

# Case Report on the Use of a Custom Myoelectric Elbow–Wrist–Hand Orthosis for the Remediation of Upper Extremity Paresis and Loss of Function in Chronic Stroke

Stefanie Dunaway, MS OTR/L\*; D. Brianna Dezsi, OTD, OTR/L†; Jessica Perkins, COTA/L‡; Daniel Tran, MD†; Jonathan Naft, CPO\*

**ABSTRACT** Introduction: This case study describes the application of a commercially available, custom myoelectric elbow–wrist–hand orthosis (MEWHO), on a veteran diagnosed with chronic stroke with residual left hemiparesis. The MEWHO provides powered active assistance for elbow flexion/extension and 3 jaw chuck grip. It is a noninvasive orthosis that is driven by the user's electromyographic signal. Experience with the MEWHO and associated outcomes are reported. Materials and Methods: The participant completed 21 outpatient occupational therapy sessions that incorporated the use of a custom MEWHO without grasp capability into traditional occupational therapy interventions. He then upgraded to an advanced version of that MEWHO that incorporated grasp capability and completed an additional 14 sessions. Range of motion, strength, spasticity (Modified Ashworth Scale [MAS]), the Box and Blocks test, the Fugl–Meyer assessment and observation of functional tasks were used to track progress. The participant also completed a home log and a manufacturers' survey to track usage and user satisfaction over a 6-month period. Results: Active left upper extremity range of motion and strength increased significantly (both with and without the MEWHO) and tone decreased, demonstrating both a training and an assistive effect. The participant also demonstrated an improved ability to incorporate his affected extremity (with the MEWHO) into a wide variety of bilateral, gross motor activities of daily living such as carrying a laundry basket, lifting heavy objects (e.g. a chair), using a tape measure, meal preparation, and opening doors. Conclusion: Custom myoelectric orthoses offer an exciting opportunity for individuals diagnosed with a variety of neurological conditions to make advancements toward their recovery and independence, and warrant further research into their training effects as well as their use as assistive devices.

## INTRODUCTION

Myoelectric control was first introduced for prosthetics in 1945,<sup>1</sup> and since that time has been heavily researched in the United States under military funding. It became prevalent during the Vietnam War and in subsequent years, when casualties returned needing prosthetic limbs. Today, myoelectrically controlled prosthetics are prescribed for individuals with upper limb amputations. Custom fabricated, myoelectric orthoses are now also being provided to civilians, veterans, and active duty personnel with intact, but impaired upper extremities due to neuromuscular damage such as stroke, incomplete spinal cord injury, brachial plexus injuries or traumatic brain injury (TBI). Prior research conducted on these devices demonstrated that users of myoelectric devices increased their independence in a wide range of activities of daily living (ADLs) and instrumental activities of daily living (IADLs).<sup>2–5</sup>

Every year in the United States, approximately 795,000 people, (civilians, active military, and veterans) experience a stroke<sup>6</sup> of which 40% exhibit chronic disability including upper extremity (UE) impairments such as paresis and spasticity. Additionally, within the military, over 350,000 U.S. personnel have been diagnosed with a traumatic brain injury since 2000.<sup>7</sup>

Survivors who undergo traditional rehabilitative therapies, are frequently left with chronic UE impairments and an associated loss of function, dependence on caregivers, and decreased quality of life. Custom fabricated myoelectric orthoses may provide an alternative solution and an adjunct to traditional therapies for those with hemiparesis and loss of UE function. It is the aim of this case report to describe the functional and rehabilitative outcomes of a veteran with one such custom myoelectric orthosis.

The myoelectric orthosis used for this case report is called the MyoPro<sup>®</sup>. The Myopro<sup>®</sup> (Myomo Inc., Cambridge, Massachusetts) is a custom fabricated myoelectric elbow–wrist–hand orthosis (MEWHO) currently available in numerous Veteran Affairs facilities across the nation, as well as to civilian facilities. Surface sensors—built into the upper cuff of the orthosis and located over the bicep and tricep muscles—detect the user's electromyographic (EMG) signal once he/she initiates a muscle contraction. The EMG signal is filtered through patented software onboard the orthosis and this activates the motor to move the elbow in the desired direction. Movement is proportional to muscle output and EMG amplitude. An additional set of sensors are positioned over the distal forearm which registers EMG activity from both wrist and finger flexors/extensors. EMG output from the forearm sensors power a second motor to open and close the fingers in a 3 jaw-chuck grip pattern, upon user initiation. The treating clinician is able to amplify the user's EMG signal and customize the level of assistance provided by the orthosis to

\*Myomo Inc., One Broadway 14th floor, Cambridge, MA 02142.

