Final Design Report

Gait Trainer With Treadmill

BME 200/300
University of Wisconsin-Madison
Department of Biomedical Engineering
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Abstract

Gait trainers are assistive walking devices that help to improve the mobility of many individuals[1]. Creating a system system that can securely attach and detach a gait trainer to a treadmill would increase the physical and mental health of many users during the winter months[2]. Our client suffers from a neurological disorder, resulting in them being severely prone to seizures and has extreme mobility impairment. Our client relies on the gait trainer to provide support and weight-bearing assistance while walking outdoors, but is unable to utilize the gait trainer during the winters due to the bulky nature of a gait trainer and the restricted space inside their home. By attaching a gait trainer to a treadmill, it would allow for our client to continue to get their physical exercise and mobility strengthened all year round. Multiple designs exist but do not provide the detachable aspect or stability access that the client wishes for. To resolve this, our solution consists of a ramp attached at the end of the treadmill, and two tracks attached on each side of the treadmill that can be clamped onto the treadmill, allowing the gait trainer to easily slide up and be stabilized in the tracks system. Through the use of durability and strength tests, the materials used were assessed, ensuring the comfortability, success, and safety of the system.

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Introduction

Gait trainers are designed to help maintain proper posture and gait patterns, as well as improve balance, coordination, and motor skills, and are quite frequently used by individuals who have suffered injury which affect these skills [1]. Gait trainers are relatively large devices, resembling that of a walker, and are an impractical aid to be used indoors. This results in individuals only being able to utilize their gait trainer outside, which leads to inconsistent usage as it can only be used whenever weather permits. Especially during the winters, it is difficult to utilize the gait trainer outside. This inconsistent use of the gait trainer due to the lack of opportunity can result in users suffering significant damage to physical and mental health, as a lack of physical exercise can lead to such issues. Research has shown that there is a positive correlation between the amount of exercise one gets and the happiness one feels[2]. Additionally, any progress already made in terms of rehabilitation and mobility strengthening could be reversed with inconsistent use. If one were able to use a gait trainer on a treadmill, during the imperfect weather conditions, it would improve the overall health of the client. The solution could lead to greater progress in rehabilitation as well as improving the mental health of the individual.

All current systems of a gait trainer attached to a treadmill have support beams and a harness hanging from a pole attached to the front of the treadmill. These designs were created with the intent of being a permanent system. These systems are either a body-weight system or one where an individual can use the bars as support beams and body-weight support. While these designs are not detachable, if some alterations were to be made one would be able to make it a detachable system.

One popular design is the Body-Weight Treadmill Gait Training System[3]. This design has a sling and harness to reduce the bearing capacity of the individual and act as a body-weight support. It included an electrical point control as its mode of operation, meaning that an electrical component is used to adjust the height of the harness. A wheeled system with a large pole is centered around the treadmill, with the pole being behind the front of the treadmill. The harness hangs over the treadmill track and once the individual is on the treadmill, they can adjust themselves into the harness. This system however is not feasible for those who struggle to get onto the treadmill in the first place as no ramp system is installed in addition to the harness system.

Figure [1]. Body-Weight Gait Training System

Another design, the LiteGate 4 Home follows a similar design pattern as the Body-Weight Treadmill Gait Training System in that it has the support systems in place, however instead of a harness it has support beams that are placed where one would rest their arms [4]. Within this design there are attachments that can be added based on the individual, making it a more personalized solution. Attachment harnesses could be included, as well as attachment cables and straps. This system is a detachable system as the system is on wheels and can easily be maneuvered around the treadmill when not in use. However, this system would not be a feasible solution for our client as the cost of this device is outside of our client's range and the harness system is one that would have to be utilised from the gait trainer, and one of the requirements of this project is that not permanent alterations should be made to the gait trainer, and this solution would do so.

Figure [2]. LiteGate 4 Home

Gait trainers are used to assist and support those who have issues with significant mobility impairments. They play a critical role in the rehabilitation process and help in improving a patient's quality of life by allowing them to get some physical exercise in their day-to-day routine. Gait trainers are meant for outdoor use and are not suitable to be used indoors, thus during winter times or whenever the weather may be bad, patients are unable to get their physical exercise in, which can affect them mentally and physically. Thus a system in which a gait trainer can be attached and detached to a treadmill is a critical solution and can ensure that the rehabilitation process does not stop simply due to inclement weather conditions.

Background

Amanda Parjeski is an occupational therapist at continuum therapy in Madison, Wisconsin. Parjeski has a client with significant mobility impairment and seizure disorder which requires support moving due to poor postural strength and high seizure risks.

The requirements for the design of the project will revolve around various client requirements and background research. The client uses the Rifton Pacer Gait Trainer 2022[5], so it is essential that the design is built around the dimension of the Rifton pacer gait trainer. The client will use the device on the Horizon T101 treadmill. The dimensions must apply to the Horizon T101 of 71" x 34" x 57"[6] as well as be applicable to other competing treadmills with similar dimensions for versatility. The design should support the client on the treadmill in the gait trainer for 10-15 minute increments at 1-3 miles per hour. While the design is in use, the client may be prone to a seizure, in case of emergency, there should be an emergency unlocking system within the design.

Due to the clients mobility impairments and seizure disorder, there will be additional forces to account for in the design. The design should be able to withstand the weight of a 30-year-old woman of about 174.9 lbs [7]and 57.9 lbs of the gait trainer [5]. The design must last for a sustainable amount of time at various temperatures [8], approximately 10-15 years [9]. The device must follow FDA regulations and in the use of a ramp in the design, should follow ADA ramp recommendations [10]. Overall, the project should be completed within a $500 budget. To see full product design specifications, see Appendix A: PDS.

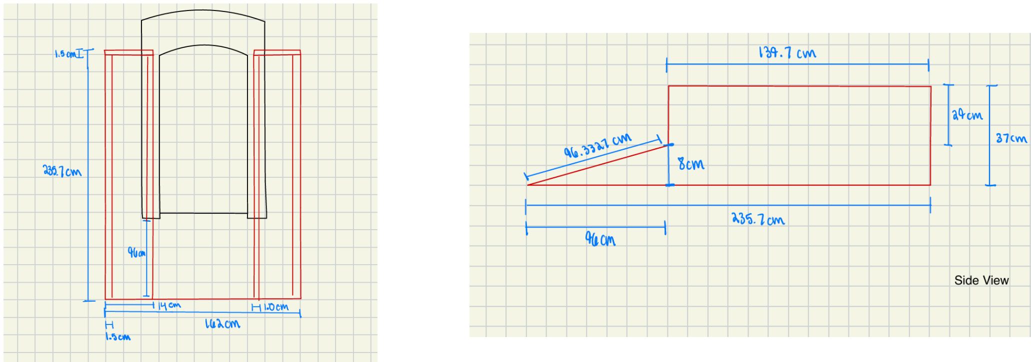
After reviewing the design requirements, background information is necessary in order to execute the design properly. The first aspet to understand in order to execute the design is seizures and neurological disorders that induce seizures. During seizures, there are various symptoms that can happen sensorly and physically. Sensory, the subject can suffer from blurry vision, flashing light, hallucinations, out of body sensations, and loss of awareness[11]. The physical changes can include difficulty talking, inability to swallow, repeated non-purposeful movements, convulsion, difficulty breathing, and heart racing[11]. Because of these intense symptoms, it is essential that the design be compliant to support the client during a seizure and allow for exit from the design in case of emergency.

