Adaptive Rowing Machine

Preliminary Report

BME 301

Lab Section: 305

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Abstract

Exercise is essential to maintaining a healthy lifestyle. Fitness centers offer a wide variety of workout equipment for individuals to strengthen and exercise different muscle groups within the body. However, a majority of this equipment is not constructed in a way that makes it accessible to individuals with disabilities or injuries that require a wheelchair. Thus, there is a need for more wheelchair accessible exercise equipment. One such workout machine that requires adaptation is a rowing machine. Standard rowing machines do not offer easy use to individuals in a wheelchair, and thus require external modifications to extend their functionality. In order to make the standard rowing machine more accessible for wheelchair users, a combination of the 2 Pulleys with Slit design and the Highway Ridges design will be duly fabricated and added to a standard magnetic resistance ergometer. The 2 Pulleys with Slit design will allow for the user to transition the rowing machine from traditional to adaptive use by rerouting the rope and handle to the side of the rower opposite the sliding seat. The Highway Ridges design will ensure the stability of the user during the rowing exercise and prevent tipping from occurring. After fabrication, initial testing will confirm the ability to stabilize the wheelchair and the comfort level of the user during the rowing exercise. Upon completion of initial testing, any modifications to the design will be made as necessary.

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I. Introduction

A. Problem Statement

Individuals with injuries or disabilities have trouble utilizing typical workout machines due to a lack of exercise equipment that is accessible for them. One affected group are individuals who require the use of a wheelchair. People require wheelchairs for a multitude of physical disabilities or injuries to the brain, spinal cord, or lower extremities. The majority of exercise machines are not designed for wheelchair use, and thus exercise options for wheelchair users are limited. In order to solve this issue, modifications need to be made to current manufactured machines. A standard Matrix rowing machine [1] will be adapted to accommodate individuals who require the use of a wheelchair. The Adaptive Rower will secure the wheelchair into the rowing machine, preventing the user from tipping backwards during the course of the workout. This modified design will increase the accessibility and ease of use of a rowing machine by individuals in wheelchairs, and will help to improve their overall well being through exercise.

B. Motivation

Currently, there is a lack of workout equipment that is wheelchair accessible in fitness centers. Fitness centers can often present themselves as an unfriendly environment which leads to wheelchair users feeling self conscious. Common complaints among the wheelchair community include a lack of space between equipment for wheelchair access and an overall lack of adaptive equipment at fitness centers [2]. In addition, it has been reported that there is a fear of the unknown and concern about needing or requesting assistance. Even when all of these criteria are met, this population has a need for other facilitators in order to obtain a proper workout. These requests are often regarding additional stability measures that are not present at fitness centers. Requests include obtaining velcro to improve grip, straps to secure themselves within the wheelchair, and not having to continuously leave their wheelchair to complete particular exercises [2]. These requests are not unreasonable and should be provided at every fitness center. Proper exercise leads to a healthier life, therefore, wheelchair users should not be denied this right due to a lack of equipment. To combat this, more adaptable equipment needs to be made in order to satisfy all the criteria mentioned. Specifically, there is a void for adaptable rowing machines which needs to be filled. Successfully creating a reversible ergometer that allows for full use while in a wheelchair and also having thorough stability measures will help reduce the lack of adaptive equipment available at fitness centers.

C. Existing Devices and Competition

The market for adaptive rowing machines is slim to none. As stated before, many rowing ergometers do not have disability design considerations, and exercise machines in general are not curated directly for individuals in wheelchairs. Many adaptive products are third party and will

void the warranty of the machines [3]. The two most common methods to accommodate rowing for wheelchair users are replacing the sliding seat with a fixed seat, or removing the sliding rail altogether [4].

The fixed seat method requires the user to transfer themselves from their wheelchair to the fixed seat on the rower which is often not possible without outside assistance. However, this method does allow a quick transition between the adaptive and non-adaptive forms as the seats are easily screwed on and off.

Removing the sliding rail allows the wheelchair users to operate the rowing ergometer directly from their wheelchair. This method makes the rowing machine more accessible, however, it is likely that disabled individuals will require assistance to remove the sliding rail. It is unlikely that this method would be employed at fitness facilities due to the need to maximize their space and usage of the machines.

Figure 1. AROW adaptations to Concept 2. Adaptations for the Concept 2 include a support bar extending to the users chest and a rigid attachment to the frame of the rower.

There have been developments for an adaptive rowing machine among researchers at the British Columbia Institute of Technology, who have designed the Adaptive Rowing Machine (AROW). The design and fabrication instructions are free of charge and on their website [4]. The adaptations, which can be seen in **Figure 1**, were designed specifically for the Concept 2 rowing ergometer, and the design employs the method of removing the sliding rail, so the operation of the rowing machine can be completed directly from the wheelchair. The adaptations to the Concept 2 include permanently attaching an aluminum truss onto the frame of the rowing machine and a plate at the base of the rower. The ends of the aluminum bar are enclosed in

padding to support the user's lower body, and there is an optional bar to support the upper body. The bars are screw adjustable to accommodate for different body sizes. The plate at the base of the machine extends to the front wheels of the wheelchair and under the rowing machine to prevent the translation of the ergometer during intensive activity.

II. Background

A. Client

Ms. Staci Quam is a Biomedical and Mechanical Engineer, and lead of the biomech lab at Johnson Health Tech, in Cottage Grove, WI. She is interested in transforming standard workout equipment into adaptable machines that can be accessible for individuals with different injuries or disabilities.

B. Physiological Research

Wheelchair users actively engage their upper body muscle groups and their shoulder complex during the completion of their everyday activities [5]. These activities can include the push that is needed to propel individuals forward as well as pivoting between multiple positions. The need for well developed muscles in the upper body is of utmost importance for both athletes and standard users of the wheelchair. Without it, external loads will lead to issues in the shoulder region. A common complaint from wheelchair athletes is shoulder pain [5]. It is important to note that shoulder pain in a subject could potentially be due to a lack of proper training and not implementing gradual increases in a rowing workout regimen. Other factors that affect shoulder pain include age, weight and BMI. In addition, increased intensity, frequency, and duration of a load will lead to shoulder pain [5]. However, proper increases in resistance and form will lead to reduced pain in the area [5].

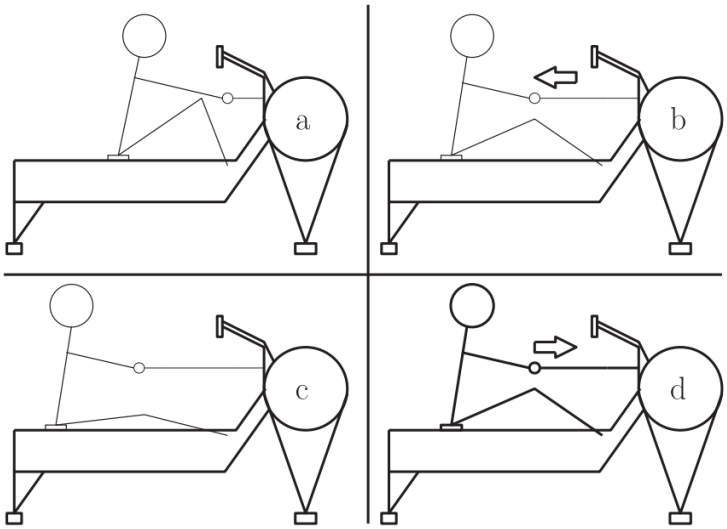


Figure 2. Visual Representation of the 4 Phases of Rowing. The figure labeled *a* corresponds to the Catch Phase, *b* is the Drive Phase, which is followed by the Finish Phase in *c*, and finally the Recovery in *d*.

