype will be remade out of an aluminum alloy to make it more portable, as wood is a heavier material.

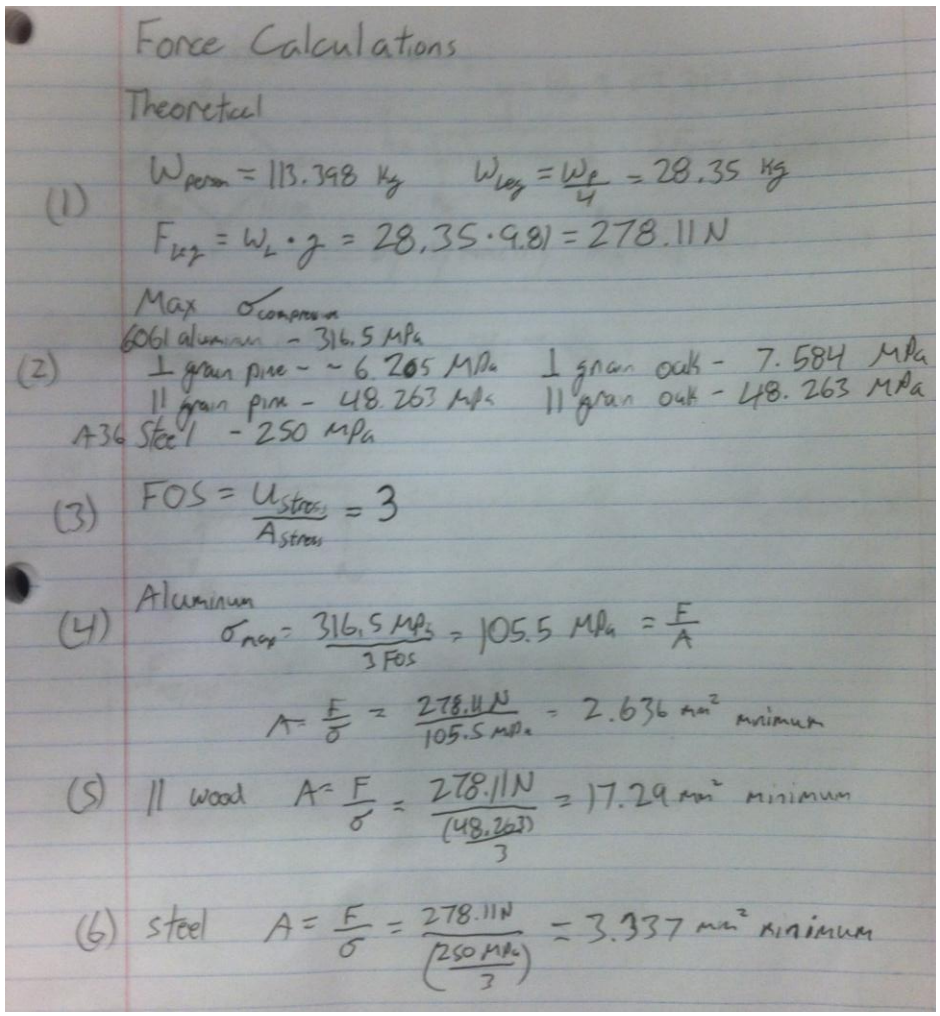
Component (Data in cm)	Length	Width	Height
Seat base	56.5	61.0	10.0
Legs supporting seat	8.9	3.8	44.5
Backrest	68.6	60.3	1.9
Back Support	59.0	45.7	1.9
Legs supporting back support	3.2	3.2	49.5
Footrest	50.2	60.3	1.9
Leg supporting footrest	8.9	3.8	54.6

Table 2: Component Dimensions also shown in schematic in appendix B

Modeling

A solidworks model was built of the final design, which can be seen in figure 9 above (located on page 12). Additionally, the team calculated the forces that each component would be subjected to and compared this to the ultimate strength of the materials considered for use (aluminum and wood).