The use of gait trainers is useful and essential for supported movement within the client's mobility limits.The gait trainer can be used to correct asymmetry, which supports the lower level of postural control of the client. Additionally, the gait trainer can be used to induce and increase mobility in many patients. The use of walking with the gait trainer can improve body balance, exercise duration, frequency and subjective health such as health status and satisfaction [12]. To execute the project, it is essential to understand the importance of gait training and walking for the client's health.

Preliminary Designs

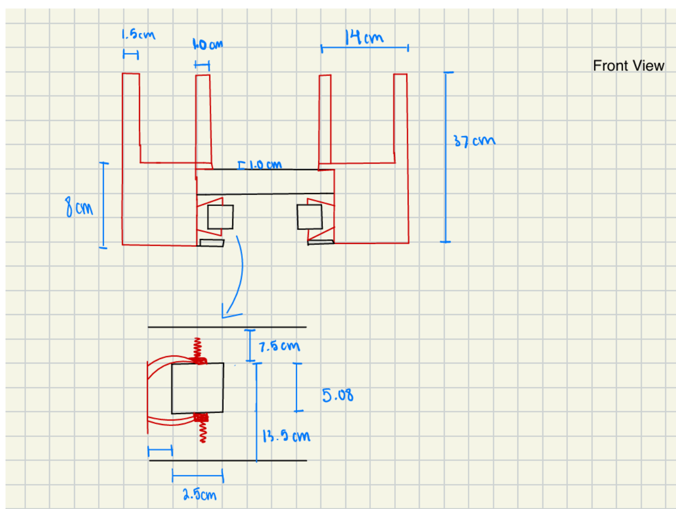
Design 1: Ramp and Tracks Connected Design

The ramp and track connected design is a concept with a ramp and a train-track inspired locking system. There are two tracks that are connected to the ramp to create one full piece. The tracks and ramp are fabricated together, so no necessary connection is needed between the sections. Due to the wheels being horizontally offset on both sides of the gait trainer, there are grooves that run the full length of the track. The grooves within the track guide the gait trainer while ensuring the gait trainer stays straight on the tracks. Additionally, there are elevated edges on the tracks to create an extra level of security for the wheels. The edges are 29 cm tall to safely secure the gait trainer into place. There are two grooves within the tracks themselves, due to the different sizes and orientation of the wheels on the gait trainer. The grooves are 5 cm and 2 cm wide.



Figure[3]. Front and side view of design 1

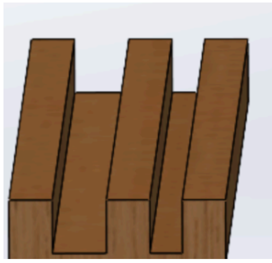
The system itself is connected to the treadmill via C Clamps. There are various C Clamps placed on the inside of the design itself. There are 3 placed on the inside of each track. The C Clamps screws into the treadmill to allow full security.

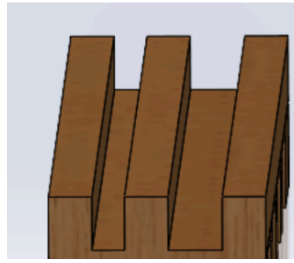


Figure[4]. Front View of Ramp and Tracks Design

Design 2: Ramp and Tracks Disconnected Design

This design is a three part system that includes a ramp, a right track, and a left track. Each of the tracks include long, deep grooves that extend along the entire length of the tracks to fully support and secure the wheels of the gait trainer, as well as to ensure that the gait trainer is correctly positioned on the treadmill. The right track and the left track are mirror images of one another. Given the shape and orientation of the wheels on the gait trainer, there are two grooves per track. The groove on the outer edge of the track will be approximately 5 cm thick to accommodate the larger outside wheel of the gait trainer. The groove on the inner edge of the track is approximately 2 cm thick to accommodate the thin, inner wheel of the gait trainer. The two grooves are 3 cm apart, and 5 cm deep, with 1 cm of space under the grooves.





Figure[5]: Front View Left Track

Figure[6]: Front View RightTrack

The two tracks will be attached to the treadmill via multiple C-Clamps. Each track will have three C-Clamps attached to its outside edge. These clamps will be able to screw into the side edge of the treadmill and secure the tracks.

Figure [7]: Side view of track Example

Figure [8]: C-Clamp

This design will include a ramp that is also separate from the two tracks. The ramp will be a standard wooden ramp that is equal in length to the two tracks and the treadmill. The ramp will be the same height as the treadmill track which is approximately 8 cm tall. The ramp will be easily attachable and detachable from the tracks and the treadmill via the usage of a simple hook and loop system.

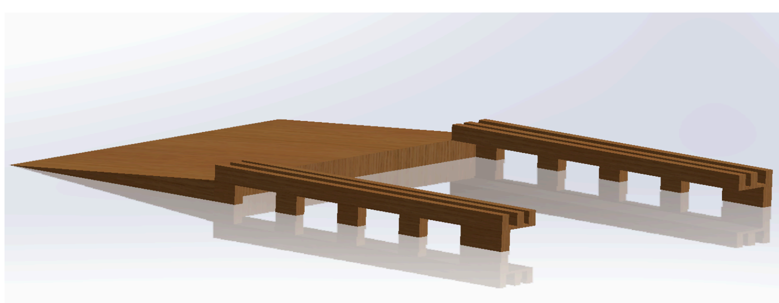


Figure [9]: Full view of device

Design 3: Altered Gait Trainer

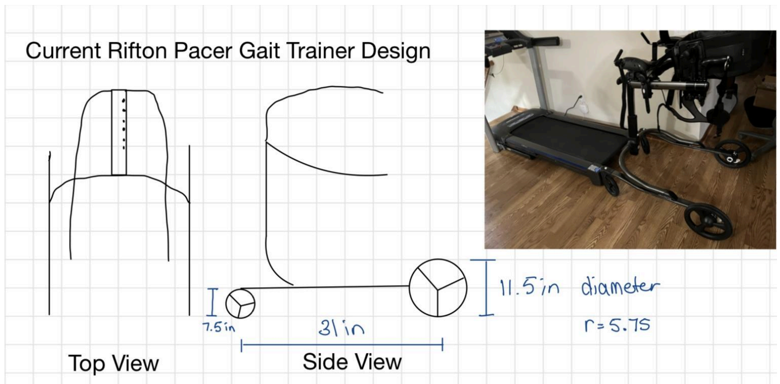


Figure [10]: Current Gait Trainer Model

The current gait trainer design is shown in figure [x] above, illustrates that the base is too narrow to fit around the frame of the treadmill. As a result, the gait trainer and treadmill are incompatible together in their current configuration.

