Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

RISE

EML 4501 Spring 2020

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Abstract

Although using an elliptical during rehabilitative gait therapy is proven to be more helpful than traditional therapy, existing body weight support devices are unable to provide constant and consistent support as the patient moves vertically and laterally. Rise is mounted to a wall or ceiling with a steel frame above a stationary elliptical. The hexagonal column and triangular legs provide a weightlifting aesthetic and structural stability. Mounted motors adjust the length of polyester cables using two spools, raising or lowering the patient from either side to account for changes in vertical or lateral position measured with elliptical encoders and force sensors placed on elliptical pedals. Cable length is adjusted cyclically to provide consistent support throughout use. The winch raises the patient vertically, and primary motors move the patient over the elliptical laterally. The user inputs the desired weight offset on a tablet and hard-wired emergency stop buttons are always accessible to both the patient and therapy personnel.

Product Summary

- The shape and size of the structure allow the design to remain stationary, as the patient is lifted into position from a wheelchair above the elliptical with minimal effort from both the patient and trainer. A winch slowly raises the patient vertically, before the other motors pull the patient into position laterally.
- Once a user inputs weight offset, the motors will reduce the tension in the cables to allow the patient to support a percentage of his or her own weight and the elliptical training begins. As the patient presses down on the pedals, this force is recorded by force sensors on either pedal, tracking the location of the patient's center of mass so that the PID controller can account for the lateral position of the patient and adjust tension in either cable. An encoder within the elliptical provides data about the speed and vertical motion of the patient, which is also offset by adjusting tension in either cable. The motors continuously adjust the amount of tension in the cables, ensuring that the patient experiences the same amount of support, no matter what position they are at while using the elliptical.
- At any point, the trainer or patient can press one of two emergency stop buttons to stop all motor and elliptical motion immediately, and the patient will be fully supported by the winch safety cable.
- The accessible tablet provides a portable and easy to use platform for users to adjust the weight offset and additional parameters.

Cost Overview

- OTS Parts: $ 1,305.37
- Raw Materials: $ 2,212.54
- Manufacturing and MFG Labor: $911.19
- Energy Consumption: $ 99.02*
- Assembly Labor: $62.00
- **Total Cost: $ 4589.93** *Per year of use

Acknowledgments

We would like to express our gratitude to our class sponsors, Cummins and Northrop Grumman, for supporting the UF Mechanical Engineering Department and the capstone design course.

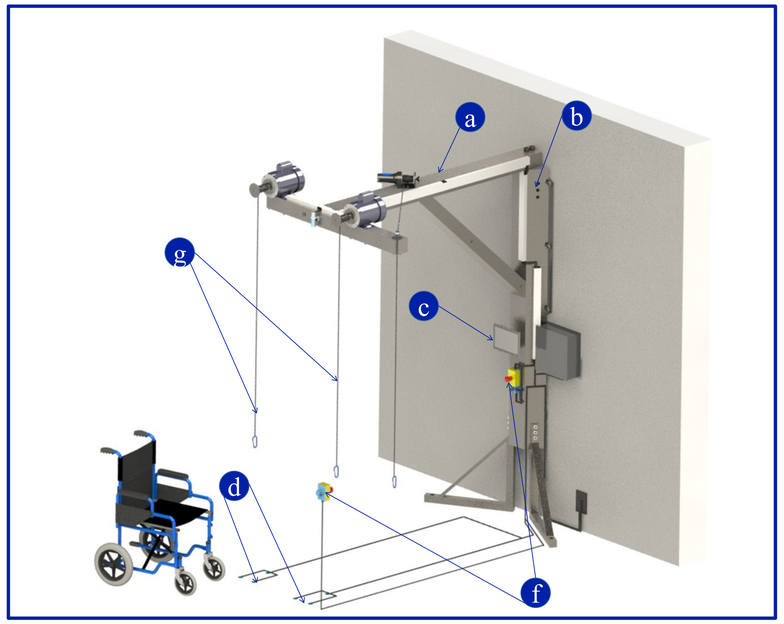

Figure 1. Rendered isometric view of full assembly. The wheelchair is included as a size reference.

Lateral Translation Key Feature

The structure does not need to translate nor rotate during operation. When mounting, the system lifts and translates the patient to the elliptical laterally. This approach negates the need for motion of the structure. This ensures safer operation and requires a smaller operational space.

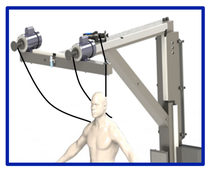

Figure 2. Motors moving patient over elliptical

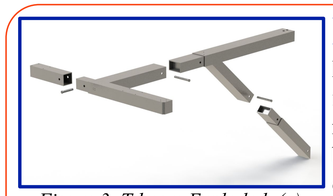

Figure 3. T-beam Exploded. (a)

Modularity Key Feature

Rise features a fully modular design. With a design focused on modularity, cheaper maintenance and more compact storage options are possible. Parts can be disassembled to save space for storage, and defective or damaged parts can be individually replaced if needed (a).

Installation Key Feature

For installation of Rise, the system's center column is mounted to the wall using anchors, with two support legs resting on the floor. However, the assembly can also be rearranged to a ceiling-mountable configuration, placing the legs at the top of the center column. This provides options for different office, house, and lab space settings (b).

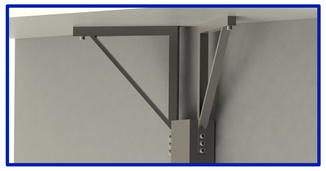

Figure 4. Ceiling Mounted Assembly

Figure 5. Detachable tablet (c).