Theoretical forces were calculated early on in the semester and then after the prototype was made, actual forces were calculated. Using a person weight of 113.398 kg from speaking with the client the force per leg was calculated (eq. 1). The table of max compressive stress was researched online (19) and can be found in (eq. 2). A factor of safety of three was applied. Using the factor of safety, the force per leg, and the max compressive stress, the amount of area needed for each material was calculated (eq. 4, 5, & 6). Only parallel grain wood was calculated, because it is significantly stronger than perpendicular wood and strength was desired when it comes to the legs. The very small needed area for the legs gave a lot of leeway when it came to designing hollow tubes to allow for less weight and other brainstormed ideas. Equations 7-10 show two different ways of calculating distributed forces on the seat frame. Equation 11, resulting in 13.85 N/cm of force around the entire seat frame is a more accurate representation of what the force would actually be. Equations 7-10 are using a simple beam model assumption, which doesn't account for the other two sides of the frame carrying weight.



Force Calculations

Theoretical

(1) $W_{person} = 113.398$ kg $\quad W_{leg} = \frac{W_p}{4} = 28.35$ kg

$F_{leg} = W_L \cdot g = 28.35 \cdot 9.81 = 278.11$ N

Max $\sigma_{compression}$

(2)
6061 aluminum – 316.5 MPa
⊥ grain pine – ~ 6.205 MPa $\quad$ ⊥ grain oak – 7.584 MPa
∥ grain pine – 48.263 MPa $\quad$ ∥ grain oak – 48.263 MPa
A36 Steel – 250 MPa

(3) $FOS = \frac{U_{stress}}{A_{stress}} = 3$

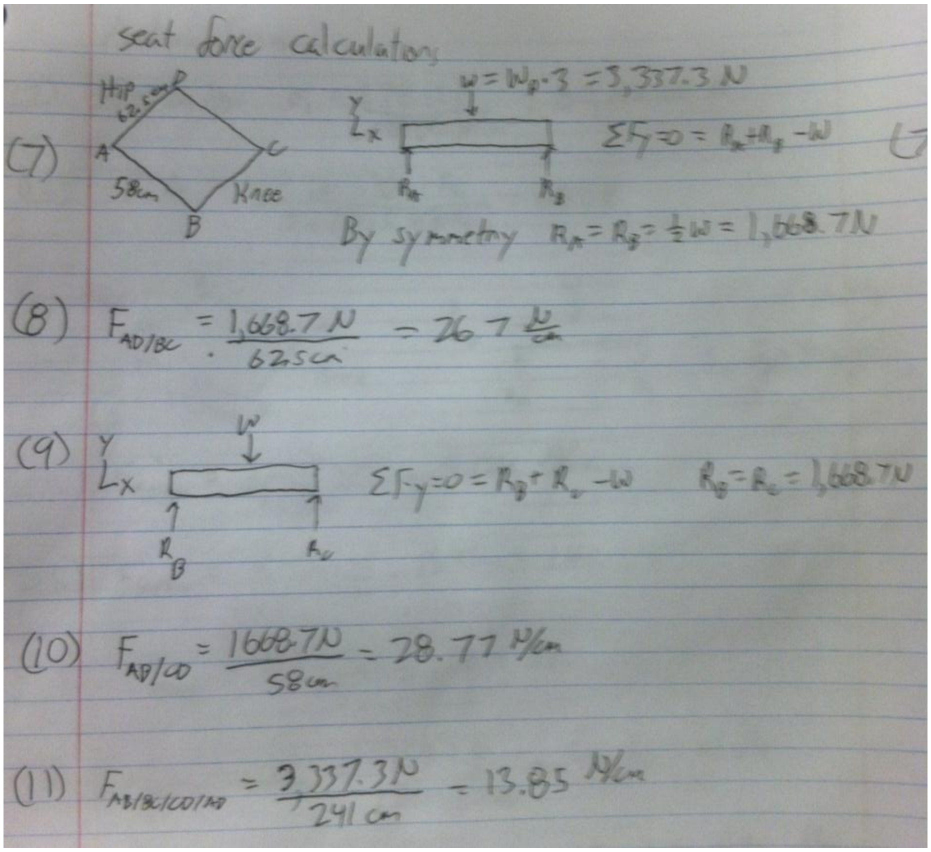
(4) Aluminum

$\sigma_{max} = \frac{316.5 \text{ MPa}}{3 \text{ FOS}} = 105.5 \text{ MPa} = \frac{F}{A}$