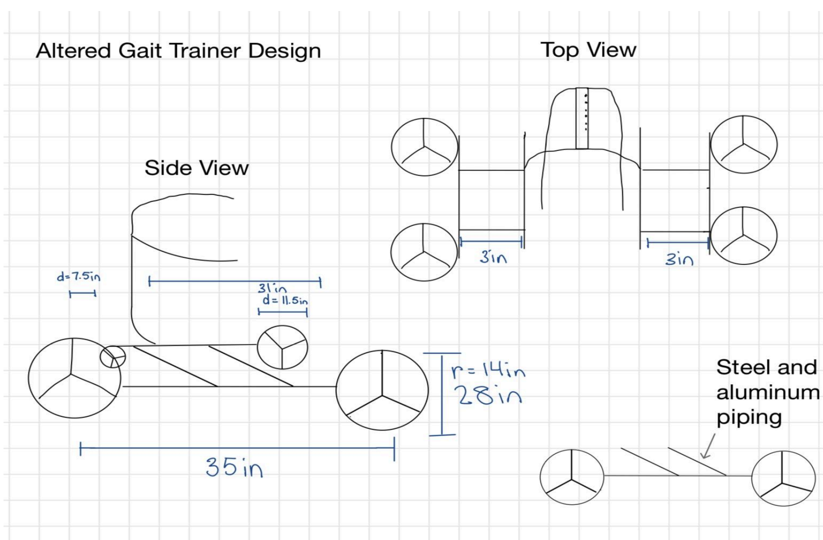
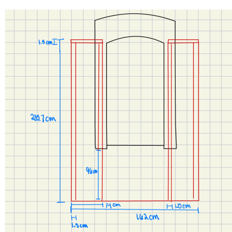
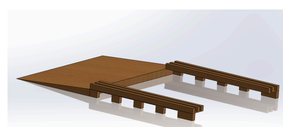
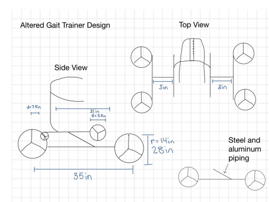


Figure [11]: Altered Gait Trainer Design

Our third design offers a new approach to the challenge of integrating the gait trainer with the treadmill. By modifying the gait trainer we are able to make it compatible to use with any standard size treadmill with measurements no larger than 84 inches long and 36 inches wide[6]. Aluminum steel rods extend outward by three inches on each side allowing the base to fit around the treadmill frame. Additionally 28-inch diameter wheels are added, slightly elevating the entire gait trainer allowing it to hover just above the treadmill belt for stability. The aluminum steel attachments are screwed into the current base for stability and support. When looking into this design, testing must be done on these attachments to ensure they can support the weight of the gait trainer and client. The horizontal attachments must be able to withhold the shear force acting on the screws. The client's safety, especially in the occurrence of a seizure is our biggest priority looking at this design.

Preliminary Design Evaluation

Design Matrix

Criteria	**Ramp and Tracks Connected** 		**Ramp and Tracks Disconnected** 		**Altered Gait Trainer** 	
Safety(25)	4/5	20/25	4/5	20/25	2/5	20/25
Ease of Use (30)	3/5	18/30	4/5	24/30	2/5	12/30
Cost (10)	4/5	8/10	4/5	8/10	2/5	4/10
Ease of Fabrication (15)	4/5	12/15	4/5	12/15	2/5	6/15
Durability (20)	4/5	16/20	4/5	16/20	2/5	12/20
Score (100)	74/100		80/100		44/100	

Design Criteria

To effectively evaluate the design concepts, the Preliminary Design Specifications were referenced in order to develop 5 distinct criteria: Safety, Ease of Use, Cost, Ease of Fabrication, and Durability. These criteria were chosen and weighted to highlight the more crucial aspects of the design while ensuring that the less significant categories had a limited impact on the final score.

Safety- The safety of the project is one of the most important factors to consider because of the use of the design. The design will be used for the client with a neurological disorder which causes mobility issues. The design should restrict gait trainer movement while in use, withstand a large amount of force, and effectively guard the gait trainer and client from injury. Safety is one of the most important aspects of the design, which is why it is ranked on the higher end.

Ease of use - The ease of use of the project is the most important factor to consider due to the nature of the device, and the purpose of it. The design will be used by our client with severe mobility restrictions. She is aided by two people at all times and cannot walk without the assistance of these two people, and her gait trainer. The device must be extremely simple to install on the treadmill, use to get onto the treadmill, and while on the treadmill, and take off the treadmill. The purpose of this project altogether is to allow for the client to easily utilize her treadmill, if the design is not easy to use it defeats the purpose of the project altogether.

Cost - The cost rankings are based on the ability for all design materials to stay within our $500 budget. The materials used should ensure maximum safety, durability, ease of use and ease of fabrication all while staying within the budget. This helps to prioritize design choices and components to keep it both functional and economical. Staying within budget will allow for flexibility for unforeseen expenses.

Ease of fabrication - The ease of fabrication is based on the ability to fabricate the prototype within the allotted time period of this class. This includes leaving time for testing and making an aesthetic finish.This also includes the ability to alter materials with the technology available to us. This helps us prioritize the designs with practical materials, and designs that we will be able to improve upon through hands-on fabrication.

Durability- The durability of the design refers to its ability to withstand pressure over time, while still maintaining its functionality. All designs are ones which are removable solutions and will be consistently attached to the treadmill, so it is important to ensure that the design can withstand constant amounts of friction and force applied. Durability rankings will be assessed by ranking factors such as material strength, response to environmental stressors, and its predicted longevity.

