Design and Implementation of an Adaptive Robotic Head Support for Children with Low Head Control

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Abstract

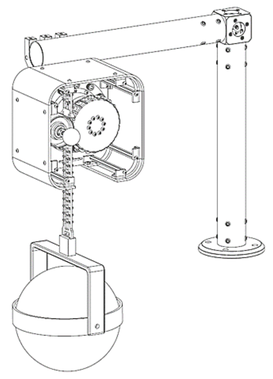
Research topic: Designing and conducting preliminary benchtop testing of a new head-neck rehabilitation robot.

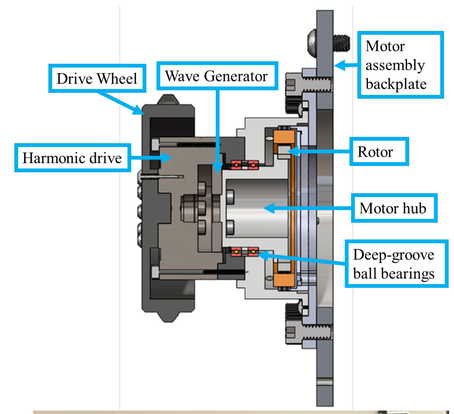
The Adaptive Robotic Head Support is mechanically capable of:
1. Sustaining the weight of a child's head (~20 N) at rest,
2. Lifting a child's head from rest,
3. Axial loading to resist motion up to approximately 75 N,
4. Supporting 180-degree rotational cervical range of motion,
5. Estimating position using Hall Sensors within the motor.

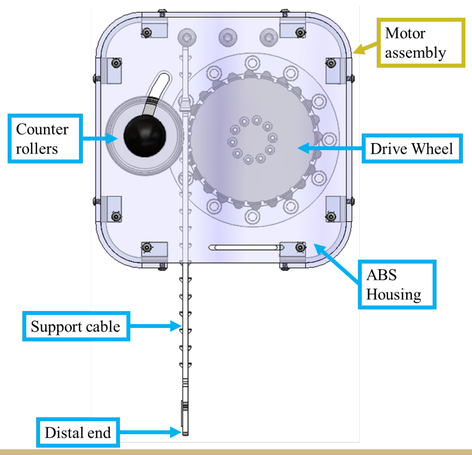
The 1-DoF head support can vary the amount of support provided to users who may lack the trunk control required to maintain an upright head posture for extended periods. Mechanical testing performed in this study demonstrate physical capability to support a 6-year-old's head prior to human testing.

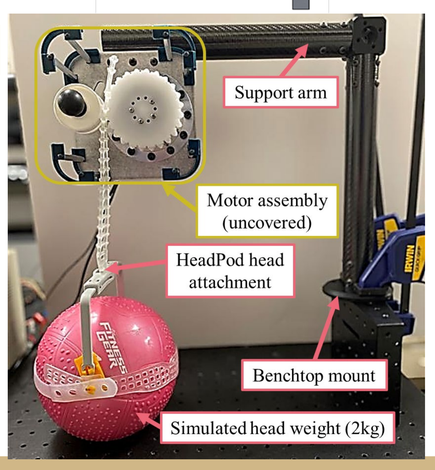
Designing a 1-DoF Robotic Head Support

- The head support was designed to mount behind a user's chair and reinforce the weight of the head from above.