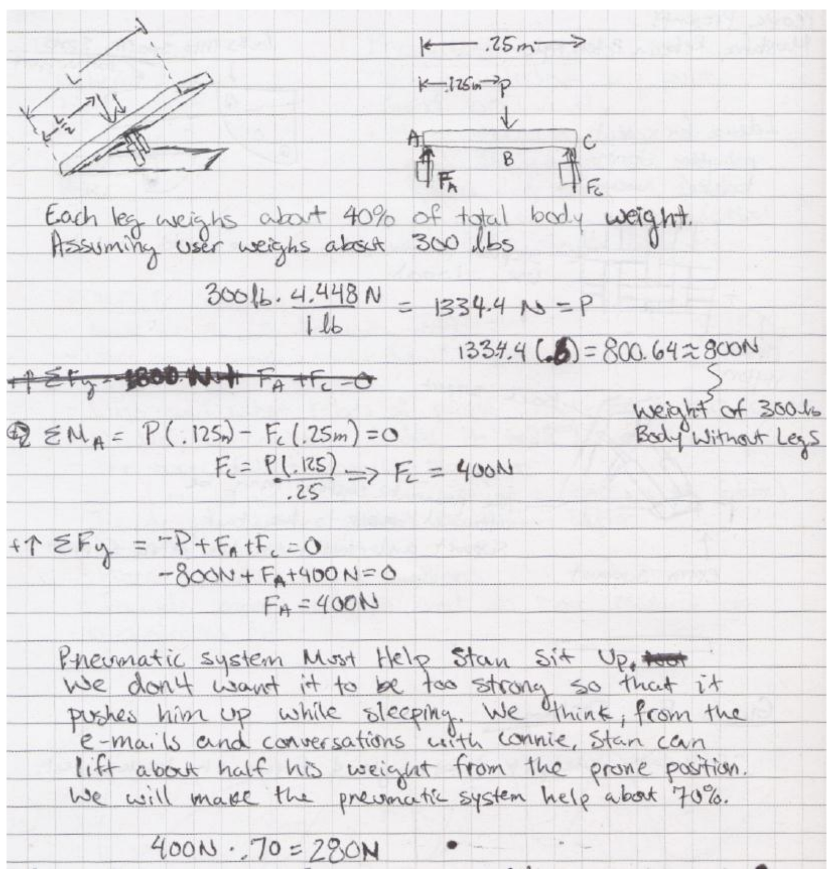
$A = \frac{F}{\sigma} = \frac{278.11 \text{ N}}{105.5 \text{ MPa}} = 2.636 \text{ mm}^2$ minimum

(5) ∥ wood $\quad A = \frac{F}{\sigma} = \frac{278.11 \text{ N}}{\left(\frac{48.263}{3}\right)} = 17.29 \text{ mm}^2$ minimum

