Forward Reach-to-Grasp Movement Performance with a Powered Elbow Exoskeleton

Pei-Chun Kao[1], Yi-Ning Wu[1], Hannah Allgood[1], Lian Orifice[2], Cooper Ferrari[1], Holly Yanco[3]

I. MOTIVATION

Powered upper-limb exoskeletons hold promise in augmenting or restoring the ability to perform activities of daily living (ADLs) for individuals with limited upper-limb movement function or strength [1]. However, it is important to ensure that these devices assist users in functional tasks without impeding their natural movement patterns. This study aims to investigate reach-to-grasp movements when using a myoelectric-controlled, powered upper-limb exoskeleton (MyoPro, Myomo, Inc.) [2]. We compared forward reach-to-grasp movement performance with and without powered assistance, as well as without wearing the exoskeleton, across three practice blocks. The insights gained from this study could help improve upper-limb exoskeleton designs.

II. METHODOLOGY

Ten healthy young participants performed reach-to-grasp movements in both forward and randomized directions under three conditions: without wearing the exoskeleton (NoEXO), wearing the exoskeleton with and without the power (EXO-powered and EXO-unpowered, respectively) (**Fig. 1**). Each practice block for forward reach comprised 10 repetitions of reach-to-grasp movements (**Table 1**). For the randomized reach blocks, participants completed 30-50 trials of reach-to-grasp movements toward three or five locations in a randomized sequence.

Figure 1. Experimental setup

Table 1. Experimental protocol.

Block 1 (Early) Forward reach (10 trials)	Reaching in randomized directions (30-50 trials)	**Block 2 (Mid)** Forward reach (10 trials)	Reaching in randomized directions (30-50 trials)	**Block 3 (Late)** Forward reach (10 trials)

An 8-camera motion capture system was used to record the positions of reflective markers attached to participants' bony landmarks, including the sternum, acromion (shoulder), lateral epicondyle (elbow), lateral styloid process (wrist), thumb and index finger. Spatiotemporal measures were used to assess the performance of both the reach-to-grasp (i.e., Reach) and grasp-and-return (i.e., Return) phases of the movement, including the mean and variability (coefficient of variation) of time duration, peak transport velocity, normalized time to achieve peak transport velocity (as a % of the Reach or Return phase), normalized time to achieve peak aperture (% of the Reach phase), and the range of the 3-D wrist marker trajectory during both Reach and Return. We used two-way repeated measures ANOVAs to test for differences in the outcome measures between the three conditions and the three practice blocks.

III. RESULTS AND DISCUSSION

We found significant condition effects across nearly all measures, with no significant difference among the three practice blocks. During EXO-powered, participants took the longest time to complete the Reach, Return, and the entire reach-grasp-return movement, compared to EXO-unpowered and/or NoEXO. Peak transport velocities during Reach and Return were the slowest when EXO-powered. Although the timings of peak transport velocity during EXO-powered were similar to EXO-unpowered, they occurred significantly earlier during Reach and significantly later during Return, compared to NoEXO. Additionally, the timing of reaching maximum aperture during Reach was similar between EXO-powered and EXO-unpowered conditions but significantly earlier than in the NoEXO condition. In terms of the range of reaching movement trajectories, participants exhibited significantly smaller ranges in all three dimensions during the Reach phase with EXO-powered compared to EXO-unpowered and/or NoEXO. Similarly, during the Return phase, participants demonstrated a reduced movement range in the anterior-posterior and medio-lateral directions, while maintaining similar vertical movement range with EXO-powered. Furthermore, there was significantly greater variability observed in all spatiotemporal measures during EXO-powered, whereas EXO-unpowered and NoEXO conditions exhibited similar variability. While the movement restriction posed by the exoskeleton brace itself presents a challenge, the findings of this study suggest that implementing an adaptive controller that can dynamically update the control parameters might facilitate a more natural movement performance and learning for exoskeleton users.

REFERENCES

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[1] P-C Kao (Phone: 978-934-4399; email: PeiChun_Kao@uml.edu), Y-N Wu, H. Allgood, and C. Ferrari are with the Department of Physical Therapy and Kinesiology, University of Massachusetts Lowell, Lowell, MA 01854.

[2] L. Orifice is with the Department of Biomedical Engineering, University of Massachusetts Lowell, Lowell, MA 01854.

[3] H. Yanco is with the Department of Computer Science, University of Massachusetts Lowell, Lowell, MA 01854.