The highest weighted category is Ease of Use. This is because it is important that the client can easily use the gait trainer on the treadmill whenever the weather does not permit her to use the gait trainer outside. The Ramp and Tracks Disconnected design scored well in this category because the set up for this design is minimal with only taking a couple clamps, and it is a smooth ride up to the treadmill. The Ramp and Tracks Connected Design scored slightly lower because of the sheer bulkiness of the design. With this design being one piece, it would be difficult to make small adjustments.The Altered Gait Trainer design scored the lowest in this category because it would be difficult to get the client to switch bases just to walk on the treadmill. Safety was also a heavily weighted factor. Both Ramp and Track designs scored well in this category due to their ability to stay securely on the treadmill while also being able to get off safely in emergency situations. The other design fell short in this category because it would include about a seven inch difference in walking planes to be at the height of the treadmill. The next most important factor was Durability. The two Ramp and Tracks systems scored well in this category because they use very high yield strength materials. The other design scored low in this category because it does not use the treadmill for support, and therefore the materials will be subjected to more strain overtime. Ease of fabrication was weighted lower because we did not want a challenging fabrication process to stand in the way of a good product. The two Ramp and Tracks systems scored well in this category because they use designs with easier fabrication techniques. The Altered Gait Trainer did not score well in this category because it uses techniques that take a long time to become proficient. Lastly, Cost was weighted the lowest category because this is a custom project with a fairly large budget. The Altered Gait Trainer design scored low on this design because it is estimated to be at the upper end of our budget. The Ramp and Tracks designs scored well in this category because they do not take up too much space in our budget.

Proposed Final Design

Based on the weighted criteria in the design matrix, the best design for the product specifications is the Ramp and Tracks Disconnected design. The disconnected design outranked all other designs in every section of the design matrix, making it the most suitable option. It facilitates use with minimal setup and takedown, prioritizing both safety and ease of use—key factors identified by the team at the outset of the design process. It also provides support from both the treadmill and the floor along with the stable locking mechanisms to keep the gait trainer in place. In addition to this it utilizes materials that are high yield in durability, as well as, cost effective. The techniques that are to be used in fabrication are fairly easy, making the ease of fabrication score the highest. The only disadvantage to the ramp and track's disconnected design is the transferability to other treadmills. Despite this, the team has thoroughly reviewed the criteria and concluded that this design best meets the client's needs and expectations.

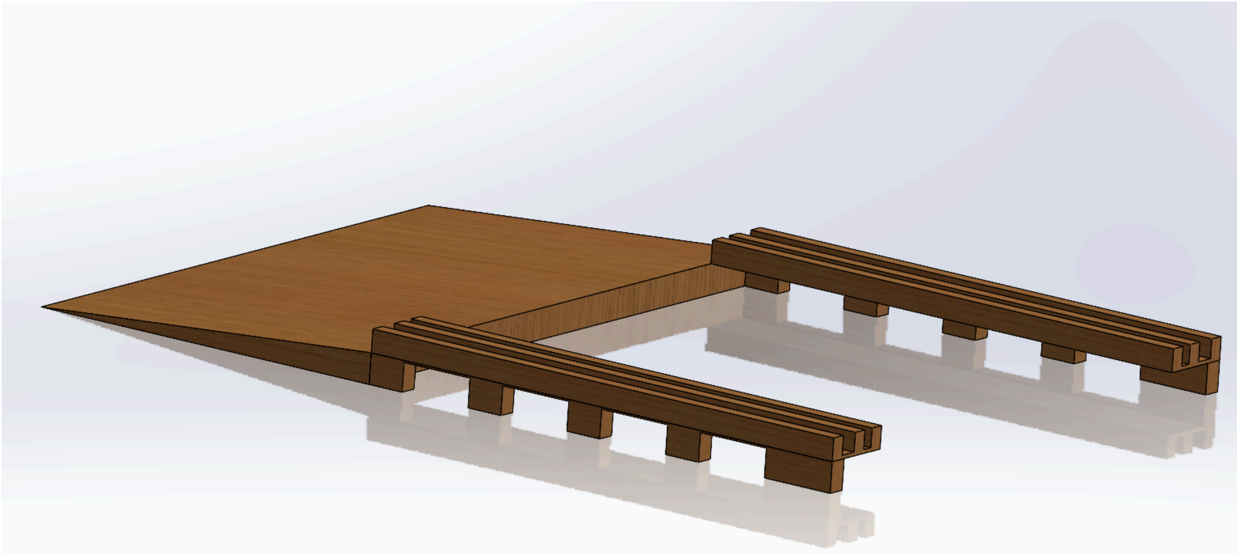


Figure [12] Proposed Final Design SOLIDWORKS Drawing

Fabrication

Materials

The materials that were utilized in the fabrication of the device can be separated into three sections. Due to the multiple components of the design, different criteria were considered to determine which different materials were best for the device. The three sections of the device that were considered were the tracks and ramp, the mechanisms to secure the tracks and ramp, and the nonslip elements needed to ensure the safety of the client. The specific materials that were used to fabricate the device were wood, nails, c-clamps, and non-slip materials.

The ramp and track were constructed out of different types of wood, nails, fasteners, and bolts. The type of wood that was used is treated wood, specifically ACQ labeled wood that had been pressure treated to withstand pressure and time.[13] For the majority of the ramp and tracks, pressure treated plywood was utilized, to ensure the strength and durability of the device. Treated two by eight inch lumber was also used in fabrication for the supports on the bottom of the ramp and tracks. As the ramp will be stored indoors and will not be exposed to the weather, it did not need to be completely waterproofed or freeze resistant. For this reason, ACQ wood was an effective, reasonably priced type of treated wood to be used for the device. ACQ or alkaline copper quaternary is a water-based wood preservative that is used to prevent decay from insects, mold, fungus, and more.[14] It is most commonly used in wood for residential applications, and is a common wood type used in medical ramps.[13] The nails, fasteners and bolts that were used in the ramp and tracks were specifically for usage with wood and were made of either hot-dipped galvanized or stainless steel. Since the wood is treated with a copper substance, normal nails and bolts could not be used, as many of them are made of steel and copper can cause steel metals to corrode very rapidly which would be detrimental for the device[13].

The tracks and ramp were fabricated to be connected to the treadmill with several C-Clamps and aluminum bridges. These C-Clamps are platform C-Clamps that are manufactured specifically for usage with wood. The clamp that was ultimately used in the device was the WOPPLXY Wide Jaw C-Clamp.[15] This clamp is made of stainless steel and has a user friendly screwing mechanism for easy use[15].The stainless steel is extremely durable, which is important for this device, and it will also not corrode when put in contact with the copper treated wood. The clamps were attached to the treated wood using the same steel nails, washers and bolts mentioned previously.