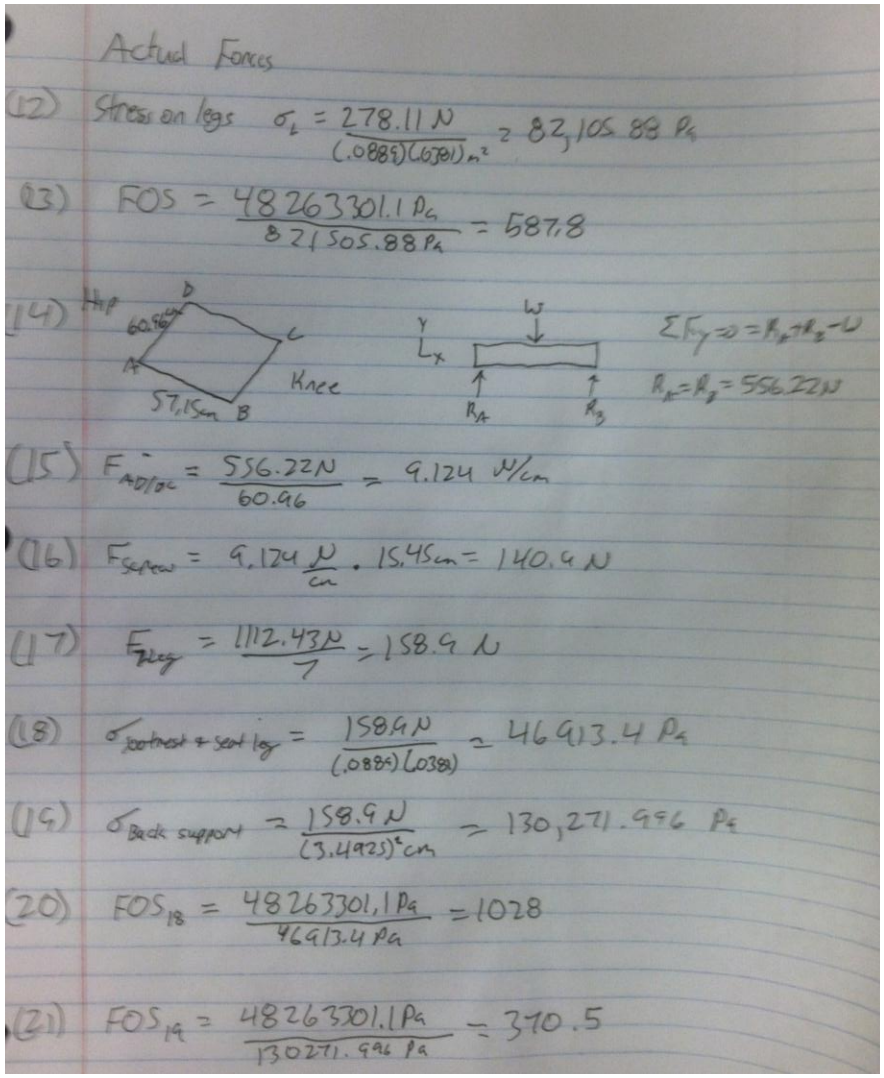
(6) steel $\quad A = \frac{F}{\sigma} = \frac{278.11 \text{ N}}{\left(\frac{250 \text{ MPa}}{3}\right)} = 3.337 \text{ mm}^2$ minimum



The second set of theoretical calculations was attempting to find the force by the pneumatic system required to lift the client. It was assumed that the bar the pneumatic cylinders were going to be attached to was going to be half way up the back. This made the calculations simpler and resulted in a reasonable length and size of the cylinders. In this assumed, ideal situation the calculated needed force was 280N to lift the client from prone to sitting up.



After the prototype was built, calculations were redone with the actual sizes of the beams and bars. Using the area of the seat legs and the force on each from previous calculations, the stress on each leg was calculated to be 82.10588 kPa (eq. 12). This gave a factor of safety of 578.8 using the max compressive stress data from before. The idealized simple bar mode was used again to calculate distributed forces and it was found to be 9.124 N/cm (eq. 14 & 15). Then, using the dimensions of the prototype and the fact that there are three screws on each side in between the legs, it was known that each screw covered 15.45cm and thus held 140.9 N. The prototype has seven legs and if it assumed that each leg holds the same amount of weight, then the force on each leg would be 158.9N (eq. 17). Using the different areas of each leg and then the ultimate max compressive stress a factor of safety of 1028 was found for the footrest and seat legs, along with a factor of safety of 370.5 for the back support legs. The calculations confirm that the prototype is very safe.