For the common wheelchair user, small factors like improper posture while driving a wheelchair can lead to pain [5]. This further proves the importance of exercising. The rowing motion allows an individual to actively work many of the essential muscle groups needed to refine upper body strength. These muscles include the triceps, biceps, abdominals, back muscles, and lower back muscles [6]. This is completed through the 4 phases of rowing as shown in **Figure 2**.

The first phase is the catch, and it primarily activates the triceps and the flexor muscles in the fingers. During this phase, the abdominal muscles are engaged and allow the user to flex the torso in a forward motion. The following phase is called the drive. In standard rowing, this phase includes the contraction of the hamstrings while the user propels themselves backwards. However, for an adapted user, it will activate the biceps as they pull the handle towards their abdomen. The back muscles will also contract as the torso swings to open. The drive's movement is completed by the finish phase. This is the final pull where the abs and lower back stabilize the body and the biceps engage to help keep the torso in place. The full rowing motion is completed during the recovery phase. This phase occurs when the individual returns back to the catch phase. The triceps engage to push the arms away from the body while the abs flex the torso forward. The four phases, all together, allow for a complete workout that will act to strengthen the shoulder complex and upper body muscles [6].

C. Design Specifications

The client has provided the team with a $200 research and development budget to create adaptations that will allow wheelchair individuals to use the Matrix Rower with minimal outside assistance. Adaptations will first and foremost provide safety and stability to users, allow users to operate the rowing machine from their wheelchair, maintain the majority of aspects from the four phases of rowing and stimulate the same muscle groups, and lastly allow a seamless transition between non-adaptive and adaptive use. Adaptations will be able to withstand at least ten years of usage which amounts to eight million meters, as well as withstand stresses from tension up to 1050 N [7]. These benchmarks fall in line with the typical durability of a rower [8]. Additionally, the adaptations must be viable for fitness centers where space is often limited, therefore any adaptations designed will be removable and extend no more than four feet from the rower frame. Further specifications can be found in **Appendix A**.

III. Preliminary Designs

A. Pulley Design 1: 2 Pulleys with Slit

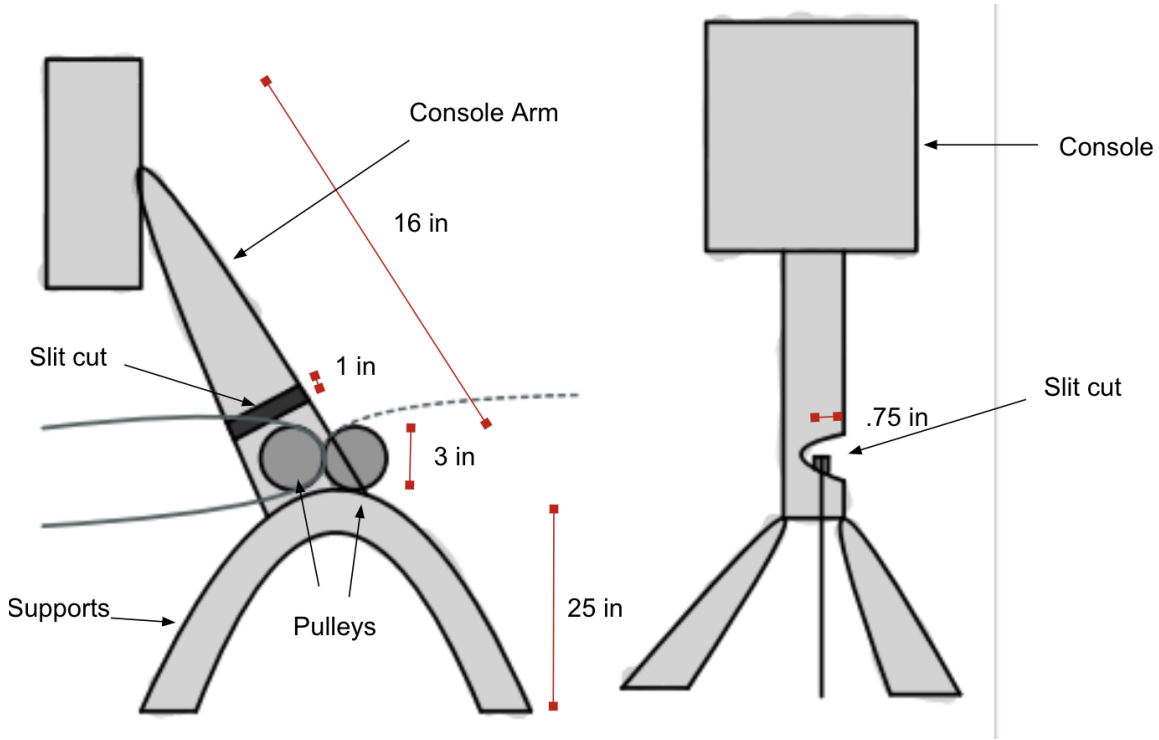


Figure 3. Visual Representation of 2 Pulleys with Slit Design. The 2 Pulleys with Slit design consists of two pulleys that are at the same height. The rope can be transferred from one pulley to the other to switch from traditional to adaptive rowing. A slit cut will be made in the console arm to allow for this to happen.

The 2 Pulleys with Slit design (**Figure 3)** includes using two pulleys that are located at the same height on the rowing machine. The purpose of adding the second pulley is to allow for the rope and handle to be repositioned on the adaptive side of the rower, opposite to the sliding seat bar. This is where the wheelchair user will be located during use of the adaptive rower. This design concept uses the original rope and handle of the traditional rower. However, the 2 Pulleys with Slit requires a cut to be made on the console arm in order to allow for the rope and handle to be transitioned from the traditional to the adaptive side of the machine.