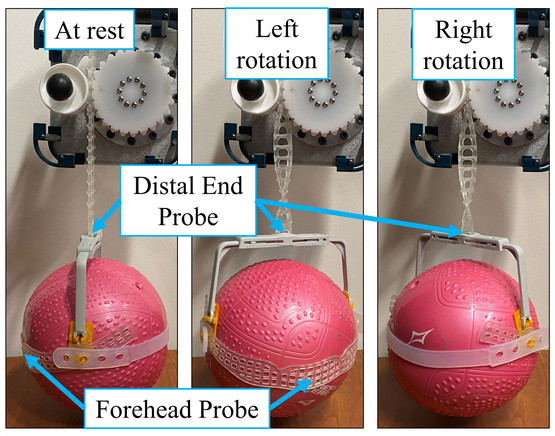


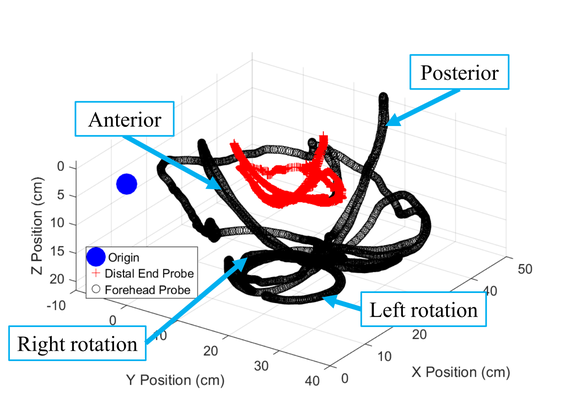


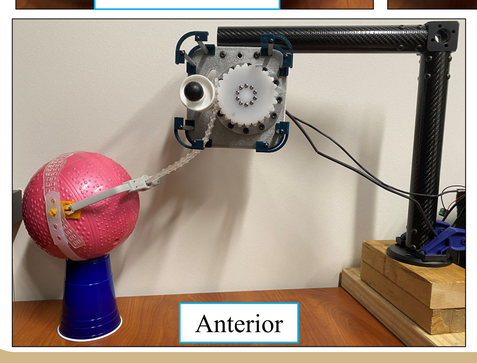


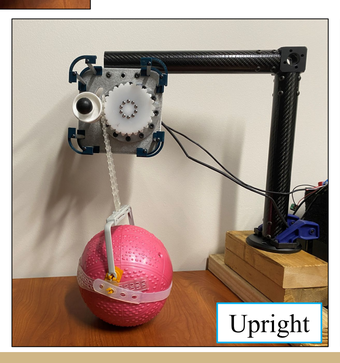
Estimating Range of Motion

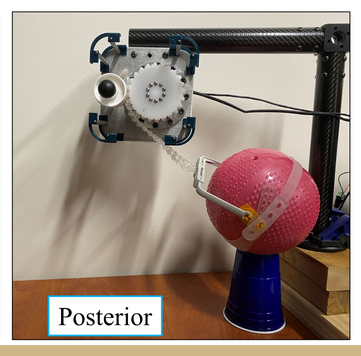
- A 2 kg medicine ball was turned 180 degrees each direction to demonstrate that the robot supports full cervical rotation.
- Polhemus Motion Capture tracked the rotational movement of the head while being able to feed the support strap.





