Continuous Load and Offset Weight Neuromuscular System

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Abstract

This design consists of five different components: the frame, the hoist mechanism, the suspension system, the safety system, and a tension force sensor. What makes this design unique is that it is organized in a simple manner that makes assembly time quick and easy to manufacture. The base of the frame is made up of caster wheels and stoppers so the device may be easily moved, with a handle, and fixed into place. A box that contains the main functional components organized in a compact way so that it does not take up too much space is attached to the frame. The box is also to prevent any injuries from occurring by not having the running motor exposed. The design operates with a real time dynamic system attributed to the tension force sensor that communicates with the hoist mechanism and adjusts the offset weight accordingly.

Exploded View of Components

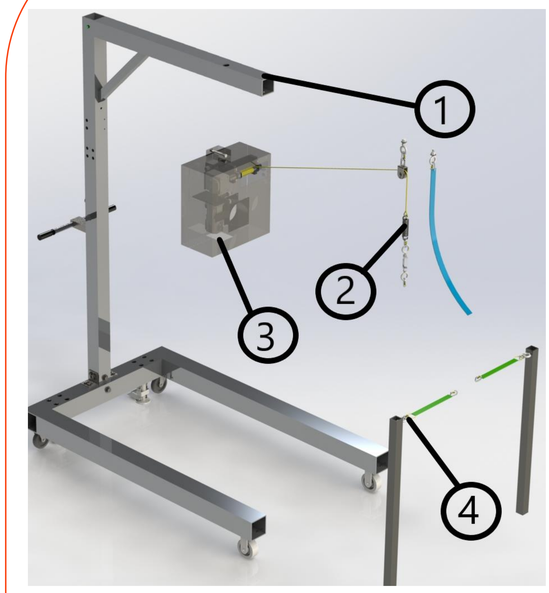


Fig. 2 The exploded view of the device showing the labeled subsystems. 1) The frame, 2) the force sensor attached to the lifting cable, 3) box containing the hoist and suspension subsystems, and 4) the safety system.

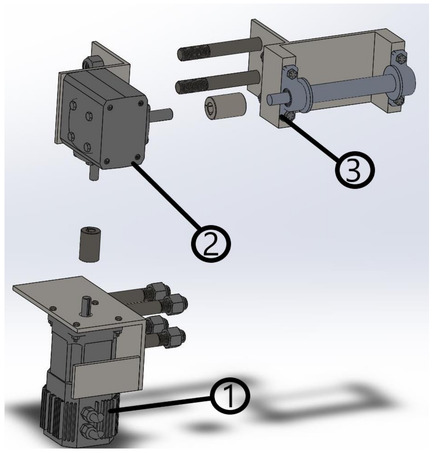


Fig. 3 Exploded view of the hoist and suspension system components which are inside the box from Fig. 2. Depicted here is a motor (1) attached to a speed reducer (2) which provides power to the spool (3). In addition to the main motor mount, there is also a side support to reduce motor instability due to vibrations.

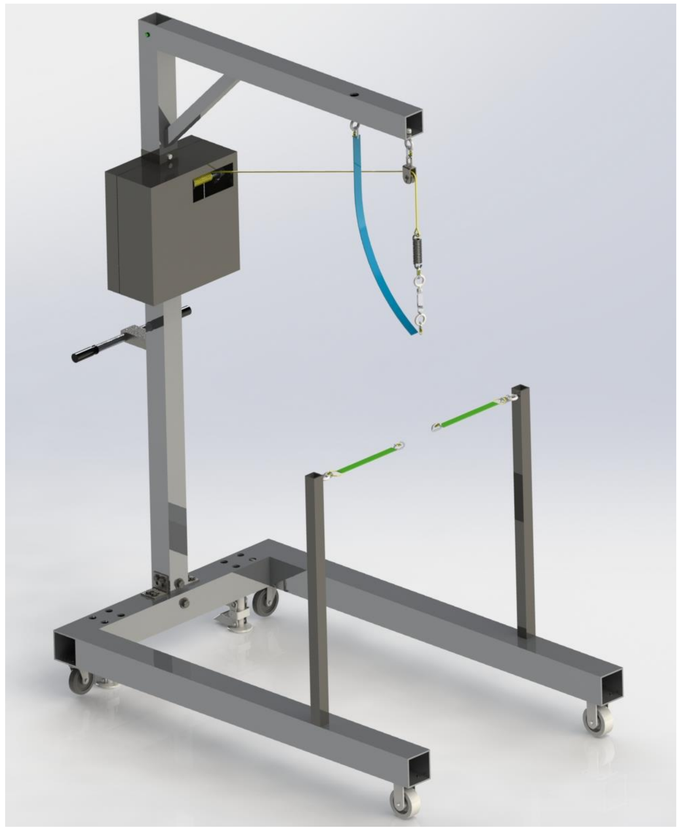
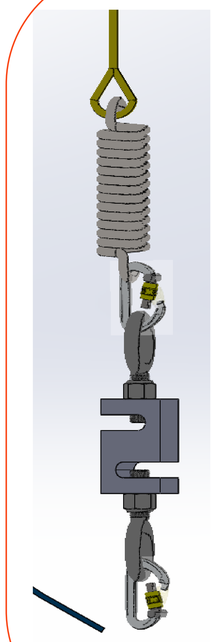