User Interface Subsystem

- Utilizes a tablet for the patient and trainer to adjust the weight offset.
- Tablet mount allows for easy detachment and mobility of the tablet from the central column for the trainer to observe the patient from multiple angles, while still being in control (c).

Mount/Dismount and Stabilization Subsystem

- While seated, the user is strapped into a harness around their torso and shoulders and connected to two motors and a winch.
- Placed next to the elliptical, the winch cable is attached to the patient while in his or her wheelchair.
- The winch raises the patient into position vertically, and the motors pull them into position laterally, all while the device and elliptical remain stationary.
- Patient height is monitored with an ultrasonic sensor from above.
- Patient support is monitored using force sensors placed on elliptical pedals (d).

Figure 6. Top view of system.

Figure 7. Foot sensors (d).

Patient Support Subsystem

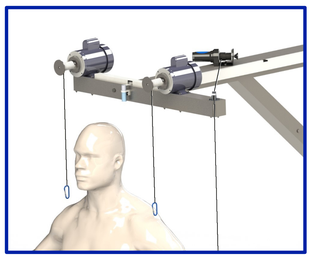

Figure 8. The patient being supported by the cables (g) connected to the two motors.

- A simple chest harness supports the patient at three connection points, connected by carabiners to the winch and dynamic control motors.
- The harness is fabricated using nylon seatbelt straps and cam buckles, allowing for size adjustments.
- Carabiners are purchased off the shelf, rated sufficiently for all users within the 95% confidence interval of weight.
- All purchased lifting cables are made from polyester (g).

Structural Support Subsystem

- Constructed with rectangular and square steel tubing pieces, the structure can be assembled and disassembled using sockets and pins, akin to gym equipment structures.
- Main column attached to wall prevents tipping.
- Leg extension to floor prevents shear loading at wall
- Alternate leg mounting points at top of column allow for support from ceiling instead of floor.
- Control box panel provides easy access to circuitry, also serving as a heatsink.

Figure 9. The support system.

Safety Subsystem

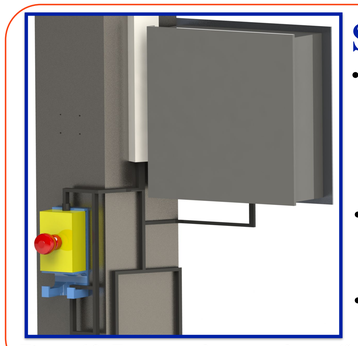

Figure 10. E-stop on the center beam (f).

- One emergency stop (E-stop) button is attached onto the elliptical for the patient to have access to the button in case of an emergency
- Another E-stop button is located on the center beam for the trainer.
- Once pressed, these buttons cease all motion of the motor and elliptical (f).

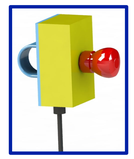

Figure 11. E-stop that is attached to the elliptical (f).

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Customer Needs

1. Must fit inside a medical or rehabilitation facility, taking into consideration a. Clearance through doors (when assembled)
2. If powered, runs from 120 VAC electricity from a standard wall outlet with 15-amp breaker capacity
3. Allows the user to stand and exercise on a standard elliptical machine without interfering with the elliptical machine's operation
4. Supports the full weight of the user up to the full capacity of the elliptical machine
5. All design margins have an acceptable factor of safety
6. Includes a fail-safe system to catch the user, preventing a fall should the primary system fail
7. The user is lifted from the wheelchair and placed on the elliptical trainer at safe and comfortable speeds.
8. The system will prevent the suspended user from swinging and/or hitting the elliptical trainer or the wheelchair during transfers to/from the wheelchair or elliptical.
9. Allows the user to translate unencumbered in the vertical direction during exercise
10. Prevents the user from losing balance in a sagittal (backward or forward) fall
11. Prevents the user from losing balance in a transverse (left or right) fall
12. Lifts the user from a seated position (e.g., a wheelchair) to fully suspended
13. Moves the fully suspended user from their original location over a standard elliptical trainer
14. Holds the user suspended over the elliptical trainer while they are being strapped into the trainer
15. Accommodates user body sizes ranging from a 5% female to a 95% male
16. Once user is attached to the elliptical trainer slowly transitions to preset offset weight
17. Allows user to select offset weight to any value between 0% and 100% of their body weight
18. Can be mounted from structural members in walls or ceilings or can sit on the floor.
19. Provides continuous user-defined offset weight support for the user while the user is exercising
20. Offset weight support feels continuous to the user despite the repeating periodic motion of their exercise
21. Must provide pre-set weight offset over the full vertical, horizontal, and transverse range of the user's motion during exercise
22. Is programmable (i.e., control parameters can be changed, or a more complex control routine added in software)
23. Has an intuitive user interface
24. Prototype cost for materials cannot exceed $4,000
25. Includes an emergency shut-off that can be actuated by the user or a nearby trainer that safely stops all motion while fully supporting the user's weight
26. Includes an automatic force-based safety limit shutoff that shuts down the device if either 1) a maximum force on the lift is exceeded or 2) the lift experiences an unexpected rise in force magnitude or direction [e.g., it gets caught on something during motion].
27. Has a visual indicator easily seen by the user and a nearby trainer that shows when the system is on, what mode it is functioning in, and how much user weight is being offset Customer Needs Statement EML4501 Lift & Harness Providing Offset Weight Support 2020 Spring Page 3 of 3
28. Has an operational lifetime that exceeds by three times the operational lifetime of a standard elliptical trainer
29. FES stimulation pad electrical connections must be accessible
30. Overall footprint of lift system plus elliptical trainer cannot exceed 2.43 m X 3.05 m (8' X 10')

Key

Customer Needs | Metrics | Sub Systems | Features

* Denotes revised metric

Map from Customer Needs to Final Design