B. Pulley Design 2: 2 Pulleys with 2 Ropes

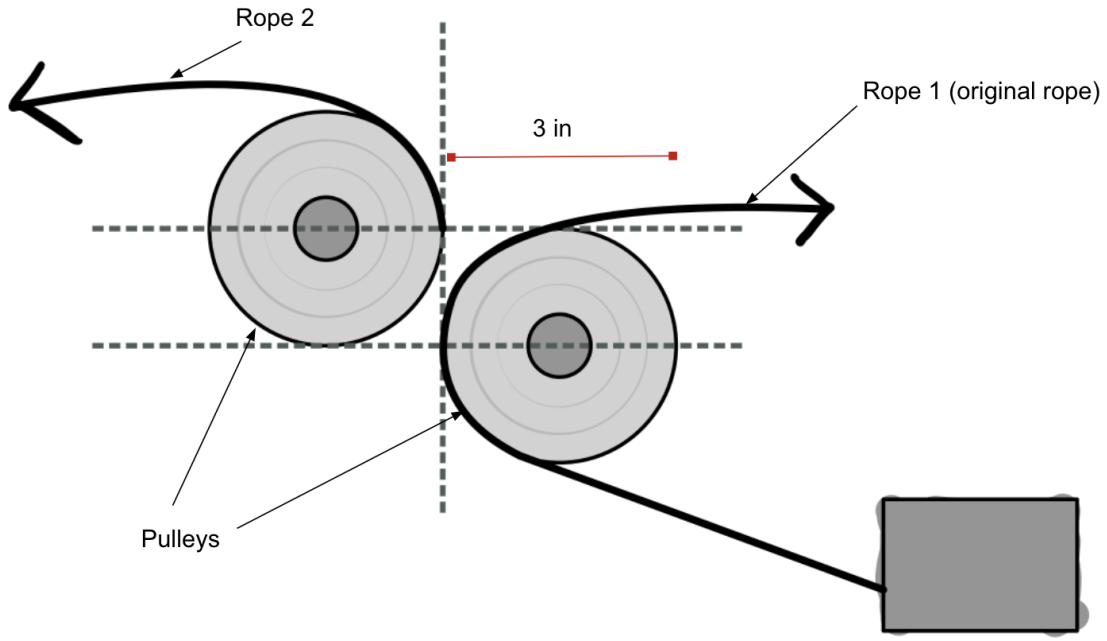


Figure 4. Visual Representation of 2 Pulleys with 2 Ropes. The 2 Pulleys with 2 Ropes design involves adding an additional pulley, handle, and rope to the existing rowing machine. The transitioning of the handle and rope from the traditional side to the adaptive side would not be required since there would be a rope permanently positioned on both sides of the rowing machine.

The second pulley concept is called the 2 Pulleys with 2 Ropes design (**Figure 4)**. This design also involves adding an additional pulley to the rowing machine. However, the 2 Pulleys with 2 Ropes design differs from the 2 Pulleys with Slit concept because this design adds an additional rope and handle to the rowing machine so that one rope and handle can be located at both the traditional and adaptive sides permanently. This eliminates having to transition the rope and handle from one side to the other while switching from traditional to adaptive use. A downside to the 2 Pulleys with 2 Ropes design is that it would require adding an additional coiling mechanism to the flywheel for the second rope. The internal workings of the rowing

machine and flywheel are quite complex, so adding this coiling mechanism would add another degree of difficulty to the project.

C. Stability Design 1: Highway Ridges

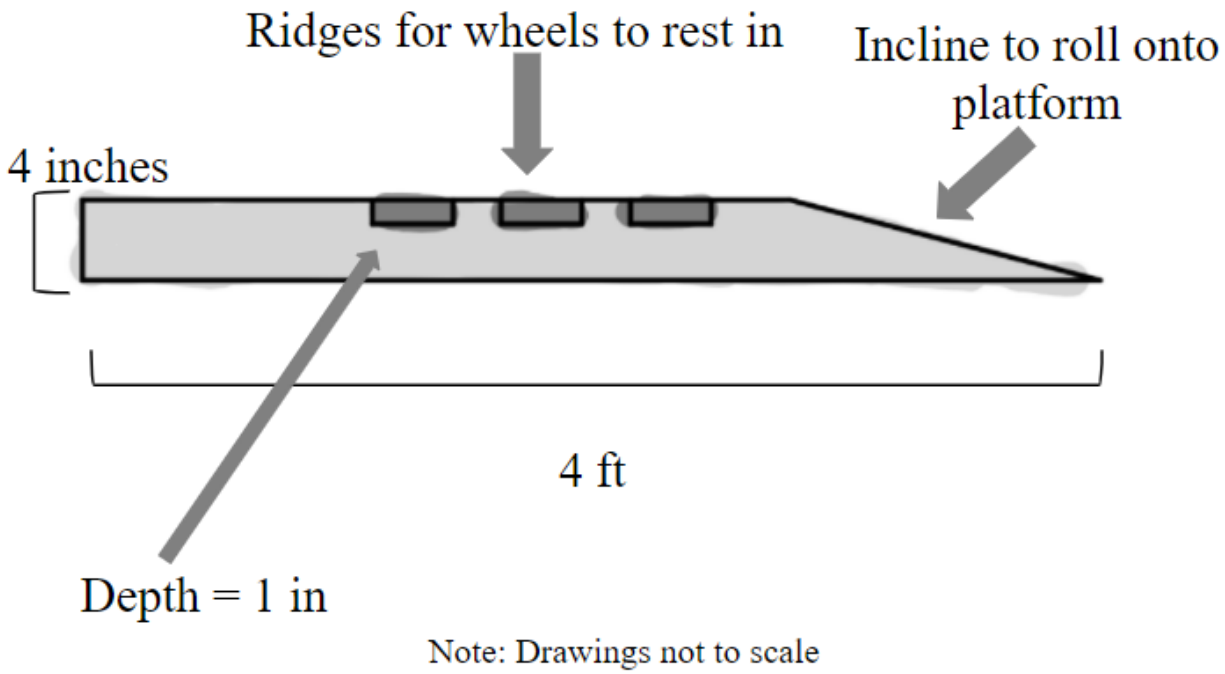


Figure 5. Visual Representation of the Highway Ridges Design. The platform has an incline down to the floor so that the user can roll up and into place on top of the platform. The base will have ridges cut into it for the wheels to rest in during the action of rowing to stabilize the wheelchair.

The Highway Ridges design (**Figure 5**) incorporates a platform that rests flat on the ground with an incline down to the floor. This incline allows the user to roll up onto the flat portion of the platform. On this flat portion, there will be 3-4 ridges cut into the face of the platform that act as resting places for the wheels of the wheelchair to rest in during the action of rowing. Thus, as the user pulls the handlebar toward their chest during the rowing motion, they will not roll backwards because the wheels are resting within the ridges. One downside of this design is that with an excessive amount of force applied to the handlebar, the user may provide enough force to actually roll up and out of the ridges, which would lead to backwards translation / rotation.

