Title: Improving an assistive glove for stroke survivors using advanced biomechanical model

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To assist with stroke survivors' finger opening for grasping objects in daily living, assistive gloves exist. Specifically, a cable-driven assistive glove assists the finger opening by pulling a cable that runs on top of the hand, from the wrist to the tip of the fingers, guided by cable supports. The current glove has the cable running parallel to the hand, applying suboptimally distributed forces/moments across the three finger joints (DIP, PIP and MCP), causing unnatural finger opening trajectory and discomfort. This study aimed to improve the current glove design using biomechanical modeling to predict the optimal glove design that will result in natural hand opening for stroke survivors.

We developed a dynamic biomechanical model for the hand wearing an assistive glove. MATLAB simulations predicted the trajectory of stroke survivors' hand opening when assistance (tension) is applied to the cable. We used the joint stiffness (0.5 Nm/rad) and damping coefficient (0.01 Nm/rad/s) documented for stroke survivors, and average hand size and weight for healthy people. The model output the finger joint angle profiles during finger opening, given inputs of cable support heights at four finger locations and cable tension. Optimization determined the optimum glove design that resulted in minimum deviation between the simulated joint angles for stroke survivors using the glove and measured joint angles for a healthy subject opening the fingers (control; obtained using 3D motion capture system). The deviation was computed as the sum of norms of three joints' error vectors. The error vector was the difference between the simulated and control joint angles over 100 time points, from the beginning till the end of finger opening. After obtaining the optimal design parameters from the optimization, we compared the deviations for the optimal design vs. the current glove (with the cable support height of 9 mm along the hand and cable tension of 250 N).

The optimum glove design was determined to be the cable support heights of 10.9, 9.0, 29.7, and 14.9 mm at the fingertip, DIP, PIP, and MCP joints, respectively, with the cable tension of 53.2 N. The deviation from the control hand opening trajectory was less for the optimal glove design (4.4 rad) than the current glove (15.9 rad).

Our results showed that the cable-driven assistive glove can be modified with the new optimum design parameters for better finger opening assistance and performance for stroke survivors. This study demonstrates the potential that biomechanical modeling can be used to optimize design for an assistive device, and improve rehabilitation processes. Our next step is to evaluate this model prediction clinically.