†Louis Stokes Cleveland Veteran Affairs Medical Center, 10701 East Boulevard, Cleveland, OH 44106.

‡AMSUS – The Society of Federal Health Professionals, 2017

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**FIGURE 1.** MEWHO with grasp.

move the paretic limb. The clinician is also able to select whether the orthosis moves based on activity from a single or multiple muscle groups, tailored to the user's clinical presentation. The orthosis weighs approximately 4 lbs and provides 0 to 130 degrees of motion and 7 Nm of torque at the elbow and 1–2.7 Nm torque for the fingers (Fig. 1). This translates into the ability to lift approximately 5–8 lbs (depending on the user's clinical presentation).

### CASE DESCRIPTION

The participant is a 62-year-old veteran, who served in the U.S. Marines Corps as a Corporal and in the U.S. Navy as a Seaman. He was awarded the Purple Heart medal as a result of a combat injury during his service in the Vietnam War. He is a right-hand-dominant male who presented with dysarthria and left hemiplegia in December 2013 due to an infarct of the posterior limb of the right internal capsule. Past medical history is positive for hypertension, tobacco use, a previous transient ischemic attack in 2010, hyperlipidemia, and a left Bell's Palsy in 2013. Immediately following his stroke in 2013, the participant completed an inpatient rehabilitation stay during which he received traditional occupational therapy (OT) for 1 hour a day. The participant began outpatient OT in January 2014 to treat the ongoing functional deficits associated with his left hemiparesis, where he was prescribed a custom MEWHO (without grasp capability) in April 2014. The participant met the criteria for the MEWHO including intact cognition, no UE contractures, and sufficient EMG signal strength in his bicep and tricep to power the orthosis. Measurements and a cast were taken of his affected arm and a custom MEWHO was manufactured. The participant continued to participate in OT with his orthosis until August 2014, at which point he was reevaluated for the advanced model that includes additional myoelectric grasp capabilities. The participant received his upgraded orthosis in November 2014. At this time, the overall fit and comfort of the device was assessed, appropriate sensor locations were found, and the device was programmed with the appropriate level of assistance using the manufacturers programming software.

At the time of starting to use the MEWHO with grasp, the participant presented with unresolved UE deficits in range of motion (ROM), strength, fine and gross motor skills, and functional use of the paretic left arm.

### METHODS

The participant completed a total of 21, 1-hour outpatient OT sessions that began with traditional OT interventions for 3 months, such as functional electrical stimulation, mirror therapy, dynataping, massage wand, fluidotherapy, proprioceptive neuromuscular facilitation, therapeutic exercise, active-assisted and passive ROM, and task-oriented/occupation-based interventions. He and his therapist then incorporated the custom MEWHO without grasp into his plan of care, upon delivery in April 2014. The participant received training in proficient use of the orthosis: donning/doffing technique, repetitive task practice drills, and application of the orthosis during multistep functional tasks such as meal preparation. He was also given a home activity plan and a wearing schedule, beginning at 30 minutes daily, to increase endurance and facilitate functional use of his affected extremity. After upgrading to the custom MEWHO with grasp in November 2014, the participant completed an additional 14 sessions under the supervision of his therapist and fitting prosthetist. These sessions were dedicated to mastering the operation of the new orthosis and utilizing it during daily functional tasks such as self-feeding, drinking from a cup, carrying a laundry basket. A progressive, functional training protocol from the orthosis manufacturer was incorporated at this time (Table I). The participant also completed an online manufacturers' survey to track usage and user satisfaction for 6 months. Outcome testing throughout treatment included ROM testing, strength (Manual Muscle Testing [MMT]), and the Modified Ashworth Scale (MAS)<sup>8</sup> to assess spasticity and functional task assessment. Once the participant upgraded to the MEWHO with grasp, the Fugl–Meyer<sup>9</sup> assessment was also utilized to quantify progress.

### RESULTS

Active left UE ROM and strength both increased (Table II). He also demonstrated an improved ability to incorporate his affected extremity (while wearing his orthosis) into a wide variety of bilateral, gross motor ADLs and IADLs such as carrying a laundry basket (Fig. 2), lifting heavy objects (e.g. a chair), using a tape measure, meal preparation, and opening doors. To demonstrate the specific improvements in grasp and release while wearing the MEWHO with grasp, the following data points illustrate how the participant continued to lack active hand function until that time (November 2014). However, once the orthosis had been donned, the participant was able to achieve an immediate active and functional grip pattern. Furthermore, these data points demonstrate the presence of both a training and a rehabilitative effect of using the MEWHO over time, as the participant was able to