D. Stability Design 2:Traction Blocks

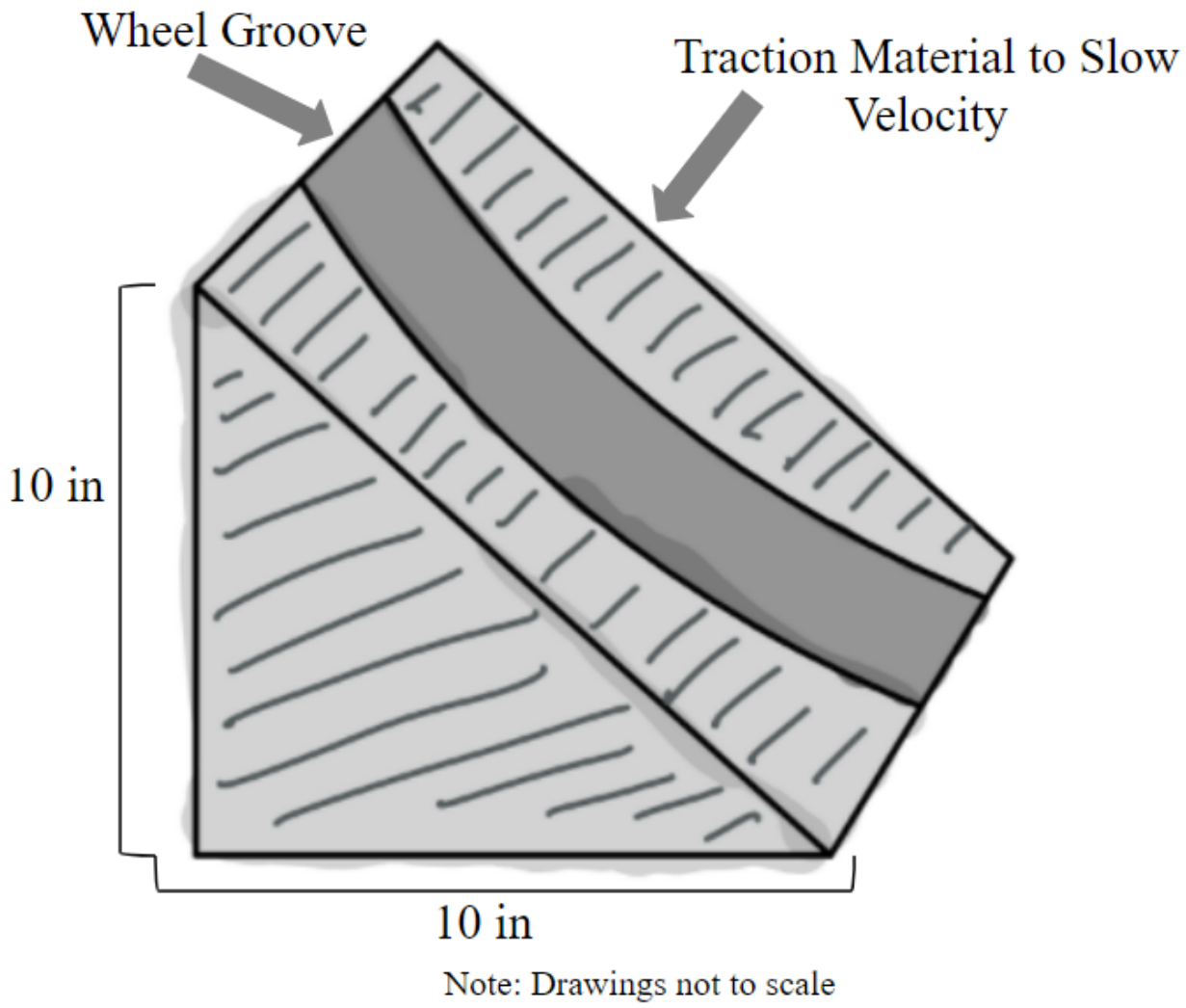


Figure 6. Visual Representation of the Traction Blocks Design. The block has a semicircle groove down the middle which allows for the user to experience slight recoil during the action of rowing. The user will roll up and into the block, which is covered in a traction-like material to reduce velocity, to prevent forward / backward tipping.

The Traction Blocks design (**Figure 6**) includes two triangular prism shaped blocks that are placed in front of the wheels, and two that are placed behind the wheels. Each block has a semicircle groove cut down the middle which is wider than the wheelchair wheel width, to accommodate different sized wheels. As the user rolls slightly forward or backward, they would roll into the groove and the force of gravity, along with the reaction force provided by the block, would reduce their velocity and prevent forward or backward tipping. The surfaces of the block would also be covered in a traction-like material to further reduce the user's

velocity. One downside to this design is that it would require external assistance to place the blocks in front of and behind the wheels once the user has rolled into place on the adaptive side of the rowing machine.

E. Stability Design 3: Combined Design

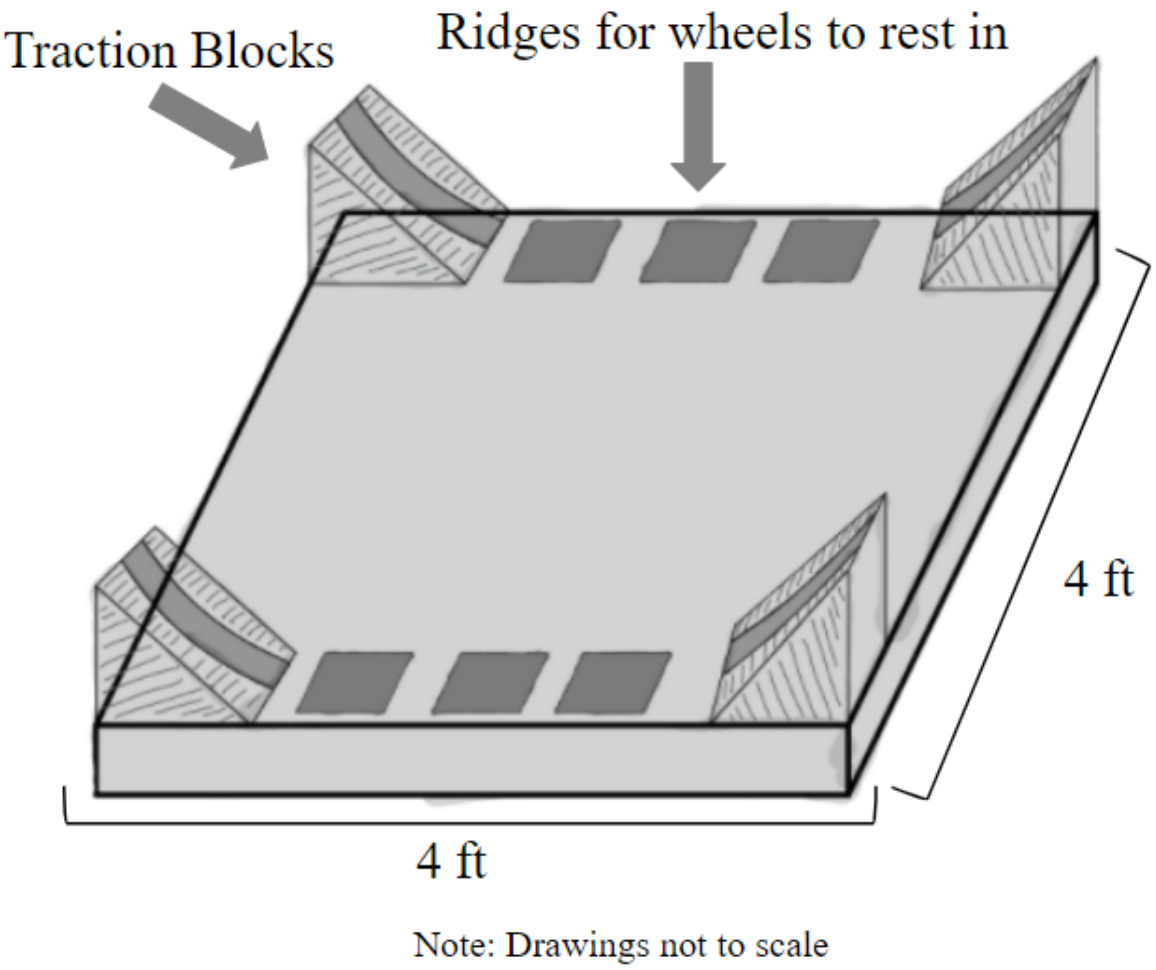


Figure 7. Visual Representation of the Combined Design. The inclined platform with ridges is combined with 4 traction blocks to prevent translation / rotation of the wheelchair during the action of rowing.