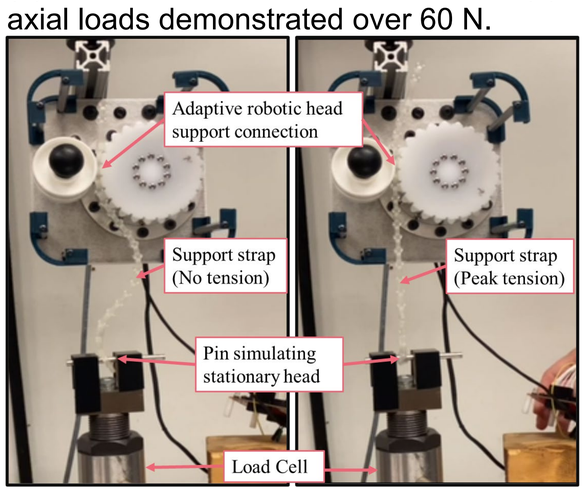


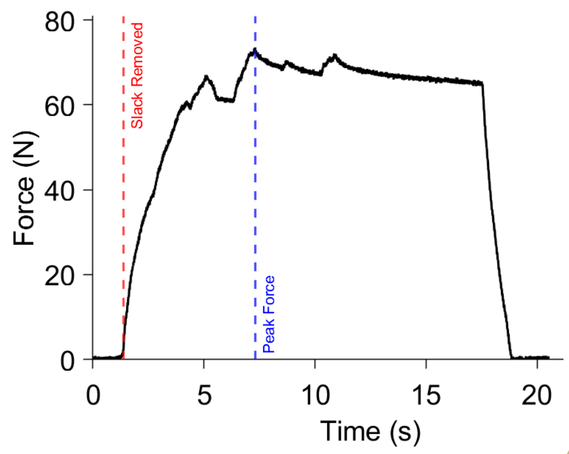




Axial Loading Tests

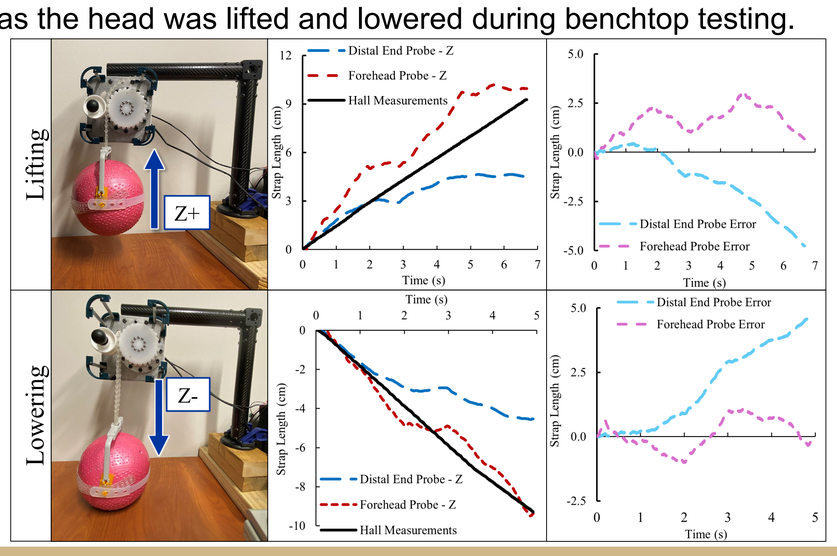
- The head support was affixed to a tensile tester and lifted from no tension until the motor stalled (n=20). Maximum forces measured in axial tension reached up to 73.6 N (66.1 ± 3.9 N).
- Time to motor stall ranged from 3.31 to 6.65 s (4.06 ± 0.98 s).
- Enough force is produced to (a) assist user head motion, sustain forces up to 20 N; (b) lift the head from rest, F > 20 N; or (c) resist volitional head movements, peak axial loads demonstrated over 60 N.





MoCap vs Hall Sensor Position Tracking

- External motion capture showed out-of-plane movement that was not captured by the motor's position Hall sensor.
- The error between the head attachment and the Hall sensor measurements increased as the head was lifted and lowered during benchtop testing.



Summary

The Adaptive Robotic Head Support is mechanically capable of:
1. Partially supporting the weight of a child's head,
2. Fully supporting the weight of a child's head,
3. Resisting volitional motion away from an upright position, and
4. Returning the child's head to an upright position if needed.

The prototype relies on position tracking via Hall sensor position, although out-of-plane movement is not captured by the Hall sensor readings. External motion capture is still needed to evaluate the prototype.

A healthy 6-year-old should be able to rotate their head freely in the transverse plane, while lateral bending, extension, and flexion would be constrained by the head support's strap length.

Future Work

- Comfort & usability testing with healthy control user.
- Motion capture of head-neck movements with healthy subject with and without head support.
- Identify rehabilitation measures of head-neck mobility.
- Feasibility testing with patients who have CP.
- Comparison of 1) no support, 2) passive support, 3) powered support for children with CP.
- Longitudinal evaluation of benefits / risks associated with the head support.

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