The Utilization Effects of Powered Wearable Orthotics in Improving Upper Extremity Function in Persons with SCI: A Case Study

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Abstract Persons with upper extremity (UE) impairments due to spinal cord injury (SCI) have limited capacity to move or perform basic activities of daily living (ADL). Such movement limitations significantly reduce a patient's quality of life (QOL) and level of independence. Restoration of UE motor function in people with SCI remains a high priority in rehabilitation and in the field of assistive technology. UE myoelectric powered wearable orthoses (UE-MPWO) specifically designed to restore wrist/hand movements may help fill the gap by increasing strength of the participating muscles, range of motion (ROM) of the joints, and ability to perform daily tasks involving using wrist/hand in persons with SCI. The goal of this study was to evaluate the effects of the UE-MPWO (MyoPro) in ameliorating wrist/hand/UE movement capability, and increasing ADL and QOL in people with SCI.

1 Introduction

Spinal cord injury (SCI) is a medically complex and life-disrupting condition. An estimated incidence of 17,700 new traumatic SCI cases are reported each year in the United States [1]. In about half of those, the injury involves some part of the arm and hand, representing significant disability and dependence for those patients [1–4]. Following an SCI there is also often loss of sensory and/or motor control of the upper and lower limbs. The characteristics of the impairment depends on the extent and level of the SCI [5, 6]. Individuals with higher levels of SCI have limited capacity to move or perform basic activities of daily living (ADL). Such movement

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Fig. 1 A myoelectric upper extremity orthosis (MyoPro)

limitations significantly reduce a patient's quality of life (QOL) and level of independence, particularly when the UEs are impaired [7]. UE myoelectric powered wearable orthoses (UE-MPWO) specifically designed to restore wrist/hand movements (that are most difficult to recover after injury) may help fill the gap by increasing strength of the participating muscles, range of motion (ROM) of the joints, and ability to perform daily tasks involving using wrist/hand in persons with SCI [3]. Researchers have recently adopted task-specific methods of improving function and independence in individuals with SCI who have upper limb paralysis [3, 7, 8], for example, robotic assisted training for UE in individuals with incomplete SCI [9–11]. The overall goal of this study was to evaluate the effects of the UE-MPWO (MyoPro) in ameliorating wrist/hand/UE movement capability, and increasing ADL and QOL in people with incomplete SCI.

2 Material and Methods

2.1 Upper Extremity Robotic Orthosis (MyoMo)

The MyoPro (Myomo Inc., Cambridge, Massachusetts) (Fig. 1) is a noninvasive, lightweight (approximately 4lbs), wearable system currently available in numerous rehabilitation facilities across the nation [12]. The orthosis provides 0–130 ° of motion and 7 Nm of torque at the elbow and 1–2.7 Nm torque for the fingers. This translates into the ability to lift approximately 5–8 lbs (depending on the user's clinical presentation) [12]. This orthotic device uses surface electromyography (sEMG) signals from affected muscle groups to control a powered orthosis, providing powered assistance for elbow flexion and extension and gross grasp motions via motors attached to the exterior of the brace. It functions by continuously monitoring the sEMG signals of the user's bicep and triceps muscles for elbow motion and the forearm flexor and extensor muscle groups for grasp motion (a 3 jaw-chuck grip

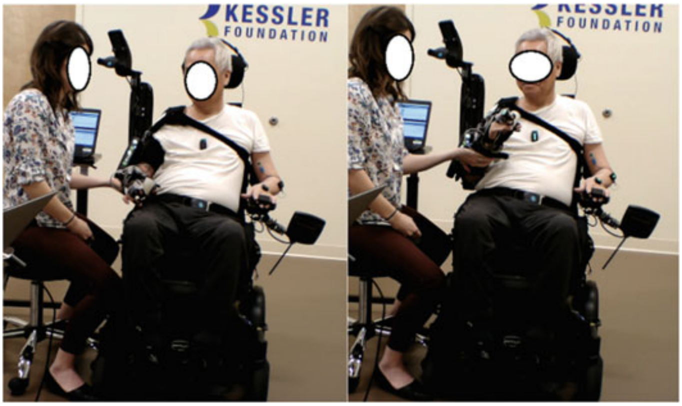

Fig. 2 A participant with SCI is utilizing the UE-MPWO (Myo-Pro) to hold on to an object and bring it closer to his face

pattern). These signals are filtered and processed to provide a desired joint torque proportional to the exerted effort of the user.

2.2 Experimental Procedure

The data analyzed in this paper consist active elbow-joint angler ROM 75 year old male subject with SCI (ASIA Impairment Scale (AIS) C level (C3-C4). Subject was tested with and without the UE-MPWO while seated in his wheelchair (Fig. 2) using Trigno Wireless system (Delsys, Massachusetts, USA) and 9-axis Inertial measurement unit (IMU) and EMG sensors. IMU data were analyzed using a bidirectional zero-lag Butterworth low-pass filter (cutoff frequency = 10 Hz) using MATLAB 2020 (The MathWorks, Inc).

3 Results

Our pilot randomized controlled trial compared the immediate orthotic effects using an UE-MPWO during ADL tasks. The participant received training sessions in an outpatient therapy gym 3 times per week over a 6-week period. Each session was supervised by a licensed therapist, over 60 min, and involved a customized level of training and assistance using the UE-MPWO orthosis. The participant demonstrated a 359% improvement in elbow-joint ROM with the UE-MPWO compared to without it (i.e. 10.6° without and 48.9° with UE-MPWO) (Fig. 3). Further, while utilizing the UE-MPWO, the participant was able, for the first time after his SCI, to drink from a bottle of water and was able to touch his face independently.

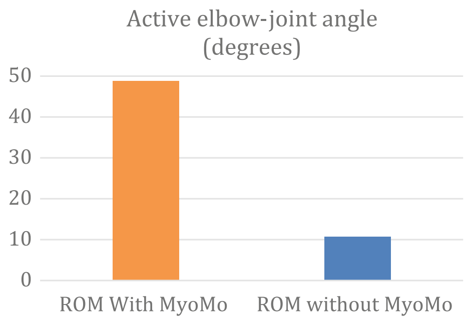

Fig. 3 The active ROM of elbow-joint against gravity with and without UE-MPWO (Myo-Pro)

4 Discussion and Conclusions

Applying the UE-MPWO condition was successful, given that, the participant demonstrated a 359% improvement in elbow-joint ROM with the UE-MPWO (i.e. 10.6º without and 48.9° with UE-MPWO). This may be explained due to the robotic training effects received over six weeks of participation in this study where UE muscles showed increased strength which was also translated to a better coordination and control of participants' UE while using the UE-MPWO to complete ADL tasks. This increase in elbow ROM was further translated to other immediate assistance in completing functional tasks (i.e. drink from a bottle of water and was also able to touch his face). The UE-MPWO enabled the participant to use his own motor control signal (as captured from the upper and lower arm muscles by the UE-MPWO sEMG sensors) to self-initiate and control movement of his UE for completing these ADL tasks that have significant impact on the participant's self-esteem and ability to be engaged in daily self-care activities. Data analysis of a larger sample is underway to confirm the findings.

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