The Combined Design (**Figure 7**) is a combination of the Highway Ridges and Traction Blocks designs. Thus, this design utilizes an inclined platform with ridges for the wheels of the wheelchair to rest in, and includes four traction blocks that would allow for recoil motion and reduce the users velocity if they were to roll out of the ridges on the platform. This design provides the most stabilization to the wheelchair, but requires the most complex fabrication process.

F. Common Design: Armrest Hooks

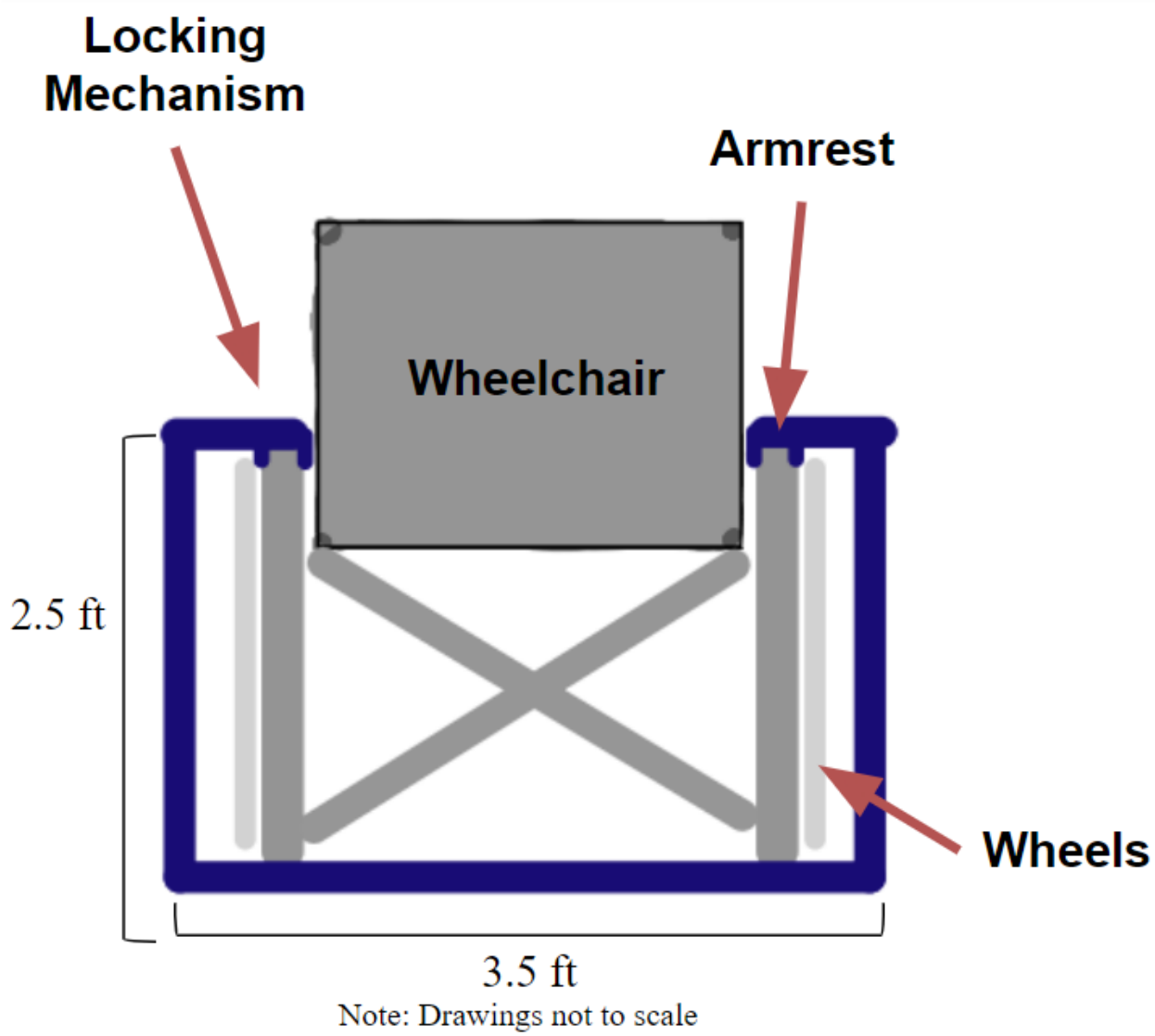


Figure 8. Visual Representation of the Armrest Hooks Design. The base platform will have two sideboards connected via a hinge that can swing up to be parallel with the wheels. Extendable hooks will reach out and grasp the armrests of the wheelchair to prevent side-to-side rotation during the action of rowing.

The Armrest Hooks design (**Figure 8**) will be utilized across all designs, and thus was not considered in any design matrix. The above stability designs focus solely on preventing forward or backward rotation of the wheelchair during use. However, the Armrest Hooks design prevents both forward / backward and lateral rotation of the wheelchair. This design incorporates side plates that are connected to the base platform that the wheelchair rests on via

a hinge. When erect, the side plates will be parallel with the wheels of the wheelchair. Extendable arms with hooks will come off the top of each side plate and grasp the armests of the wheelchair. This will essentially secure the wheelchair from tipping over side-ways, as the arms will make a rigid connection between the thin wheels of the wheelchair and the flat base plate it rests on.

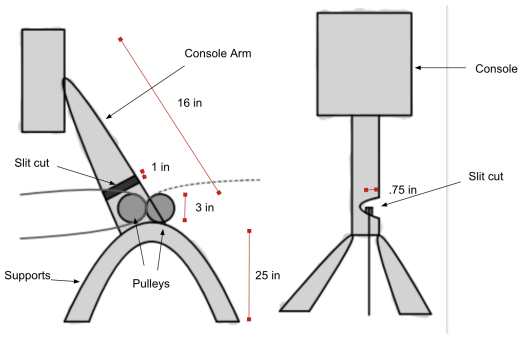
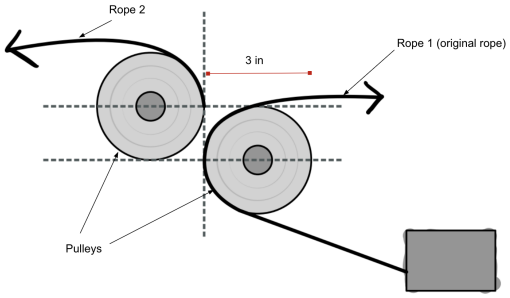
IV. Preliminary Design Evaluation

A. Pulley and Stability Design Matrices Criteria

In order to adequately compare the designs against one another, several criteria were chosen that captured the most important aspects of the Product Design Specifications. The designs were then scored in each category, and their scores totaled to choose a preliminary design. The most important criteria is user stability / safety. For pulley designs, this refers to the safety of the user while changing the direction of the rope / handle to the other pulley, and the stability of the rope in the new pulley during use. For designs stabilizing the wheelchair, this refers to the ability to secure the user so that they do not tip over during the course of the repetitive rowing motion. Additionally, no parts of the design should cause harm to the user during use of the rowing machine. Another equally important criteria is the ease of fabrication. Designs that do not involve drastic disassembly of the current rowing machine will score higher in this category. Designs were also scored based on their ease of use and ergonomics. The overall device should be easily accessible for individuals in a wheelchair, and not require extensive outside assistance to use the rowing machine properly. Pulley designs were scored in versatility of the pulley mechanisms as well. The incorporated pulley mechanism should minimize the complexity to convert the standard rowing machine into an adaptive state. Each design's potential materials were scored using the durability criteria, which takes into account the potential wear and tear of the device. The materials used should not affect the overall functionality of the device. Finally, each design's estimated cost of the materials needed was considered; components should not be unreasonably priced and cheaper components are preferable.