**TABLE I.** MEWHO With Grasp Training Protocol

Treatment Phase	Treatment Activities	Objective
MEWHO Proficiency Training and Motor Learning/Sequencing	Elbow–bicep mode	Maintaining arm in relaxed position during ambulation
Basic Task Training	Hand–open mode	Volitional relaxation of spastic muscles; improved motor control and isolation
	Elbow–bicep and tricep modes	Proficiency with orthosis
	Hand–open and close modes	Functional use of elbow flexion/extension
Advanced Functional Task Training	Grasping beanbags and releasing into buckets	Functional use of grasp/release
	Elbow–dual mode	Bilateral feeding task
	Hand–dual mode	Carrying laundry basket Drying dishes Sweeping

independently open his hand (75%) by January 2016, without assistance from the MEWHO:

Date: 12/7/2014 Active Open at hand: 0% without orthosis with grasp, Full (100%) open with orthosis

Date: 1/29/2016 Active Open at hand: 75% without orthosis, Full (100%) open with orthosis

These results demonstrate how working with a custom MEWHO may have contributed to the remediation of UE deficits, in particular elbow, wrist, and hand function. The participant also demonstrated substantial improvements in daily functional use of his paretic left arm, and an increase in his overall level of independence both at home and in his community. While wearing the MEWHO, the participant was able to use his left arm to carry weighted objects bilaterally, to stabilize objects such as a cup or plate during use, and to put items away in overhead cabinets. Independence also increased with household chores such as laundry, meal preparation, and light cleaning tasks. Information from the manufacturers' survey and home log (September 2015–March 2016) show that the participant was able to complete additional tasks such as sweeping/mopping the floor, washing and folding clothes, and moving/lifting chairs. During this 6-month timeframe, the participant logged 25 entries and wore his orthosis at home for a total of 34 hours. The participant wore his orthosis between 30 minutes and 2 hours each time and reported an average satisfaction rating of 8.78/10 (0 = not satisfied at all, 10 = extremely satisfied). Overall, the participant reported a high level of satisfaction, improvement in his quality of life, and increased functionality of his paretic arm. He also reported a few areas for improvement. These included addressing technical glitches such as sensor and electronic malfunctions, decreasing the weight and bulk of the orthosis (4 lbs); redesigning the harness, increasing the battery life (it is currently 2 hours), and making the orthosis waterproof so he could wear it outside during wet conditions. Battery life and fatigue were the most common reasons for needing to stop use of the orthosis. The participant was able to self-don his orthosis independently in 3 to 5 minutes, but he did express the need

to practice and that it was difficult when he first tried to do it alone. Interestingly, the participant noted that if he stops using his orthosis for longer than 2 days, his arm—in particular his hand and fingers—begin to stiffen and cause discomfort, and he loses ROM and function.

## DISCUSSION

Regular and consistent use of the custom MEWHO in conjunction with traditional OT has resulted in many benefits and positive functional outcomes for the participant. The orthosis was shown to provide both assistive device benefits as well as rehabilitative benefits. While wearing his orthosis, he is able to be more independent with daily ADLs and IADLs such as meal preparation, folding and washing clothes, accessing items in overhead cabinets, bilateral lifting tasks (e.g. laundry basket, dining chair), sweeping/mopping and stabilizing objects such as cups and plates. Once fitted with the MEWHO with grasp, the participant demonstrated additional improvement in his affected hand function in particular, again both with and without the orthosis donned. Consistent use of this myoelectric orthosis over time has also resulted in improvements in the ROM and strength and a reduction of spasticity in his paretic arm. The participant's comment that not using his orthosis with grasp for longer than 2 days results in his arm and hand stiffening and losing function, suggests that the changes he has experienced in his arm are potentially due to the integration of the orthosis into his therapy regime. Looking at the data from November 2014 onward (in particular March 2015–October 2015), we see improvements in gross grasp, lateral pinch strength, wrist ROM, and emerging ulnar and radial deviation. With this newfound hand function and increased UE strength overall, the participant demonstrates competence with tasks such as opening doors and cupboards with his affected hand, as well as using a measuring tape, picking a phone off the hook, and holding papers, all without using the orthosis. Results from the Fugl–Meyer assessment (Table III)—specifically in the wrist, hand and coordination/speed categories—also indicate a training effect and remediation of UE paresis.