Fig. 1 Rendered image of the full device.



Force Sensor/Suspension Spring Key Features

Spring: Provides smooth, continuous vertical translations for the user as they exercise. This is accomplished as the spring absorbs energy from vertical oscillations. The spring has a stiffness of 501 lbs/in.

Sensor: Provides real time continuous data acquisition at 0.1 lb increments with an accuracy ±1.6 oz. The sensor has a max capacity of 500 lbs which is more than enough to support the max user weight of 350 lbs. This is a resistive type sensor.

Fig. 4 Image depicting the suspension spring and Force sensor attached to the lifting cable.

Narrative Summary

This lift and harness system will be used to raise up patients with neuromuscular disorders (ND's) from a seated position to allow for the use of a motorized FES elliptical machine. The product will allow for an offset weight input so that each patient will be able to have their own individualized therapy plan. The product has been broken down into five subassemblies of the frame, hoist, suspension, sensor, and safety. The frame is the structural support of the entire lift and harness system. It is used to get the user from point A to B and is used to mount the other components. The hoist mechanism is a motor and a speed reducer that winds the spool to lift and suspend the user and provides non-stop support. The suspension system controls the motor to maintain continuous offset weight. The safety system consists of tethers attached to the top of the frame and to the vertical bars on the sides to catch the user if the design were to fail and prevent the user from falling in any direction. Lastly, the force sensor attached to the cable that suspends the user will measure the tension associated with the user's weight. The data will be sent to the suspension system to adjust the offset weight.

Failure Analysis

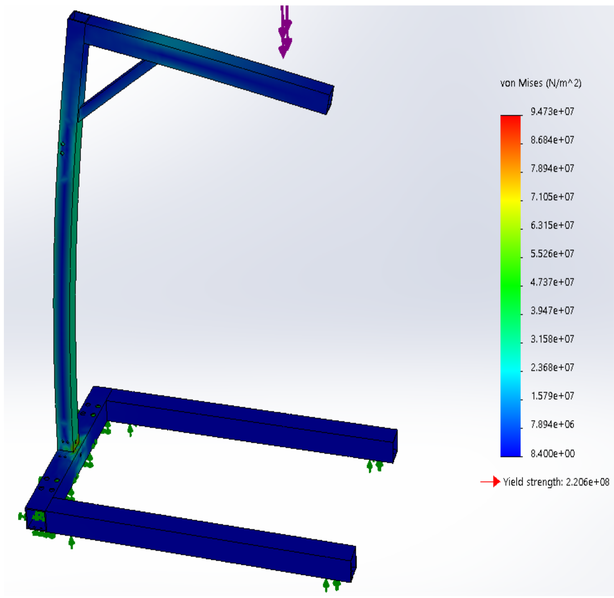


Fig. 5 Von Mises stress plot of frame with patient load applied.

Finite element analysis Stress plot of the device frame loaded with 350 lbs (maximum user weight). The maximum stress found after the analysis was 14,895.38 psi. The frame is made of ASTM A500 grade B steel which has a yield strength 45,700 psi. The factor of safety is 3.07, therefore the frame can withstand all forces it will be subjected to.