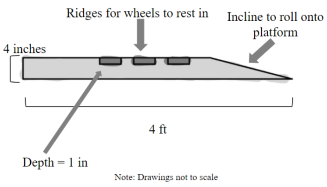
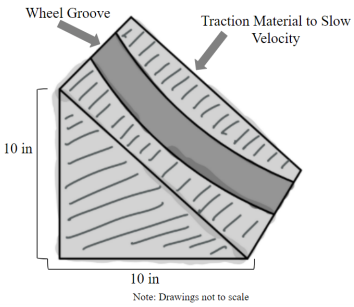
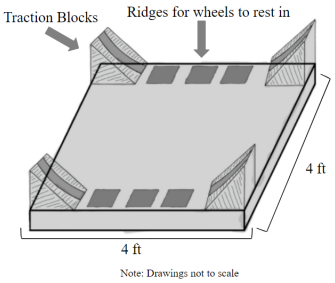
B. Pulley Design Matrix

Table 1. Design Matrix for Pulley Designs. The two design ideas were compared against each other to determine which pulley design to proceed forward with.

Design	2 Pulleys with Slit		2 Pulleys with 2 Ropes	
				
User Stability / Safety (25%)	4/5	20	5/5	25
Ease of Fabrication (25%)	4/5	20	2/5	10
Ease of Use / Ergonomics (20%)	4/5	16	5/5	20
Versatility (10%)	5/5	10	5/5	10
Durability (10%)	5/5	10	5/5	10
Cost (10%)	5/5	10	3/5	6
Total for each design:	**86**		**81**	

C. Stability Design Matrix

Table 2. Design Matrix for Wheelchair Stabilization. The three design ideas were compared against each other to determine a winning stabilization design that the team would proceed forward with.

Design	Highway Ridges 		Traction Blocks 		Combined Design 	
User Stability / Safety (25%)	4/5	20	4/5	20	5/5	25
Ease of Fabrication (25%)	5/5	25	4/5	20	3/5	15
Ease of Use / Ergonomics (20%)	5/5	20	3/5	12	3/5	12
Durability (15%)	5/5	15	4/5	12	4/5	12
Cost (15%)	5/5	15	4/5	12	3/5	9
Total for each design:	**95**		**76**		**73**	

D. Pulleys: Design Matrix Discussion and Proposed Final Design

The two pulley designs were compared to each other using the design criteria, as can be seen in **Table 1**. Although both pulley designs ended up scoring very similarly, the 2 Pulleys with Slit concept was determined to be the best option to move forward with. This design requires the addition of a second pulley to the rowing machine to allow for the rope and handle to be used from the adaptive side of the rower. In order to allow the rope to pass from one side to the other, a slit cut will be made along the console arm to allow for this transition.

Both pulley designs ended up scoring highly in terms of user stability / safety. However, the 2 Pulleys with Slit design scored a 4/5 instead of a 5/5 due to the fact that it would be slightly less safe for a person in a wheelchair to transition the handle and rope from the traditional side to the adaptive side as opposed to there being a rope and handle on each side with the 2 Pulleys with 2 Ropes design. The ease of fabrication design criteria was the differentiator for both pulley designs. The 2 Pulleys with Slit design scored a 4/5 on this criteria since fabrication would only require adding an additional pulley to the rower and cutting a slit in the console arm. The 2 Pulleys with 2 Ropes design scored a 2/5 for ease of fabrication due to the difficulty that would be involved with adding an additional coiling mechanism within the rower for the second rope.

For ease of use / ergonomics, the 2 Pulleys with Slit design scored a 4/5 due to the minimal external assistance required to move the handle and rope from one side to the other. The 2 Pulleys with 2 Ropes design scored a 5/5 here due to there being a rope on each side of the rower. Therefore, no outside assistance is required for aligning the handle and rope on the adaptive side. In terms of versatility, both designs scored a 5/5 since they both allow for the transitioning of the machine from traditional to adaptive use and vice versa. Both designs also earned 5/5 scores for durability since the pulleys / rope / handle used for each design will be sourced directly from JHT, and therefore be as durable as the existing rowing machine materials. Lastly, in terms of cost, the 2 Pulleys with Slit design scored a 5/5 since this design would only require purchasing materials to secure the second pulley to the rowing machine. The 2 Pulleys with 2 Ropes design would require the same cost to secure the pulley, but would also require additional materials to create a second coiling mechanism for the second rope. Since these additional materials would create additional purchasing costs, the 2 Pulleys and 2 Ropes design scored lower with a 3/5 for the cost criteria. Overall, the 2 Pulleys with Slit design most closely adhered to the design criteria outlined in the design matrix and scored the highest at 86/100. Thus, it is the best option for solving the problem outlined by the client.

E. Stability: Design Matrix Discussion and Proposed Final Design

After comparing the three stability designs against each other (**Table 2**), the Highway Ridges design proved to be the design that will most closely accomplish the project goals

outlined in the PDS. This design utilizes a platform with built in ridges that the wheels of the wheelchair rest in during the action of rowing. The wheels sit in these ridges so that the wheelchair does not translate or rotate backward during rowing. However, this design is not capable of preventing all backwards rotation, and thus received a 4/5 in the user stability / safety category. The Traction Blocks design received a 4/5 for user stability / safety because it is capable of preventing backwards rotation, but if the user applies an excessive amount of force, the wheelchair could still tip over. The Combined Design received a 5/5 due to containing both mechanisms from the Highway Ridges and Traction Blocks designs, which gives it the best ability to prevent backwards tipping or rotation.

The three designs were then scored according to their ease of fabrication. The Highway Ridges design received a 5/5 because it only involves minimal external changes to the platform for cutting the ridges out and inserting an incline down to the floor. The Traction Blocks design received a 4/5 due to the challenges presented by covering the entire block in a traction material and cutting out semicircular grooves in each of the traction blocks. The Combined Design received the lowest score of a 3/5 because it involves the most complex fabrication process, since it would require the fabrication of both the Highway Ridges and Traction Blocks design at once. With regard to ease of use / ergonomics, the Highway Ridges design received a 5/5 because this design only requires the user to roll up the incline onto the platform and rest in one of the built in ridges. Since no external assistance is required to use this design, it received the highest score. Contrastingly, the Traction Blocks and Combined Design both require external assistance to insert the blocks behind the wheels of the wheelchair. Since the client would like for minimal outside assistance to be required, these two designs both received a 3/5.