As this device is to be used for someone with severe mobility constraints, safety is a number one priority. For this reason, several non-slip elements were included in the final design. In the grooves of the tracks, where the wheels will be, a rubber non-slip mat was installed to ensure that the wheels of the gait trainer did not slip when the device was in use. A rubber ramp cover not only makes the device safer, but it also makes it more durable in the long run[16]. Additionally, the bottom of the ramp and tracks were equipped with non-slip, silicone tape to further ensure that the ramp and tracks stay put the entire time they are in use [17].

Methods

As previously mentioned in the materials section, the final design was fabricated using a combination of wood, nails, bolts, non-slip elements, clamps and hooks. These materials were ordered or purchased from a variety of locations including Amazon, Home Depot, and the UW Makerspace. A fully detailed expense spreadsheet as well as SOLIDWORKS renderings of the design are displayed in the appendix [A].

The ramp and tracks were fabricated using bandsaws, hand saws, table saws and drills. The wood was cut by the team into the correct shapes and sizes in the Makerspace. The wood pieces were then put together using nails, washers and drills. The ramp and each track were all built separately due to the disconnected nature of the final design. The two tracks were fabricated to be mirror images of one another and consist of multiple wood blocks drilled into one another to reach the desired shape. Also, two plywood “railings” were added to the edges of the ramp per the client's request at the end of fabrication. Two strips of plywood were cut, then drilled and nailed into the ramp to prevent the gait trainer from potentially rolling off the sides of the ramp. All wood elements were sanded and wood glued at the end of fabrication to prevent splintering and/or injury to the client or her caregivers and to remove any rough edges.

The clamps were drilled into the tracks and secured with nails, washers, and super glue. There are three C-Clamps per track, located on the outer edge of the tracks. The ramp, as well as the tracks each have small aluminum bridges or ramps to facilitate the movement of the gait trainer along the device. These aluminum fixtures were cut in the makerspace and attached to the device with screws and hinges. All drilling, cutting, sanding, screwing, etc was completed in one of the two UW Madison engineering fabrication labs.

Finally, the non-slip elements of the device required the least amount of fabrication. Both the rubber mat and the non-slip silicone tape were ordered and delivered to the team. The rubber mat was cut and glued to the areas of the track where the wheels would touch. Additionally, the non-slip tape was cut to size and glued to every aspect of the ramp and tracks that would be in contact with the ground. This was to prevent any slipping while the device is in use.

Final Prototype

Figure [13] Final Prototype Side View

Figure [14] C-Clamp Installation

Figure [15] Final Prototype Front View

Testing and Results

SOLIDWORKS Testing

To test the strength and support of the ramp and tracks under load similar to that of the gait trainer, including the added body weight, SOLIDWORKS simulation modeling was used. This testing occurred before fabrication to ensure safety of our design. For the tracks a balsa wood material was applied with a yield strength of roughly 20MPa and elastic modulus of approximately 3GPa [18]. These properties indicate that the wood is extremely resistant to elastic deformation. Figure [16] shows the tracks, modeled in the balsa wood, attached to the treadmill which is represented in black.

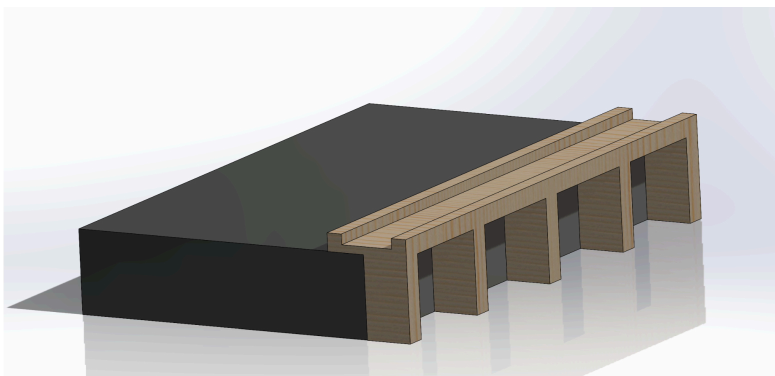
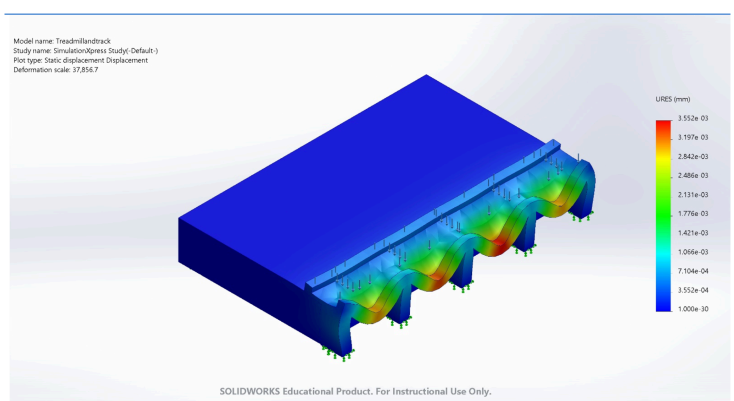


Figure [16] Track and Treadmill Assembly

To test for deformation in the tracks, two separate Finite Element Analysis (FEA) simulations were conducted under static conditions. For the first test, a 900N (200lb) force was applied to the face of the tracks at 5 points between the supports. This weight simulated the combined weight of the gait trainer and the clients body weight. The maximum deformation was found to be 0.0035mm between supports.



Treadmillandtrack-SimulationXpress Study-Displacement-Displacement

Figure [17] Simulation under 900N load

In the second simulation, a 20,000N distributed load over the 54in tracks. This distributed load equivalates to about 80lb/in which exceeds the weight of any gait trainer that would be used on the treadmill. Despite the large load, a maximum deformation was found to be 0.063mm.

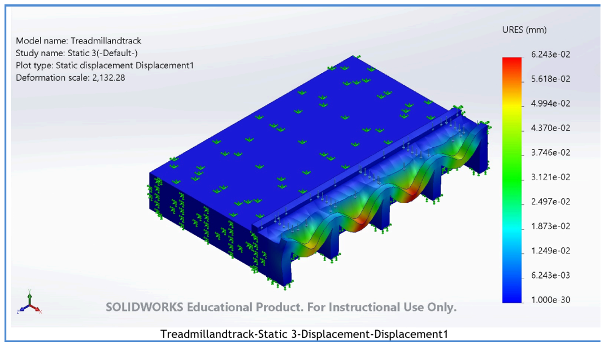


Figure [18] Simulation under 20,000N distributed load

Additionally, SOLIDWORKS testing was done on the ramp portion of the device. A concentrated, 1400 N force was applied to the top face of the ramp to simulate a slightly larger than 300 pound load on the entirety of the ramp. This test highlighted any potential weak points of the ramp, and demonstrated extremely minimal, basically zero deformation.