**TABLE II.** ROM, Strength (MMT), and Spasticity (MAS) Results Completed Without the Orthosis

	May 2014 (MyoPro Classic)	September 2014	November 2014 (MyoPro Motion G)	January 2015	March 2015	May 2015	March 2016
Active ROM (Degrees)							
Shoulder Flex	91 (Supine)	133 (Supine)	120 (Seated With Compensation)	120 (Seated With Compensation)	155	WFL	WFL
Shoulder abd/add	90 (Supine)	105 (Supine)	82 (Seated With Compensation)	82	120/Full	WFL	WFL
Elbow Flex	97 (Seated)	WFL (Supine)	125 (Seated)	125	130	WFL	WFL
Elbow Ext	-30 (Seated)	WFL (Supine)	-20 (Seated)	-20	0	WFL	WFL
Supination/Pronation	NT	NT	60/40	NT	60/Full	NT	NT
Wrist Flex	20 With Gravity Assist	20	20	35	40	55	NT
Wrist Ext	40 With Compensation	45	50	60	65	70	NT
Radial/Ulnar Deviation	NT	NT	NT	NT	NT	15/30	NT
	May 2014 (MyoPro Classic)	September 2014	November 2014 (MyoPro Motion G)	January 2015	March 2015	March 2015	March 2016
Strength (MMT)							
Shoulder	3-/5	3-/5	3-/5	3-/5	3-/5	3-/5	4/5
Elbow	3-/5	3-/5	3-/5	3-/5	3/5	3/5	4/5
Wrist	3-/5	3-/5	3-/5	3-/5	Pro/Sup 3/5 Flex 3-/5 Ext 3/5	NT	NT
Hand	3-/5	3-/5	3-/5	3-/5	2-/5	NT	NT
Grip (L Hand)	21 lbs	31 lbs	36 lbs	40 lbs	47 lbs	NT	NT
Lateral Pinch	NT	NT	NT	NT	11 lbs	NT	NT
	January 2014	May 2014 (MyoPro Classic)	September 2014	November 2014 (MyoPro Motion G)	January 2015	March 2015	March 2016
Spasticity (Modified Ashworth Scale)							
Elbow Flex	1+	1	0	0	0	NT	0
Elbow Ext	1+	0	0	0	0	NT	0
Wrist Flex	1+	0	0	0	0	NT	0
Wrist Ext	1+ With 2 Beats Clonus	1	1	0	1 With Clonus	NT	0

NT, Not Tested; WFL, Within Functional Limits.



**FIGURE 2.** Carrying a laundry basket with the EWHO.

Since the participant also engaged in traditional OT simultaneously, it should be noted that it is challenging to separate the progress made by traditional therapy alone versus the effects of the MEWHO without grasp capabilities. It is however reasonable to conclude that incorporating a MEWHO into a comprehensive treatment program can offer excellent results. Given the participant's level of hand function immediately before receiving the orthosis with grasp, it is also reasonable to conclude that the added myoelectric grasp feature specifically contributed directly to the participant's significant distal fine and gross motor recovery. It is also noteworthy that the participant began use of the MEWHO only a few (4) months after his stroke. He was able to incorporate the technology during the majority of his first year post stroke and therefore it is also a challenge to determine the specific effects of the orthosis from the natural spontaneous recovery that occurs during this same timeframe. What is apparent is that the participant benefitted tremendously from the use of the myoelectric orthosis in conjunction with traditional OT. Previous studies have illustrated the importance of an individually tailored, progressive, high-repetition, and UE task-specific intervention to increase stroke patient outcomes and motor recovery.<sup>10,11</sup> This MEWHO is portable, able to be used in the clinic and at home, and enables the user to complete high repetitions and functional task practice. Traditional OT frequently falls short of these standards. For example, stroke

patients receive an average of 47 minutes a day in OT, of which only 4 to 11 minutes are spent on UE rehabilitation.<sup>12</sup> Fitting patients with a custom MEWHO may be an effective method of providing intensive UE treatment, facilitating motor recovery, and improving the user's independence with practiced tasks.

## CONCLUSIONS

A custom MEWHO was shown to provide this veteran with an increased ability to move and use his affected arm in a variety of functional tasks, in particular bilateral tasks. The participant wears his orthosis on and off throughout the day and reports improvements in his independence with daily functional tasks and overall quality of life. The participant has also demonstrated significant recovery in his affected UE including improved active ROM at the shoulder, elbow and hand, improved strength, and a reduction in tone. This case report highlights both the assistive/functional benefits as well as rehabilitative benefits of a myoelectric orthosis. These devices offer an exciting opportunity for other individuals diagnosed with chronic stroke, brain injury, or incomplete spinal cord injury to make advancements toward their recovery and independence. Additional research is warranted on the application of custom MEWHOs in the neurorehabilitation of our veterans and active duty personnel.

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**TABLE III.** Fugl–Meyer Assessment Results—Completed Without the MEWHO (With Grasp)

	March 2015	March 2016
Upper Extremity	31/36	31/36
Wrist	9/10	10/10
Hand	9/14	14/14
Coordination/Speed	3/6	6/6
Sensation	11/12	11/12
Passive Joint Motion	24/24	24/24
Joint Pain	24/24	24/24
Total Score	111/126	120/126

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