In terms of durability, the Highway Ridges design received the highest score of 5/5. This design only involves the wheelchair resting in the built in ridges of the platform. This platform will likely be made out of metal, and thus will be a strong and durable material that will not wear down quickly during successive uses. The Traction Blocks design and Combined Design each received a 4/5 due to the possibility of the traction material wearing down over time. If this material degrades, it will be less effective at reducing the users velocity to prevent rotation, which then reduces the users safety. Thus, these designs received a lower score. Finally, the three designs were compared against the cost to fabricate. The Highway Ridges design received a 5/5 due to the reasonable cost to purchase a platform and build in the ridges. The Traction Blocks design received 4/5 due to the higher cost of buying a sufficient traction material and rigidly attaching it to the blocks. The Combined Design received the lowest score of a 3/5 due to summing the costs of fabricating both the Highway Ridges and Traction Blocks designs. Overall, the Highway Ridges design most closely follows the design criteria outlined in the design matrix and scored the highest at 95/100. Thus, it is the best option for solving the problem outlined by the client.

V. Fabrication and Development Process

A. Materials

The main material goal is to create a conformable rower that can alternate between the standard and adapted format with minimal changes to the original machine. The client has been contacted to inquire about pulleys and other leftover materials that could be used in the 2 Pulleys with Slit design. A rubber material will be used in unison with a metal frame and supports to construct the Highway Ridges design. If extra additions to the rower are needed to further increase user safety and stability, materials to fabricate those components will be sourced and ordered.

B. Methods

The pulley system will be constructed using screws bolted to the supports of the console arm on the rower. Once the CAD files of the 2 Pulleys with Slit and Highway Ridges designs are complete, the team will be able to begin fabrication with confidence that the holes and cuts made to the frame will be placed correctly. This will require the use of electric tools to drill the holes and cut the slit in the frame. The Highway Ridges stability system will be constructed by milling out ridges from a large sheet of metal while additionally carving out the incline.

C. Testing

A wheelchair will be acquired to test the durability and functionality of the adapted rower. Each team member will row on the adapted model and standard model for five minutes on each mode. All members will record their experience with each mode of the machine individually and then rate their experience based on a list of criteria, including safety, comfort level, ease of use, etc. Ideally, the machine will be tested by a wheelchair user to ensure that no important considerations were missed, and to ensure that the user feels comfortable and safe while rowing. These additional possible testing scenarios will be pursued more fully in the future if the timeline of the semester permits it. Additionally, tensile tests will be conducted on the amount of force required to row from the adaptive and standard side to ensure it is a comparable experience while rowing from either end of the machine.

VI. Results

There are no results for the pulley or stability designs at this time.

VII. Discussion

Fabrication of the adaptations to the rowing ergometer are currently in progress, so no testing has been conducted. One ethical consideration to be made once testing is underway will

be how to ensure the safety of the test subject. Other considerations include determining how to quantify ease of use and effectiveness of the adaptations for disabled individuals. During testing, it will be important to consider that the severity of disability varies between all individuals and the adaptive rowing tests should reflect as such. If during testing, it is observed that the Highway Ridges design is not providing enough stability to the user while rowing, additional support systems / mechanisms will be discussed and then added to the platform. Additionally, if any of the materials used to fabricate the adaptive rower fail during testing, they will be replaced with more durable materials.

VIII. Conclusion

Currently, there is a lack of modified workout equipment that is accessible for individuals in wheelchairs. In order to increase the accessibility for wheelchair users to gym equipment, adaptations to equipment currently available are necessary. One such machine that is in need of adaptation is the standard rowing machine. As requested by the client, a standard rowing machine will be converted into a transformable rowing machine, capable of accommodating normal and adaptive rowing. This device will enhance the experience of exercising for wheelchair users, and provide a means to actively engage their upper body and core muscles via rowing which will improve their exercising experience. The preliminary design includes using both the 2 Pulleys with Slit design and the Highway Ridges design. The 2 Pulleys with Slit concept allows for the transitioning of the rope and handle from traditional to adaptive use. For stability, the Highway Ridges design incorporates a base plate with a series of ridges for the wheelchair wheels to rest on. The development of such an adaptable rowing machine will create the possibility to extend this design concept to adapting other common pieces of workout equipment to become more accessible to individuals with injuries or disabilities.

IX. Future Work

To further ensure the safety and stability of users, additional stability mechanisms will be discussed and developed. This could include a harness, similar to ones seen on roller coasters, to make sure users who have limited mobility in their core will be secured in their wheelchairs. For the current preliminary design, the orientation of the user while rowing from the adaptive side of the machine prevents them from easy interaction with the resistance dial. This issue will be resolved by designing an arm mechanism that will turn the dial as a result of moving a lever from the adaptive side. Lastly, modifications to the console arm will need to be made to allow the console to be viewed in an upright orientation on the adaptive side. This would include developing a gimbal rotation point that the display console can be rotated about.

The existing preliminary designs must be converted into CAD files in order to determine the quantity of materials necessary for fabrication. From here, materials for the fabrication of the

adapted rower will be sourced. Once assembly is complete, tests will be conducted with a wheelchair as stipulated in the testing section. Once these initial tests are completed, necessary adjustments will be identified and any external parties interested in using the adapted rower will be contacted to be involved in the testing process.

X. References

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XI. Appendix

Appendix A: PDS

Johnson Healthtech: Adaptive Indoor Rower for Wheelchair Users

Product Design Specifications
March 2nd, 2022

Client: Mrs. Staci Quam (staci.quam@johnsonfit.com)
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Function:

Individuals with injuries or disabilities have trouble utilizing typical workout machines due to a lack of exercise equipment that is accessible to them. One of these affected groups are individuals who require the use of a wheelchair. People require wheelchairs for a multitude of physical disabilities or injuries to the brain, spinal cord, or lower extremities. The majority of exercise machines are not designed for wheelchair use, and thus exercise options for wheelchair users are limited. In order to solve this issue, modifications need to be made to current manufactured machines. A standard Matrix rowing machine will be adapted to accommodate individuals who require the use of a wheelchair [1]. The Adaptive Rower will secure the wheelchair into the rowing machine, preventing the user from tipping backwards during the course of the workout. This modified design will increase the accessibility and ease of use of a rowing machine by individuals in wheelchairs, and will help to improve their overall well being through exercise.

Client Requirements:

- A magnetic rowing machine will be built to better understand how the overall assembly fits together. This will aid in the design of optimized adaptations to the current assembly process.
- The adapted rowing machine should allow individuals in wheelchairs to easily fit into the machine and use it properly. Ideally, the machine should be able to be adjusted to allow for usage from non-wheelchair individuals.

- Individuals in wheelchairs, if possible, will be able to insert themselves into the machine without assistance.
- The rowing machine will be user friendly, and not add complexity to perform proper rowing technique.
- The rowing machine will be used several times in a day, and components will not degrade over a short period of time.
- The rowing machine will have a mechanism to reduce excessive recoil force to prevent users from tipping backwards in the wheelchair.
- The user will remain in their wheelchair for the duration of the exercise.