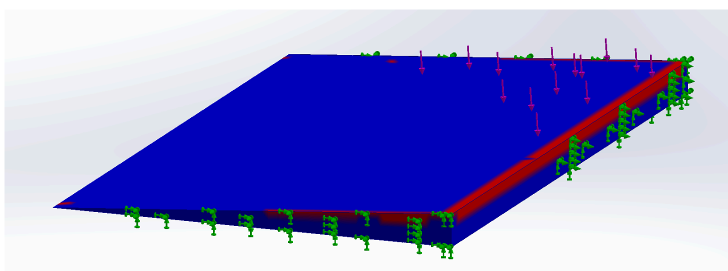


Figure [19] Ramp SOLIDWORKS Testing

Client Testing

We were unable to accomplish testing with our client utilizing the device before our final changes were made. We were able to roll the gait trainer up the ramp and onto the tracks in one smooth motion. We did not see any deformation in the tracks or ramp when performing this demonstration. One of the nurses who assists our client was able to hook herself up to the gait trainer and test the device to the best of her ability. She mimicked the gait pattern of our client and tested both the tracks and ramp by putting forces in several directions on the device. Testing was done in this manner with the wheels in a locked position, as well as an unlocked position to test if the device would still be secure if the gait trainer wheel locks were to give out.

Survey Testing

After meeting with our client a final survey was sent out for them to complete. The survey consisted of 13 questions using the likert scale [19] to receive feedback on what the client thought about the safety, and usage of our design. All 13 questions are shown in the appendix [C] below. A short answer question was asked to see if there were changes to the device they would have liked to see if more time was permitted. The client responded with "If there was more time, perhaps making an easier on/off system with the c-clamps so that caregivers have less work to attach it to the treadmill each time they want to use it" (Pejerski). The average rating of all 13 questions using the likert scale was a 9.8/10. The client rated the safety of the device a 10/10, the support of the device a 10/10, and the overall satisfaction of the device to be a 10/10. A score of 9/10 was given to the overall ease of use of the device and the security of the gait trainer on the treadmill. In the closing remarks of the survey the client stated "We are all very excited to start using this now that the snow has started and the weather doesn't allow us to get outside to walk as much. Thank you for all of the hard work!"(Pajerski).

Results

All of the SOLIDWORKS simulations gave strong evidence that our design is stable and safe. The maximum deformation in both cases was found to be less than 0.1mm which demonstrates that the risk of failure in the design is very minimal. The factor of safety, calculated in the first simulation report of the tracks, was determined to be 560. A factor of safety of 4 is genuinely acceptable for high risk processes, indicating that our design far exceeds this safety threshold. The simulation testing done on the ramps revealed a factor of safety of 24773 which is extremely high and even further shows the degree of safety and stability of the device.

Before fabrication began, SOLIDWORKS testing was done on a ramp design with less supports which resulted in more deformation and a lower factor of safety, which was an additional factor in that aspect of the final design. Overall the testing done on SOLIDWORKS proves that the device and the design chosen by the team, are extremely safe and stable. Given the nature of the device and the fact that it is to be used for the health of the client, safety and simulation testing were crucial.

The survey testing completed by the client as well as the testing done in person by the client and the nurses was also crucial in testing the possible flaws of the design. The testing done in person was conducted to ensure that the risk of the gait trainer running off the sides of the ramp and tracks, or onto the treadmill belt was minimal, even without the wheels locked. Even with strong lateral forces applied, the gait trainer did stay on the tracks and ramp and the device itself did not move or shift at all. The tracks and ramp also showed no deformation when the gait trainer, plus an additional load were applied. Additionally, due to the manner in which the tracks were fabricated and attached, there is no risk of the gait trainer running off the front of the treadmill which adds another level of safety to the device. Finally, the results of the survey testing were very promising for the project as a whole. The client rated the device an overall 9.8 out of 10 when asked to judge the device with several different criteria such as ease of use, safety, etc.

Discussion

Results from testing were important when considering the functionality of the design for the clients. SOLIDWORKS testing concluded that there was little to no deformation within the tracks when a 900 Newton force was applied. Additional SOLIDWORKS testing was completed on the ramp, leading to more successful results. The ramp testing showed the weakest points being on the edges of the ramp, however, the factor of safety was extremely high, allowing the conclusion that the ramp is strong. The combination of survey testing and client testing led to successful results. The client's gratitude with the design as well as the resistance to applied loads is significant improvement than the first set of testing. The results indicate that potential work can be completed to make the device more versatile and marketable to broader audiences.

The team fabricated the ramp and track's disconnected design within the allotted budget of $500. Fabrication of the design cost well under the budget, leading to an efficient cost that can be comparable to competing market prices. Ethical considerations applicable to the design are safety, ease of use for the client, and the variability of the device. The ramp was constructed according to ADA recommendations [10], with additional rails on each side. The ramp is safe and easily accessible for the client, leading to universal use for the client. The tracks are constructed with additional railing on both the inner and outer ends. Along the ends of the tracks are five supports to support the weight of the client and gait trainer while walking on the treadmill. The tracks are attached via C-Clamps onto the treadmill, which have proven to successfully secure the tracks to the treadmill. Aluminum sheets are attached to both the end of the ramp and end of the tracks. The aluminum sheets have proven to decrease the gapping between the ramp and the floor and minimize bumps induced by the gait trainer. Additionally, the top of the tracks are lined with non-slip material to ensure the security of the gait trainer on the treadmill. The bottom of both the tracks and ramp are lined with additional non-slip material to decrease movement as well as protect the surfaces the design comes in contact with. The design of the ramp and track's disconnected design allows for safe use of the treadmill. Due to the process of attachment of C-Clamps and heavy bases of the ramp and tracks, the design lacks in ease of use. Once secured, the ease of use is simple, however, attachment is more complicated. The process may be more hingering for a wider variety of people, so improvement is needed to allow for ease of attachment. Solely based on the structure of the design, the design can only be used with the Horizon T101 Treadmill[6]. The success of the device itself indicates future work would allow for larger market applications, however changes would need to be made to allow applications to all treadmills and for all users.

