Feasibility of a Passive Exoskeleton for Shoulder Abduction Support in People with Stroke

Elizabeth D. Vasquez[1], Cole S Simpson[2], Genggeng Zhou[1], Grace Waguespack[1], Bryce N. Huerta[1], Elliot W. Hawkes[3], Maarten G Lansberg[4], Allison M. Okamura[1]

Summary—**Post-stroke upper extremity function can be improved by devices that support shoulder abduction. Many of these devices are inaccessible or unportable – limiting their utility for assistance in activities of daily living. Here, we describe a wearable device to aid in arm abduction, a clinical trial planned to evaluate its effectiveness, and pilot data from use by a stroke survivor.**

I. INTRODUCTION

Stroke – damage caused by loss of circulation to part of the brain – is a leading cause of long-term disability. High volumes of activity using stroke affected limbs are thought to yield more complete motor recovery. Assistive devices can help stroke survivors exercise stroke affected limbs more frequently and for longer periods of time. One class of assistive devices are those that support shoulder abduction and have been shown to increase reachable workspace [1] which is essential for both efficacy of therapy and activities of daily living (ADLs). However, many such devices are heavy, complex, and costly – making them difficult for stroke survivors to use. Here, we present clinical metrics we will use to test the use of a lightweight, passive, low-cost wearable shoulder abduction support device by stroke survivors and results from a pilot trial.

II. METHODS

Our exoskeleton generates a moment that supports the user in shoulder abduction via energy stored in elastic bands connected to a 1 degree of freedom aluminum exoskeletal frame. The frame attaches to a 3D printed arm cup via a quick release push pin connection and to daisy chains sewn into a neoprene posture vest via carabiners or zip ties. The user wears both the arm cup and the vest to use the device which is depicted in Figure 1a. For further details on the device design and moment profile see the following thesis [2].

The exoskeleton was tested in healthy participants where it was shown to reduce muscle activation and not inhibit range of motion [2], but until this point was not tested in stroke survivors. A clinical trial is underway to determine if the device can improve two metrics in stroke survivors (1) reachable workspace area in the transverse plane and (2) quality and time of movement in ADLs. For metric 1, we followed the protocol used to measure reachable workspace in Simpson *et al.* [3] and placed motion capture markers on the following positions: C7, Sternoclavicular, Acromion, Humeral Head, Olecranon, Lateral Humeral Epicondyle, Medial Radial Styloid, and Ulnar Styloid. Participants are asked to trace the six largest circle-like shapes possible by moving their elbow and shoulder at shoulder level both with and without the device in a randomized order. We used the boundary function in MATLAB to compute the largest

[1]Department of Mechanical Engineering, Stanford University, Stanford, CA. {vasqueze, g9zhou, bhuerta, aokamura}@stanford.edu, gwaguespack22@alumni.stanford.edu
[2]Intuitive Surgical Inc., Sunnyvale, CA. colesimpson@alumni.stanford.edu
[3]Department of Mechanical Engineering, University of California at Santa Barbara, Santa Barbara, CA. ewhawkes@engineering.ucsb.edu
[4]Department of Neurology and Neurological Sciences, Stanford University Medical Center, Palo Alto, CA. lansberg@stanford.edu

concave boundary formed by the movement of the wrist marker. Following the procedures of Simpson *et al.* [3], we remove data from LED markers that fall below 20 cm of shoulder level. For metric 2, we perform the Wolf Motor Function Test (WMFT) with and without the device to test motor ability in a series of "everyday" task such as: placing the forearm on a box, hand on a box, lifting a basket, and turning a key in a lock [4].

III. PILOT RESULTS AND DISCUSSION

The participant stated no difficulties moving with the device, and both WMFT and workspace tasks were performable with the device. Workspace (Figure 1B) improved from 0.04 to 0.11 meters squared, and the WMFT functional score for the forearm to box task improved from a 4 to a 5 when wearing the device. Other WMFT scores were either the same or worse in the second trial (unassisted) possibly due to learning effects. Further pilots are needed to determine if a longer training period is necessary.
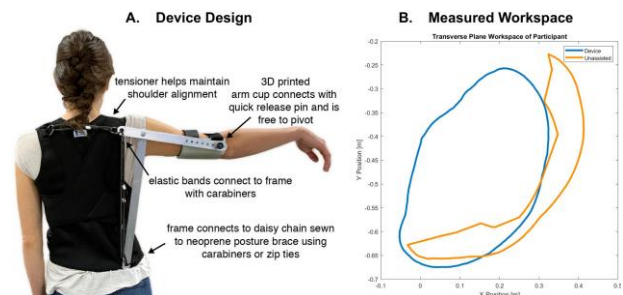

Figure 1. **Design and Workspace: A**. Device design calling out components of wearable **B.** Transverse plane workspace area with and without the device

We have shown that the device is comfortable and clinical metrics are measurable while a stroke survivor wears the device. Our exoskeleton's low-cost and lightweight nature makes for a more accessible shoulder abduction support device capable of improving the quality of therapy and aiding in ADLs. Future work includes possible adjustment and completion of the clinical trial and an ergonomic redesign of the device to make it easier to don and doff.

IV. REFERENCES

[1] T. M. Sukal, M. D. Ellis, and J. P. Dewald, "Shoulder abduction-induced reductions in reaching work area following hemiparetic stroke: Neuroscientific implications," *Exp. Brain Res*., vol. 183, no. 2, pp. 215-223, 2007.

[2] C. Simpson, "Wearable Devices for Physical Assistance: Enhancing Capabilities After Stroke and in Running," Ph.D. dissertation, Dept. Mech. Eng., Stanford University, Stanford, CA, USA, pp. 59-67, 2020.

[3] C. Simpson, B. Huerta, S. Sketch, M. Lansberg, E. Hawkes, and A. M. Okamura, "Upper Extremity Exomuscle for Shoulder Abduction Support," *IEEE Trans. Med. Robot. Bionics,* vol. 2, no. 3, pp. 474-484, 2020

[4] D. M. Morris, G. Uswatte, J. E. Cargo, E. W. Cook, and E. Taub, "The reliability of the Wolf Motor Function Test for assessing upper extremity function after stroke," *Arch. Phys. Med. Rehabil.*, vol. 82, no. 6, pp. 750-755, 2001