Design and Development of a Smart Wheelchair-Mounted Robotic Exoskeleton for People with Reduced Upper Limb Movements

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INTRODUCTION: Cerebral Palsy, Duchenne Muscular Dystrophy, and stroke not only often impair lower extremities, leading to reliance on wheelchairs, but also upper extremity mobility for such patients, severely limiting their ability to perform activities of daily living. One solution to this is the exoskeleton; however, most commercially-available are bulky and heavy, making them inherently stationary.

PURPOSE: The purpose of this study was to develop a portable, smart, and light-weight wheelchair-mounted robotic exoskeleton that augments elbow and shoulder flexion/extension and shoulder horizontal abduction/adduction.

METHODS: The exoskeleton was modeled in SolidWorks and a finite element analysis (FEA) was conducted to determine maximum stress and displacement. The Denvait-Hartenberg (DH) method was applied to calculate an end-effector workspace. The exoskeleton was prototyped from PLA and NylonX materials using a RAISE 3D Pro2 Plus printer. A smart assistive controller mechanism was designed to acquire force myography (FMG) signals from a human arm to actuate three NEMA 17 stepper motors through bipolar stepper motor controllers using FMG signals. An Institutional Review Board approval was acquired prior to human subject testing.

RESULTS: FEA results show 429.1 MPa maximum von Mises stress on one of the upper arm to lower arm links and maximum displacement of 1.65 cm at the front inside edge of the forearm shell. The end-effector can reach up to 11.57” in x-direction, 8.32” in y-direction, and 15.75” in z-direction based on DH parameters. Overall, the exoskeleton weighs less than 3 kg and costs around $800. Two participants were initially tested to observe the proposed smart controller mechanism for actuation.

CONCLUSION: FEA results show further reinforcement is needed for structural robustness of the design. Human subject testing shows promise of the force myography control system for intuitive control of the exoskeleton.

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