Fabrication

Because the material chosen for fabrication was wood, most of the techniques used in making the prototype involved work in the wood shop. The first step in fabrication was cutting out the seat, backrest, footrest, and back support platform from the plywood sheets. The next step was cutting the 2"x4"s to the right sizes and nailing them together to form the frame of the seat. Then, the seat platform was connected to the seat frame with screws. Hinges were used to connect the footrest and the backrest to the seat. Lining up the hinges was one of the hardest parts of fabrication, because it relied on such precise alignment that could be altered by a simple misplacement of one screw. Next the legs were fitted with hanger bolts and the holes that the legs can be screwed into were tapped for these same bolts. Additionally legs were attached to the back support platform with screws, and the leg to the footrest was attached with a hinge. A slot was cut out of the back part of the seat frame for the back support platform to slide into. The armrests were each created out of a 2"x4" piece and two pieces of 9/16" steel tubing. Then holes were drilled in the seat frame and the arm rests for the steel bars to support them. The next fabrication phase was the decoration and comfort phase. This phase involved painting the legs red and the rest of the frame brown. For this prototype, the cushions were stapled to the seat instead of being removable. Therefore, finally, the foam and fabric were used to staple the cushions to the backrest, footrest, and seat.

Budget

Originally the client had a target budget range of $200-300. Therefore, throughout the project this goal was kept in mind. The final total prototype cost was $219.20. The majority of this cost came from the UpEasy Lift Seat, which cost $99.00. Some other major purchases include the hinges, which cost $18.95, the fabric, which cost $14.21, the high-density foam, which cost $42.19 with a coupon, and the paint, which cost $25.26. The remaining cost ($19.59) was from miscellaneous needed hardware such as screws, paintbrushes, nails, and other pieces. All of the pine 2"x4" boards and plywood sheets were donated, which helped keep the total project cost down. The costs of this prototype are summarized in table 3 below. This prototype was kept under-budget, but future prototypes will incur greater cost. This will occur because future prototypes will need additional materials including aluminum alloys, torsional springs, locking mechanisms, and Velcro. For more information on this, see the future work section below.

Item	**Cost**
UpEasy Lift Seat	$99.00
Pine 2" x 4"s and plywood sheets	Donated
Hinges	$18.95
Screws, nails, and misc. hardware	$19.59
Fabric	$14.21
Cushion high density foam	$42.19
Paint	$25.26
Total Cost	$219.20

Table 3: Prototype Expenses

Testing

The portable recliner was tested by applying weights of 160kg to each component. The main area of focus was the base of the chair, where a load of 160kg was applied by placing weights in increments of 20kg. The most deformation that occurred was 0.254 cm with the max weight of 160kg. However there was no noticeable deformation in the seat until 100kg was applied. The seat and back were tested the same way as the base of the chair by applying weights in increments of 20 kg. Both of these components experienced 0.508 cm of deformation with the max load of 160kg. For all components, when the load was removed, the part was no longer deformed and showed no signs of failure. As the maximum normal load on the seat will be 135 kg, our test showed a factor of safety for the seat of at least 1.2. The maximum normal load on the footrest and backrest will be less than 80kg, and, thus, our tests show a factor of safety for these components of at least 2. Images of the tests being conducted can be seen in figure 10 below. The test was conducted twice for each part, and the averaged results are shown below in figure 11. Finally, this test was adapted from a test used to determine the strength of a kitchen chair sold by Lifetime products. The test that this is based off of meets industry standards (9).

Figure 10: Testing of Prototype Components Backrest testing seen on left, and footrest testing seen on right.

