X-Chair: Autonomous Wheelchair Restraint Adaptations

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BME Capstone Design 402

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Abstract

Many wheelchair users are unable to achieve the health benefits of whole-body movement due to mobility limitations. Neuromuscular conditions inhibit the straightening of joints, limiting the overall mobility of the patient, and forcing them to stay in a seated position for the majority of the day. The client, who has been diagnosed with Spinal Muscular Atrophy (SMA), has requested a device to enable autonomous body movements, via their standing wheelchair, to further prevent atrophy of his muscles and aid in bodily functions. The team has developed a design that uses motorized supports to effectively secure the client within their standing wheelchair, and allowing independent operation by the user. This design will allow the client to access and operate their standing wheelchair autonomously by enabling the user to position the restraints themselves, something previously unattainable. Due to a variety of obstacles, the team began fabrication during the second semester. The team has made significant progress but due to material delays, has been unable to complete fabrication. As a result, we have devised a hypothetical testing plan for a variety of the components. The team will have adequate documentation in order to make a seamless transition of our prototype to a future design team for final completion.

Problem

- Client is unable to enter sit-to-stand wheelchair independently because he cannot move his legs, and has limited upper mobility strength
- Client needs to be able to use STS wheelchair function to increase blood flow, improve digestion, and better his bone health
- Client needs powered restraints that require no strength or dexterity of upper or lower extremities

Motivation

Figure 1: Client's Permobil Sit-to-Stand Wheelchair

- 3.3 million wheelchair users in the U.S. [1]
- 75 million wheelchair users worldwide [2]
- Mobility benefits from a using a sit-to-stand wheelchair independently
- Allows users to move into positions that are usually unattainable
- Increase in blood flow and movement
  - Improves
    - Muscle strength
    - Bone health
    - Blood flow
    - Digestion

Figure 2: Handicap Symbol

Background

- Spinal Muscular Atrophy (SMA) [3]
  - Genetic disease
  - Affects voluntary muscle movement
  - Deficiency of motor neuron protein called SMN
  - Proximal muscles impacted before distal
- Exercising can improve… [4]
  - Range of motion
  - Muscle strength
  - Posture
  - Contractions
  - Blood circulation
  - Physical and mental well-being

Figure 3: SMA patient exercising with PT [3]

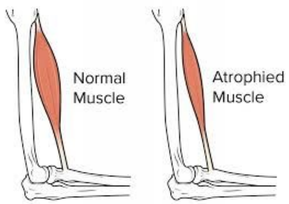


Figure 4: Normal vs Atrophied Muscle [3]

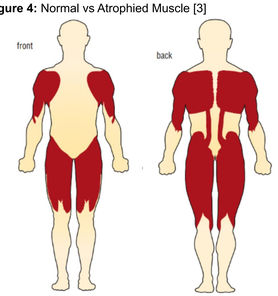


Figure 5: The red regions are the proximal muscles which are affected first in patients with SMA [3]

Design Criteria

- Autonomous functionality: client should be able to use the device without outside assistance
- Safely secure user when in standing position: secure and release restraints only in seated position
- Allow for entry via a ceiling lift: cannot restrict access from directly above wheelchair seat
- Accessible user operation: client can reposition supports with an accessible control panel
- Must be capable of at least 14 hours of use in one day while remaining fully functional