Design Requirements:

1. **Physical and Operational Characteristics**
    a. *Performance Requirements:*
        i. The modified rower will enable people in wheelchairs to use the machine. The device will be able to easily attach / detach the wheelchair to / from the rowing machine. The attachment to the rowing machine should keep the wheelchair from tipping over backwards.
        ii. The modifications made, to allow for attachment of the wheelchair, should remain intact and not break with repeated use of the rowing machine.
            1. The modifications used for the attachment should be able to resist and endure stresses caused by a pulling force up to 1050 N [2].
            2. The modifications made to the machine should be able to endure the fatigue due to the repetitive rowing cycle.
        iii. The device will be used daily.
    b. *Safety:*
        i. The modifications made to the rowing machine, to allow for attachment of a wheelchair, will not pose any biological hazards to the user.
        ii. Any modifications made to the rower will be filed and made smooth in order to prevent sharp points that could harm the user. Additionally, all modifications will be reviewed to make sure that no pinching / excess pressure is felt by the user during exercise.
        iii. The modifications made to the rower will ensure that the user is securely stabilized to the rower and will not be ejected from their wheelchair or from the machine during normal use of the rower.
    c. *Accuracy and Reliability:*
        i. The adapted rowing machine should accurately simulate the feeling of a normal rowing machine. Thus, the loading and recoil motions should

accommodate pulling the handle bars back to approximately one arms length and should be smooth and absent of excessive friction.

ii. In order to prevent backwards tipping, a mechanism should be included that provides forward force to counteract backwards accelerations. The force output by this mechanism should not cause forward tipping. The force output necessary to prevent tipping should be repeatable given a certain force input from the rower.

iii. Once the adapted fixtures are designed, proper tolerances will be assigned to each of the components to ensure proper assembly and functionality of the adapted rowing machine.

d. Life in Service:

i. The modifications and attachments added to the rowing machine should last for the same duration the rowing machine typically lasts. The lifetime of a rowing machine is categorized a few different ways. The modifications made should last:
    1. At least 10 years [3]
    2. At least 8 million meters [3]

ii. The product will be able to be used for at least 10 years and withstand normal wear and tear from the user.
    1. Weight placed onto the product from the user
    2. Friction applied by the user

iii. All modifications will provide the user with a stable and safe rowing experience for the 10 year period.
    1. This includes preventing the user from tipping over while using the machine
    2. A safe locking system that ensures the wheelchair does not move during use
    3. Support around the users body to ensure security

e. *Shelf Life:*

i. The product will be stored in an environment that minimizes external loads placed onto the rower. This includes when it is being manufactured overseas, while shipping, and during storage in various facilities. Maximum external loads applied will be limited to 158.76 kg [1].

ii. The temperature range for the manufacturing, shipping, and storage process should be maintained within -20°- 45°C (-4°-104°F).

iii. When stored at a facility, the product will remain functional for a minimum of 30 years.

f. Operating Environment:

i. Ideal temperature range for the machine is 5°-35°C (41°-95°F). Temperatures exceeding 95°F/35°C might lead to the device warming up, causing discomfort for the user.
ii. No large water sources should be used near this device. The LCD display relies on a power generator and water could destroy internal components of the rower.
iii. The device will allow a wheelchair user to attach the chair to the device.
    1. All forces applied by the wheelchair onto the rower will not hinder the machine's ability to perform at its optimal level.
    2. Forces will be minimized by the use of harnesses and supports.

g. *Ergonomics:*
i. The user will attach the wheelchair to the adaptive rower. This action will utilize only hands and arms and will be possible in an upright sitting position.
ii. A locking system will ensure the user will not move during use. A harness, support, and latch mechanism will be used.
iii. External addition to the rower will not inhibit comfort to the user. Stability measures will enhance experience for wheelchair users.
iv. After the user is secured into the machine, only the hands and arms will be used to complete the rowing motion. In addition, the user will be in an upright position.
v. The user will grip the handlebars to complete rowing movements. The wheelchair and the adaptive rower machine will remain stationary during the arm movements.
vi. No leg movements will be required during the use of the machine.
vii. Additions will extend from the device by a maximum amount of 1.6067 m (3.5 feet). This will be measured by taking the distance perpendicular from the points of addition. The current dimension of the device is 223 cm x 55 cm x 97 cm [1].

h. Weight
i. The current weight of the design is 158.76 kg/350 lbs [1].
ii. A maximum of 7 kg of mass will be added to the existing rower.

i. Materials:
i. The adaptations will be fabricated out clean, polished, or painted metal for support and durability.
ii. Hard plastics for strength and affordability
iii. Rubber for traction.

j. Aesthetics, Appearance, and Finish:
i. Adaptations made to the machine will have a smooth finish to prevent abrasions or lacerations to the user.

ii. If time permits, adaptations will be painted black to match the rower.

2. Production Characteristics

a. Quantity:

i. One rowing machine will be constructed and modified to accommodate the inclusion of a wheelchair during use.

b. Target Product Cost:

i. A budget of $200 will be used for development of the fixture to the rowing machine structure.

3. Miscellaneous

a. Standards and Specifications:

i. The International Organization for Standardization (ISO) entry 20957-7:2005 stipulates the safety requirements for rowing machines, specifically rowing machines within classes S and H and class A for accuracy. Entry 20957-1 describes the general safety requirements for stationary workout equipment. Entry 20957-1 covers the safety requirements for any additionally provided accessories to be used in conjunction with the rowing machine [4].

ii. This product does not require FDA approval as it does not fall under any of the FDA regulated products such as pharmaceuticals, medical devices, medical biologics, food, products that contain tobacco, supplements, cosmetics or electronic products that emit radiation [5].

b. Customer:

i. The adapted rowing machine should be functional for individuals in wheelchairs, but ideally should be able to function as a standard rowing machine as well.

ii. The client prefers to have the rowing machine fully built into one assembly rather than broken up into several components that need to be attached each time the rowing machine is used.

c. Patient Related Concerns:

i. The rowing machine will need to be sterilized between uses to remove debris and sweat from previous users.

ii. The added adaptations to the rowing machine should be able to accommodate a range of wheel thicknesses and wheelchair widths up to 3 inches wide.

iii. The added adaptations to the rowing machine should not cause overuse injury to other parts of the users body, such as hands and arms.

1. The user should be thoroughly taught how to properly use the machine to reduce risk of misuse or injury.

iv. If the use of patient data is deemed necessary to construct specific adaptations to the rowing machine, it should be kept secure and confidential.

d. Competition:

i. There are currently a plethora of adapted rowing options for wheelchair users available on the market. One of these options is an adapted rowing machine seat that is easily switched with a standard seat and is more accessible to get in and out of for paralyzed users [6].

ii. Adapted rowing machines such as the AROW (Adapted Rowing Machine) by BCIT REDLab [7] utilize an adapter and a stabilizer to isolate the rowing motion to the upper body of the user while keeping their chair in place .

1. These adaptations were designed specifically for the Concept 2 rowing machine.

iii. There are also existing patents for adapted rowing machines, including patents specific to wheelchair users. One such patent describes a machine that includes a unit for fixing the upper half of a user's body to the machine, straps to keep the user's legs stabilized, and a pulley system to create the rowing motion for the upper body [8]. Many of these patents appear to require an additional person to assist the user onto the machine or the user to move themself from their chair to the machine - both scenarios that have been deemed undesirable for this project by the client.

iv. There appears to be a gap in the market for a rower that can be converted between an adapted and standard model. This interconvertibility is something that the client expressed interest in and could be a unique deliverable for this project.

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Appendix B: Estimated Costs

Item	Description	Quantity	Cost					
Component 1								
Pulley	Leftover pulley from JHT can be used to fabricate pulley design.	1	Free					
Component 2								
Component 3								
TOTAL:								**$0.00**