During various stages of testing, there were multiple changes made to the preliminary design. Additional supports were added onto the bottom of the tracks to support the force of the gait trainer and client. Due to the structure of the treadmill, the C-Clamps initial placement was unsuccessful. Adjustments were made in the placement of the C-Clamps which aligned with the structure of the treadmill. Additionally, the ramp had a gap between the floor which prevented smooth movement of the gait trainer onto the ramp. The same issue was found between the ramp and the tracks. The addition of aluminum sheets on the edges of the ramp and tracks allowed for smooth transitions from the floor onto the ramp and onto the tracks. The final adjustment of the design was to the length of the tracks themselves. Due to the slight elevation in the plastics at the end of the treadmill, the tracks were not perfectly aligned with the bottom of the floor. The team cut the end of both tracks down four inches, which lined up perfectly without elevation of the treadmill. After client evaluation, the design will be used by the clients in their home and allow for efficient use of the treadmill during the winter months.

Sources of error for this project can be concentrated in testing and measurements. Due to the use of survey testing completed by the client, there could have been discrepancies due to the relationship the team has with the client. The overall success of the project could have affected the clients evaluation of the device. Additionally, the testing completed with the client could not have successfully supported the success of the project. Testing was completed by subjects who are not users of the gait trainer, which could create discrepancies in results. The final potential source of error is measurements of the device compared to the treadmill. Due to the nature of the project, the treadmill remained in the client's possession. Throughout the fabrication process, the measurements were proven to be inaccurate without taking into account all portions of the treadmill. The final design adjustments were taken while the device was attached to the treadmill, but there is still room for error.

Conclusions

Designing a system that can integrate a gait trainer and treadmill is essential in that it can allow users to receive the physical exercise they require, all year round. This would ultimately improve their physical and mental health. Current solutions involve support beams and harnesses, but do not account for a solution for the user to step onto the treadmill if mobility is restricted. After extensive background research, the team decided on the ramp and tracks design which was built around the base of the treadmill. Major components of the design included two identical tracks with three C-Clamps on three support beams. Each track has five support beams. Additionally, a ramp spanning the width of the treadmill and the two tracks which allows for safe entrance onto the treadmill.

The design was proven to be successful through various testing. The design will be used by the client throughout the winter months and allow for increased mobility. The constraints of the device apply to variability between treadmills. There are no adjustable components that would allow use on a different style of treadmill. In the future, creating a system that is adjustable in height and attachment would allow the use of the device to be more diverse.

After evaluation of the prototype, there are potential improvements to be made to the design. Implementation of an adjustable height system could be added to the track to allow for attachment between different treadmills. This would help to increase variability to be compatible with multiple treadmills. Additionally, the addition of an emergency unlocking system could be added in case of a seizure. Something such as a lever could be included in the improvements to allow for extra security during a seizure. Testing was completed through various techniques, with additional loads being applied by members of the team. To fully test the range of the device, testing using the device with the client is essential to prove the success of the device. One major concern received from the survey test was the difficulty of attaching the tracks to the treadmill via C-Clamps. Due to the placement of the C-Clamps, the attachment process is extensive. Creating an easier system of attachment to the treadmill would aleve extra work that needs to be done currently. The final focus of improvement is the implementation of wedges on each wheel. To ensure the gait trainer is securely locked into place, adding wedges on both sides of the wheels would restrict additional movement. Overall, the team fabricated a successful design that will be useful for the clients. The team deemed that work could be done to improve the device individually and expand the variability to open the potential of a product applicable to the market.

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Appendix

Appendix A: Product Design Specifications

BME 300/200 Design: Gait trainer with Treadmill

Product Design Specifications

September 19, 2024

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Function

Gait trainers are mobility devices designed to assist and support individuals with significant mobility impairments. They provide support and weight-bearing assistance through a harness that supports the individual and bars that allow the person to apply body weight for added stability while walking. In the winter, it is difficult to utilize the gait trainer outside. Due to the lack of access, users may suffer significant damage to physical and mental health. Utilizing a treadmill during the imperfect weather conditions would allow for increased mobility and less drastic damages to the overall health of the client. By creating a ramp and lock system, which will allow the client to roll the gait trainer onto the treadmill, it would provide the fix needed for the client to use her gait trainer all year-round and not simply outdoors. The ramp and lock system will be subjected to a large amount of force through the gait trainer, therefore it will be made out of treated plywood, increasing the durability and strength of the system. The overall system should work together smoothly to prevent the client from falling off the treadmill due to her gait trainer.

Client requirements

- Develop a ramp system that will lock into place onto a treadmill to allow 5 to 15 minute walks at a pace of three miles per hour.
- The lock and ramp system should have an unlocking procedure for caretakers in case of a seizure, as well as follow the ADA ramp recommendations[1].
- The lock and ramp system needs to be detachable in order to store the treadmill.
- The system should be compatible with wood flooring without damaging the flooring.
- For the overall budget, the system should be within $500.
- The lock and ramp system should be compatible with the Rifton Pacer Gait Trainer 2022[2].
- The product should last for a minimum of 5 years, in order to allow the client to use the product in different seasons.

Design requirements

1. **Physical and Operational Characteristics**
    a. **Performance requirements:**
        i. The gait trainer with treadmill product should be compatible with the width, length, and height of the treadmill. The system should be able to withstand the force of a thirty-year-old woman during a seizure[3] while also having the capability to be easily unlocked during said seizure.
        ii. The materials used for the ramp must not damage the flooring as well as hold a stagnant position during use. Materials include treated plywood, aluminum sheets, and non-slip silicone pads.
        iii. The locking mechanism must be easily adjustable and detachable in case of emergency. The gait trainer must be safely attached to the ramp and treadmill at all times of use. The system must be able to be deconstructed into parts in order to move the treadmill to different locations.
    b. **Safety**
        i. The device must be able to safely support a large amount of force. The locking system must stay into place and support the force of a thirty-year-old woman during a seizure. Additionally, the locking system must remain locked into place until a caretaker is able to unlock the device. The ramp of the device must follow ADA recommended slope rate[1]. All materials used in the device must be FDA approved and follow ADA regulations. The materials must not contain exposed adhesive and latex due to client allergies.
    c. **Accuracy and Reliability**
        i. The device must be able to seamlessly and securely lock into the treadmill every time the treadmill is used by the client. The ramp must be stable

and capable of supporting the client's weight without bending or warping over repeated usages. The device is to be used every time the client uses the treadmill and needs to have reliable locks and supports that will not wear down with regular usage.