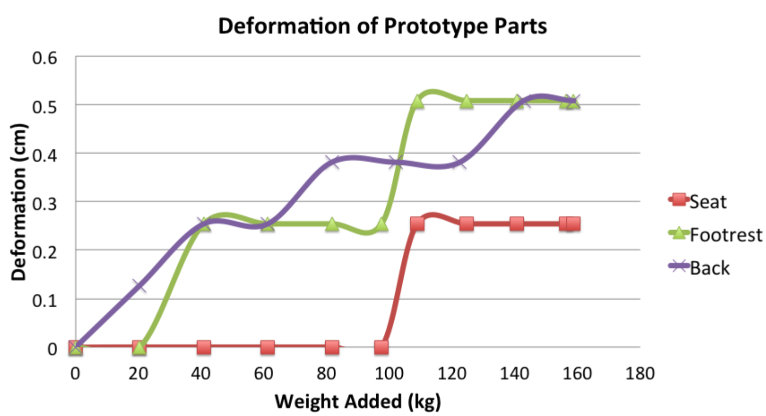


Figure 11: Deformation of parts vs. Loading Note that no part deformed more than 0.6 cm

It was also desired to test the seat, back, and footrest material to failure, but it was not feasible to break the prototype. Therefore, a piece of plywood 61cm wide and 10cm long was loaded with 225kg in 20 kg increments. It was the original intent to test the piece to failure, but the piece did not fail with this much loading. Loading was stopped at this point because of a concern about the large stack of weights piled on top of the piece, which could have fallen and injured a tester. With this amount of load, the piece deformed to 1.02 cm, and audible cracking was heard during loading, but when the load was removed, the deformation vanished and there did not appear to be any visible signs of failure. This strongly implies that the factor of safety on each of the components will be larger than 2, though more testing is needed in this area.

The legs were also tested individually in axial compression and in lateral bending. The method of testing used here for axial compression is not recommended, and was only used because it was very difficult to secure the leg while it was standing straight up. For the axial compression test, each leg was stood on end and an 11kg steel box was placed on top. A team member then placed his weight on the box by pushing his arms down on top of the box as hard as he could. It is estimated that at least 68kg of load were placed on each leg. No deformation was noted in this test, and, when the load was removed, no signs of failure were noted. This test was conducted twice for each leg. An image of this test can be seen in figure 12 below.

Figure 12: Axial compression test of prototype leg

The lateral bending test was very similar to the component tests above. The leg was placed on a steel surface with 1 cm of overlap between the wood and the steel on each side. 68kg of load were then placed in the middle of the leg, and no deformation was noted. When the load was removed, there were no signs of failure. This test was also conducted twice for each leg. This test was also adapted from a strength test for wood kitchen chairs produced by Lifetime products. The test this is based off of meets industry standards (9).

Future Work

Although the current prototype is functional and can be used for its intended purpose, it will be improved in several ways in the future. A new prototype will be fabricated out of aluminum alloys instead of wood. This will assist in making the product lighter and, thus, more portable. To further increase portability, the cushions will be re-fabricated with Velcro so they can be detached from the chair components. Additionally, a carrying case for the product and parts will be fabricated to assist the client in her transportation of all of the product components.

We also plan to make alterations to the components of the prototype in the following ways: The dimensions of the base of the seat will be changed slightly so that the footrest can fold over the seat, alleviating the need to remove the footrest to transport it. A torsional spring will be added to the footrest so that it does not need to raised and lowered manually, and a locking mechanism will be added to the backrest and footrest so that these do not resist the weight of the user when they are in a prone position. This addition of a torsional spring and lock will also be completed on the backrest, as this feature was not constructed in time for fabrication of this prototype. Finally, we will conduct more rigorous testing on the chair and components including long-term stability testing and repeated load testing.

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Appendices

Appendix A: PDS

Project Title: Portable Recliner
Team Members: Kyle Anderson, Peter Guerin, Mustafa Khan, Rebecca Stoebe
Date: 12/10/12

Problem Statement: Many individuals may require the use of a mechanical reclining chair for sleeping, but devices available are large and heavy, and therefore, not portable. The team aims to create a portable reclining chair that also features a lift mechanism to assist the user in going from a prone to a seated position, and from a seated position to a standing position. This device should be able to be carried and stored in a vehicle, and should be comfortable enough to sit or sleep in.

Function: To develop a portable reclining chair that can accommodate the specifications of our client, Mrs. Constance Fox. This device should ideally be comfortable enough to sleep in, and be able to recline and have a footrest, as well as assist in lifting the individual from a sitting to a standing position. Additionally, this device should be portable; it should ideally be collapsible and weigh no more than 40 lbs.