Cost

- OTS Parts: $3612.58
- Raw Materials: $139.45
- Manufacturing and MFG Labor: $146.61
- Energy Consumption: $0.04
- Assembly Labor: $160.00

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Customer Needs Mapping

	Customer Need	Quantitative Metric	Sub-System: Feature
1.	System height, width, and floor print are cleared by ADA regulations	h < 90 in w < 32 in weight < 2000 lb/ft^2	Frame: Two easily assembled pieces and narrowness/ lightness of frame
2.	Powered by standard wall outlet	Powered by 120 VAC electricity and outlet with 15 A breaker capacity	Sensor and Motor: Energy consumption does not exceed 120 VAC for either
3.	User can stand and exercise without interference	Boundary conditions of FES elliptical system and 95% male must not interact vertically	Suspension: Tight geometry of the suspension keeps the user clear of elliptical
4.	Supports full weight of the user	Supports 350 lb.	Hoist: High motor torque Frame: Steel frame
5.	Acceptable factor of safety	Factor of Safety > 1	Frame: Factor of Safety = 3.07
6.	Includes a fail-safe system	Fail safe that can support multi-directional fall and max weight + impulse of a fall	Frame: vertical guide rails Safety: 3 tethers with sufficient tautness and strength in diverse geometries
7.	User can be transported at comfortable speeds	Comparatively slow motor that still completes customer need 4	Hoist: Low Motor RPM
8.	Prevent the user from swinging and interfering with elliptical in horizontal direction	Boundary conditions of FES elliptical system and 95% male must not interact horizontally	Frame: short hanging bar Safety: taut vertical tether
9.	User translate unencumbered vertically	h_{max} of frame > height of 95% male user + h_{max} of elliptical pedals	Frame: Tell vertical beam and shor hanging beam to limit user/system interaction
10.	Prevent user from losing sagittal balance	Adaptable and strong vertical control	Safety: strong/taut vertical tether Frame: Floor locks
11.	Prevent user from losing transverse balance	Adaptable and strong horizontal control	Safety: strong/taut horizontal tethers Frame: Floor locks
12.	Lift user from seat to fully suspended	Can translate a 350 lb person from seat to fully suspended	Hoist: Motor with a sufficient torque Frame: Steel material that can handle 350 lb
13.	Moves fully suspended user to elliptical	Can vertically translate a 350 lb user	Frame: Mobile multi-direction caster wheels
14.	Holds the user suspended	Handle 350 lb user and keeps stable	Hoist: Motor with a sufficient torque Safety: Horizontal Tethers
15.	Accommodate 5% female to 95% male	Frame higher than 95% male and adjustable harness	Frame: tall frame, short hanging bar, and adjustable harness
16.	Slowly transition to preset offset weight	Slow / controlled motor	Hoist: motor with a low RPM
17.	User can select offset weight between 0-100% of body weight	System can be controlled to offset 0-350 lb of body weight	Hoist: Motor with a high torque that can be controlled for each weight
18.	Can be mounted from ceiling, wall, or floor	Able to mount on ceiling, wall, or floor	Frame: Floor-based mounting and floor locks
19.	Provides continuous offset weight support	High reaction speed of hoist	Hoist: Speed reducer offers diverse speed choices
20.	Offset weight support feels continuous	Controller reacts quickly and suspension provides weight offset at top and bottom of periodic motion	Sensor: Force sensor on vertical tether continuously monitors offset Suspension: Controlled by input from force sensor
21.	Provide pre-set multi-directional weight offset	Provide pre-set multi-directional weight offset	Suspension: geometry offers universal weight offset
22.	Programmable	Programmable	Suspension: offset weight can be programmed Sensor: Force sensor can be programmed
23.	Intuitive user interface	Intuitive and simple user interface	Hoist and Suspension: Easy access with accessible casing
24.	Prototype cost for materials cannot exceed $4000	Prototype cost < $4000	All sub-systems: Cost = $4058.00
25.	Emergency shut-off switch included	Emergency shut-off switch included	Safety: Kill switch on vertical strut connected to hoist and elliptical to shut down motion
26.	Shut-off if max force is exceeded or if there is an unprecedented change	Recognize when max force is exceeded and for unprecedented change in system	Sensor: Force sensor on vertical tether connected to control box monitoring for max or unexpected force with a set limit in place to shut-off at
27.	Visual indicator to show when the system is on, is mode, and offset weight	Visual indicator included to show array of options	Frame: Visual indicator on vertical strut
28.	Operational lifetime is three times standard elliptical trainer	Operational lifetime > 60 years	Frame: Steel frame with usable lifetime under periodic motion > 60 years
29.	FES pads must be accessible	System must not interfere accessibility to FES pads	Frame: Open and uncluttered design to allow for accessibility
30.	Overall footprint of the system cannot exceed 8’x10’	Overall footprint of the system cannot exceed 8’x10’	Frame: Narrow design that is 6.4’x4’