d. **Life in Service**
   i. This will be a multi-use device. The ramp and locking apparatus must remain completely functional for the entire duration of its usage by the client. As the device is to be used multiple times a week, especially in winter months, it will need to be very durable for repeated use. The device must also remain compatible with both the client's gait trainer, and treadmill model, and be capable of minor adjustments, such as if the hinges of the metal plates need to be changed, if needed in the future. It should also have an approximate life in service of 10-15 years.

e. **Shelf Life**
   i. The device should be kept indoors and at room temperature between 15 and 30℃. The device should not be exposed to hot temperatures (>48℃)[4] for long periods of time, and should be kept in humidity between 30-50% to prevent erosion or damage[5]. The device should also not be in freezing temperatures. If the device is not placed under any extreme stresses it will have a shelf life of 10-15 years[6].

f. **Operating Environmen**t
   i. This device is to be used day-to-day by the client. The operating environment will be in the clients home attached to her treadmill and gait trainer. The device should be relatively easy to install in the client's home, as well as to remove from the treadmill and store compactly in the home. The client's floor is hardwood, so the device needs to be slip resistant and able to be installed and uninstalled without scratching or damaging the floors.

g. **Ergonomics**
   i. The device will be based on the measurements of the treadmill. The width of the base of the treadmill, length, and height from the ground are all measurements that will have to be taken into account when designing the product.

h. **Size**
   i. The device should be compact and serve its function of attaching and securing the gait trainer to the treadmill. Any product designed will have to be stored away when not in use, and size limitations will be dependent on the dimensions of the storage space in which the device will be kept in when.

i. **Weight**
    i. The device should not exceed 150 lbs as it must be easily removable from the treadmill. Additionally, the product should be less than 150 lbs so that caretakers may lift and store the attachment with no injury. The device should be able to withstand forces associated with the average weight of a 30yr old woman (175 lbs [7].

j. **Materials**
    i. The client experiences adhesive and latex sensitivity. Apart from latex-based and materials with adhesive properties, there is no limitation in terms of the materials that can be used. Durability should be a driving factor when choosing materials. Any materials chosen should have a relatively high yield strength and be able to withstand a large amount of weight, approximately around 174.9lbs[7].

k. **Aesthetics, Appearance, and Finish**
    i. The Gait Trainer with treadmill device should be an easily assembled device with three main components that are easily compatible with the Horizon T101 treadmill [8] and the Rifton Pacer Gait Trainer[9]. The ramp should be made of durable material. The ramp should have a rubber bottom or other material that will be able to dampen impact and keep ramp immobile while being used. The ramp should have a shallow incline[10], following ADA recommendations of an angle of 8°[11], and lead onto tracks that start out wider and lead to a narrow secure fit to the wheels. These tracks lead to locking mechanisms that keep the gait trainer in one spot during walks on the treadmill. All of the components should be black to blend in with the treadmill, with the exception of the start of the tracks, which should be yellow for an easy guide onto the tracks. The ramp should have a rough face to ensure traction, and the tracks should have a smooth finish to let the wheels easily get to and from the locking device. Edges should be smoothed to prevent any possible hazardous sharp edges.

2. **Production Characteristics**
    a. **Quantity**
        i. For the purposes of this design, one Gait Trainer with treadmill device will need to be constructed. This will include one ramp to the specific height of the Horizon T101 treadmill, which is 8.66 inches. Additionally, two tracks will be needed for the gate trainer wheels that lead into four locking devices for the wheels.
    b. Target Product Cost
        i. The budget for the prototype is $500 or less. The budget will be used for the ramp, tracks, locking devices, and any other materials needed for

prototyping. It will also be applied to any modifications that the treadmill needs to undergo for the project.

3. **Miscellaneous**
    a. **Standards and Specifications**
        i. The Americans with Disabilities Act requires that residential wheelchair ramps have a slope no more than 1:12 (in inches) [11]. The treadmill should not exceed 3 mph when using it with a gait trainer [12]. The device must fit the current treadmill model used in home.
    b. **Customer**
        i. Mrs. Amanda Pajerski, an occupational therapist works with a client affected by a seizure disorder. The client uses a gait trainer along with the support of two people when ambulating. The Wisconsin winters have made it difficult to access safe walking locations forcing the client to walk in circles around the kitchen island.
    c. **Patient-related concerns**
        i. The device must be stable enough in the case of a seizure to stay secure to the treadmill. The gait trainer wheels must remain locked in place while the treadmill is in use but easily have access to an unlocking mechanism.
    d. **Competition**
        i. Wheelchair ramp for treadmill [13].
            - Ramp enables a wheelchair to be pushed onto a treadmill. The ramp clamps on to the back of the treadmill and stays on during treadmill use.
            - The description states this ramp can be used for gait training.
            - This ramp does not allow for the gait trainer to be locked into place.
        ii. LiteGait 4 Home [14].
            - The base of the gait trainer itself is wide and long enough to fit around the base of the treadmill. The gait trainer is able to be used over ground or over a treadmill.
            - The gait trainer consists of an overhead harness design and is customized to the user's height.

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Appendix B: Material Expense Spreadsheet

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
LabArchives Notebook	For Documentation Purposes	LabArchives	N/A	9/6/24	1	$15	$15	LabArchives
Tracks								
Neoprene Rubber Sheet roll	Non-slip sheet attached to the top of the tracks	Pamazy	N/A	10/24/24	1	$20.00	$20.00	Neoprene Rubber Sheet
Stainless Steel C-Clamps	To attach the tracks onto the treadmill	WOPPLXY	N/A	10/24/24	2	$17.92	$35.84	C-Clamps
Non-Slip Silicone Pads	To be attached to the bottom of the tracks	3M	N/A	10/24/24	4	$8.43	$33.72	Non-Slip Silicone Pads
Ramp								
4x8ft Treated Plywood	The base of the ramp	Home Depot	N/A	11/9/24	1	$50.08	$50.08	4x8ft Treated Plywood
2inx8inx10ft Lumber	Supports for the ramp	Home Depot	N/A	11/9/24	2	$8.82	$17.62	2inx8inx10ft Lumber

Appendix C: Client Survey

The client was asked to give each of these statements a rating out of 10

The overall safety of the device: 10/10

The safety of the individual tracks: 10/10

The safety of the ramp: 10/10

The safety of the attachment mechanism: 10/10

The safety of walking onto the treadmill with the device: 10/10

The safety of getting off the treadmill with the device: 10/10

The security of the gait trainer on the treadmill: 9/10

The overall ease of use of the device: 9/10

The structure/size of the device: 10/10

The overall cost of the device: 10/10

The overall durability of the device: 10/10

The force resistance/support of the device: 10/10

How satisfied are you with the device and its outcome: 10/10

Appendix D: SOLIDWORKS Drawings