Product Design Specifications

Autonomous Wheelchair Restraint Adaptations

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Function:

Moving the body has so many benefits for the brain, muscles, bones, joints, intestines, heart, lungs and many other organs. Movement is also beneficial for a number of bodily functions such as blood flow, digestion, muscle strength, bone health, and many more. Many wheelchair users are currently unable to take advantage of these benefits due to movement challenges they experience, especially those suffering from neuromuscular conditions or spinal injuries. Neuromuscular conditions inhibit the straightening of joints, limiting the overall mobility of the patient and forcing them to stay seated in one position for the duration of the day. The cost of hiring a CNA or licenced physical therapist is quite expensive and usually is not covered by health insurance for those affected by a permanent disability. The goal of this project is to develop a device that enables wheelchair users to move in various positions, allowing them to strengthen muscles, aid in bodily functions, and help reduce their current movement limitations.

Client requirements:

- Wheelchair restraint adaptations must allow autonomous use
- Must be able to secure user while at maximum standing position
- Cannot impede entry to wheelchair via ceiling lift
- Motorized to allow straightforward implementation

Design requirements:

1. Physical and Operational Characteristics
    A. *Performance requirements:* The device will be used by one individual on a daily basis, multiple times a day. The device must be in its active position during the duration of operation, for up to 8 hours at a time. The device's movement will be at the beginning and end of use and must hold in the restrained position during use and in the relaxed

position when not in use. The device will need to prevent the user from being ejected out of the wheelchair when enduring non-flat surfaces, too fast of acceleration, and abrupt stops.

B. *Safety:* When designing the device, the mechanical and electrical hazards that could arise must be considered. The electrical components must not shock the user, and the device must have a manual override to prevent the user from being stuck in the chair. The mechanical restraints cannot injure the user while entering their position, and the leg restraints cannot apply an excessive force on the user while in the standing position.
C. *Accuracy and Reliability:* The chest restraint must enter its designated position within +/- 25mm during 99% of the total number of uses. The leg restraint must enter its designated position within +/- 10mm during 99% of the total number of uses.
D. *Life in Service:* This device must function for a minimum of 3-5 years with potential daily use from the end user. Each use of the device is one cycle and may have multiple cycles per day. The average lifespan of a DC brushless motor is approximately 2-4 years, or around 20,000 hours of operation [1]. The expected lifespan of a Nucleo microcontroller is 10 years in service. [2]
E. *Shelf Life:* The device must be stored in a dry environment to mitigate damage of the electrical components. Under ideal storage and usage conditions the motor should operate for a projected 3-5 years. The device microcontroller will last a projected 10 years under proper storage conditions.
F. *Operating Environment:* The device may be used in a variety of temperatures ranging from -48 °C to 46 °C[3]. The device will also encounter varying humidities ranging from 30% to 83.8% [4][5] Various weather including, but not limited to rain, lightning, snow, hail. The device may come in contact with dirt, dust, or mud during use.
G. *Ergonomics:* The device must not impede the operation of the wheelchair by the user. Additionally, the device must not leave painful or irritating marks or scratches on the subject. Therefore, no sharp edges or points may be present in the device. The restraints must provide a comfortable and secure hold on the user during operation.
H. *Size:* The device must not exceed a width of 91.5cm and a height of 203cm during usage to allow movement through a standard door frame. The leg restraints must have an opening space of at least 30cm of length and 12.5cm in width to allow the users feet to enter unimpeded.
I. *Weight:* The chest restraint and motor must not exceed a combined weight of 22.5kg to ensure the wheelchair will not tip over while the restraint is at rest. The leg restraint must not weigh more than 9.0kg to ensure the restraint can be removed if necessary and does not weigh excessively.
J. *Materials:* The device will be fabricated using aluminum or stainless steel due to the materials' properties and corrosion resistance. DC brushless motors will be used for

powered components due to their longevity and performance. The Nucleo microcontroller will be used due to the longevity and simplicity of code implementation.

K. *Aesthetics, Appearance, and Finish:* The device's appearance must not stand out from the wheelchair it is attached to in order to be indistinguishable from the wheelchair. The device must be a neutral color and must not protrude excessively past the existing bounds of the wheelchair. The device's finish must be minimal to reduce attention drawn to the device.

2. Production Characteristics
   A. *Quantity:* One device should be constructed for testing and usage purposes for the client.
   B. *Target Product Cost:* The device should cost under the $2000 specified budget.

3. Miscellaneous
   A. *Standards and Specifications:* Currently, there are no specific OSHA standards for a device similar to this. There are standards for safe patient handling and transferring that should be enforced when the client is moving from his chair to the device [6]. These standards also include solutions to maintain a safe environment for a patient. The FDA regulates medical devices that individuals use in their homes. This device would fall under the FDA's definition of a medical device, which states a medical device is "an instrument, apparatus, implement, machine ... or accessory which is … intended to affect the structure or any function of the body of man or other animals" [7]
   B. *Customer:* The customer wishes to have a product that can increase his movement and blood flow. He wishes to autonomously operate his standing wheelchair to achieve an upright standing position. He does not like the feeling of being in the same position seated for a majority of the day, and hopes the design reduces that problem. The device must effectively operate over an extended period of time
   C. *Patient-related concerns:* The client and potential future users will need to be able to access the device using a ceiling lift or hoyer lift.
   D. *Competition:* There are currently no devices on the market that fulfill the client's needs to autonomously implement the standing wheelchair restraints.

References

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