Client Requirements
- Collapsible; should be able to fit in the trunk of a car Cadillac (<0.42 cubic meters)
- Able to recline
- Should contain a footrest
- Able to lift the individual sitting in it to a standing position
- Able to allow individual 175 cm to sit or lay comfortably
- Able to support 1350 N/136 kg
- Is comfortable; can be slept in
- For travel use

Design Requirements

1) Physical and Operational Characteristics

a. Performance Requirements: This recliner should be able to support 1350 N of weight for up to 16 hours at a time (max foreseeable time is 16 hours). It should also be able to hold a 136 kg person who sits from a standing position. It also must be able to lift this individual from a sitting to a standing position. Finally, it must be able to support this individual in a reclining position.

b. Safety: This chair may be sat in for hours at a time and should not cause body strain (back, neck or other) during this time. Additionally, the chair should never buckle or collapse under the weight of the individual. The chair should also not pinch or otherwise harm the user. Finally, the seat should not move while the individual is being seated or raised.

c. Life in Service: This product should be able to be used for up to 24 hours at a time and should be able to be sat in and the individual lifted or seated multiple times in a day (standing to sitting or vice versa 8 times per day). Similar products have a three-year warranty on the electrical mechanisms. However, the product will only be used for traveling which only occurs 3-4 times per year over a 1-5 day span.

d. Operating Environment: For indoor and stationary use only. However, it will be used in many different locations. This will be primarily be used in hotel-room locations (18-24 degrees C, 35-50% humidity), but could be stored in potentially hot or humid environments (in the trunk of a car) for several hours. Thus, this environment could range up to 100% humidity and have a temperature range between -23 and 93 degrees C for 8-12 hours maximum). This product will primarily only be handled and used by the client and their spouse, but other individuals may also be around or be handling the product. Therefore, the product should be relatively safe for people of smaller size and the mechanisms to use it should be relatively intuitive.

e. Ergonomics: Should be able to comfortable seat a man that is 175 cm. The seat should also not cause back, neck, shoulder, or leg pain if an individual is sleeping in it when it is reclined. The seat should also be able to raise and recline without causing strain to the person who is sitting in it.

f. Size: Product should be able to fit in the trunk of a car (<0.42 cubic meters) or be checked as baggage on a plane (68x53x35 cm to not be considered oversize). Therefore, chair should be collapsible.

g. Weight: For portability reasons, product should weigh less than 18 kg. As stated previously the chair should be able to seat, recline, and raise a person who is 136 kg.

h. Materials: The materials used should be lightweight in order to keep the chair within the weight limit and should be mildly non-corrosive. Soft materials should be used for the outer portion of the chair so that it is comfortable for the user.

2) Production Characteristics

a. Quantity: 1

b. Target Product Cost: Similar non-portable lift chair range between $600 and $1600. Client budget is $200.

3) Miscellaneous

a. Client: Our client was very unsatisfied with the previous result of this design project, which she described as a “dolly with a lawn chair.” Additionally, the individual that this chair is being designed for must undergo daily dialysis treatment, involving 2 needles, which should be taken into account in the design of this product.

b. Competition: There are many non-portable lifting recliners in market and also many portable lift systems/chairs. However, there are no known portable recliners with built in lift systems currently on the market.

Lifting Recliner examples:

- **http://www.la-z-boy.com/Furniture/Lift-Chair-Recliners/**
- **http://www.usmedicalsupplies.com/Lift-Chairs.htm**
- **http://www.livingincomfort.com/indoor-store-back-pain-relief-lift-chairs.html**

Portable Lift System examples:

- **http://www.oakpointemedical.com/mangar-camel-86.html**
- **http://www.portableliftchairsllc.com/**
- **http://www.dynamic-living.com/product/upeasy-power-lifting-cushion/#clear**

Appendix B: Final Design Schematic