Final Design

Figure 6: Overall Design Implemented on STS Wheelchair

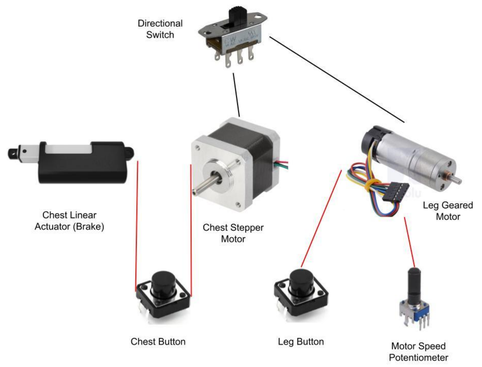


Figure 7: Electronic Control System Diagram

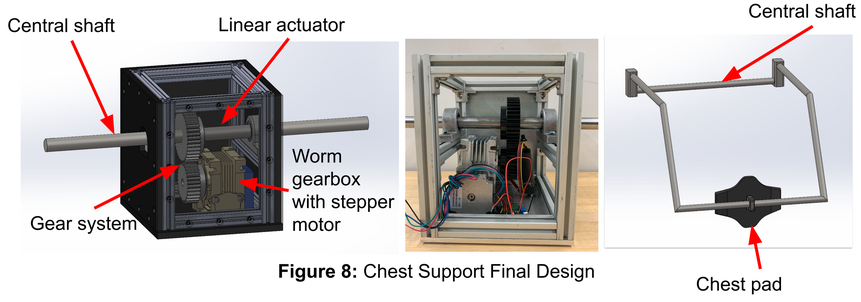


Figure 8: Chest Support Final Design

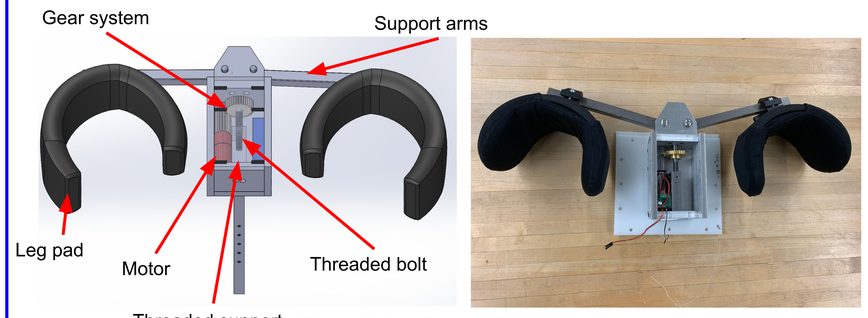
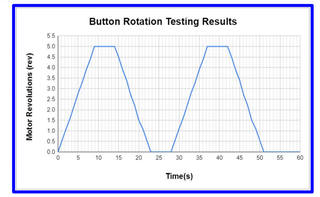
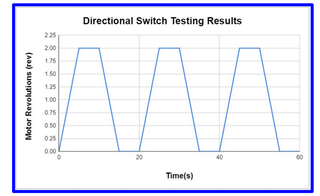


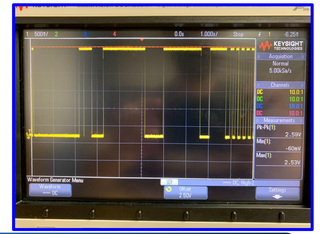
Figure 9: Leg Support Final Design

Testing

- Electronics:
  - Button to rotation communication
    - Motor revolves during 5 second periods of button presses
    - Ensures that the motor rotates when the chest or leg buttons are activated
  - Results: 100% accuracy out of 25 trials
  - Direction switch
    - Motor's direction changes when the engage switch is flipped
    - Ensures the motor rotates the correct direction
  - Results: 100% accuracy out of 25 trials
  - Force Sensor Calibration
    - An increased voltage output occurs when a force is detected on a sensor
    - Will ensure that the supports do not continue to engage after the engage button is no longer being pressed
  - Results: force sensors accurately detect pressure







Future Work

- Chest Support Fabrication
  - Integration of stepper motor and hardware components
  - Outsource client-customized, padded support bar and support
  - Design simpler method of attaching box plates
- Leg Support Fabrication
  - Attach foam padding for leg restraint
  - Outsource client-customized supports
  - Mitigate binding of rack & pinion system
- Hardware and software
  - Design PCB for control system
  - Integrate ultra-low power microcontroller operation
  - Install limit switches and force resistors
- Verification & Validation Testing
  - Position Repeatability
  - Daily Timed Stress
  - Fail-safe verification

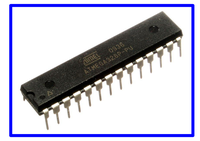


Figure 10: ATMega Microcontroller

Figure 11: Force-sensing Resistor

Figure 12: Limit Switch

Acknowledgements

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References

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