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ORIGINAL RESEARCH

# "Reps" Aren't Enough: Augmenting Functional Electrical Stimulation With Behavioral Supports Significantly Reduces Impairment in Moderately Impaired Stroke

Stephen J. Page, OTR/L, PhD, MS, FAHA, FACRM,[a] Peter G. Levine, BA, PTA,[b] Brittani A. Basobas, BA[a]

*From [a]The Ohio State University, School of Health and Rehabilitation Sciences, Division of Occupational Therapy, Columbus, OH; and [b]Synapse Together, LLC, Cincinnati, OH.*

**Abstract**

**Objective:** To determine the impact of repetitive task-specific practice (RTP) integrating electrical stimulation and behavioral supports on upper extremity (UE) impairment, gross manual dexterity, and paretic UE amount and quality of use in chronic stroke survivors exhibiting moderate, stable UE deficits.

**Design:** Case series with 3-month follow-up.

**Setting:** Outpatient rehabilitation hospital.

**Participants:** Persons (N=9) who experienced a stroke >12 months before enrollment and exhibiting chronic, moderate, stable UE impairment.

**Interventions:** After administering outcome measures, RTP was administered 3d/wk for 120 minutes with an electrical stimulation neuroprosthesis (60min in a supervised clinical setting; 60min at home) over 8 weeks. Behavioral supports (eg, behavior contract; weekly reviews of UE use) were provided during clinical sessions and integrated into home exercise sessions to increase paretic UE use and maximize carryover to subjects' community environments.

**Main Outcome Measures:** The UE section of the Fugl-Meyer Impairment Scale, the Box and Block Test, and the Motor Activity Log.

**Results:** Subjects exhibited statistically significant ($P<.01$) increases on all measures at both time-point comparisons (ie, preintervention to postintervention; preintervention to 3mo postintervention). Subjects reported a new ability to perform valued activities they had not performed in months.

**Conclusions:** Addition of behavioral supports to RTP augmented by electrical stimulation significantly increased paretic UE use and function. Significant motor changes were exhibited across ages and etiologies, and no other intervention was administered to this stable population, making it likely that results were not due to chance and suggests a larger trial is justified.

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Most stroke survivors exhibit upper extremity (UE) motor impairments that compromise valued activities.[1,2] The most efficacious poststroke regimens[3-5] address these impairments by integrating functional practice using the paretic UE (termed *repetitive task-specific practice* [RTP]), because such repetition is critical to neuroplasticity and motor return.[6] However, most contemporary RTP-based therapies[3-5] have targeted patients with minimal UE impairment—a group exhibiting considerable distal UE movement and only comprising approximately 5% to 25% of all stroke survivors.[7]

Survivors with moderately impaired UEs are thought to constitute a larger proportion of the stroke population,[8] and often exhibit little to no active movement in their paretic wrists and fingers, and limited active proximal movements. These diminished abilities hamper full participation in UE rehabilitative therapies, and this group shows less response to conventional UE therapies.[9] However, over the past decade, RTP augmented by electrical

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stimulation during movement attempts has enabled participation in UE motor practice, and significantly increases paretic UE function in individuals with moderate UE impairment.[10-13]

In addition to motor control deficits, stroke survivors also exhibit maladaptive compensatory behaviors that contribute to overall UE disability levels. RTP integrating behavioral support strategies grounded in cognitive-behavioral training, motor learning, and neuroscience increases paretic UE use and function in survivors with minimal UE impairment.[5,14,15] Yet, previous electrical stimulation studies[10-13] and work by others targeting moderate to severe UE impairment[16,17] have focused only on repetitive UE use, without integrating a program of behavioral support strategies that would effectively address UE use and increase UE reintegration.

This study determined the impact of RTP integrating electrical stimulation and behavioral supports on UE impairment, gross manual dexterity, and paretic UE amount and quality of use in chronic stroke survivors exhibiting moderate, stable UE deficits. We hypothesized that subjects would exhibit significant UE impairment reductions 1 week after intervention (our primary endpoint) as measured by the UE Fugl-Meyer (our primary outcome measure). To our knowledge, this is the first study to integrate a program of behavioral support strategies with electrical stimulation to comprehensively address the motor and behavioral deficits observed poststroke.

# Methods

## Participants

After approval by the local institutional review board, subjects were recruited from local outpatient rehabilitation clinics and support groups. Based on previous work,[10-13] the following study criteria were applied: (1) minimum motor inclusion criteria were $\geq 20^\circ$ of active humeral flexion, $\geq 30^\circ$ of internal and external active humeral rotation, $\geq 20^\circ$ of active elbow flexion, and $\geq 20^\circ$ of active elbow extension, all in the paretic UE, and repeated at least 3 times in 1 minute in the seated position. All measurements were made using a hand-held goniometer. Concurrently, subjects had to display a UE Fugl-Meyer score $\geq 20$ and $\leq 31$ to be eligible for inclusion; (2) 1 stroke (hemorrhagic or ischemic) experienced $\geq 12$ months before study enrollment; (3) Mini-Mental Status Examination score $\geq 24$; (4) age $\geq 21$ and $\leq 80$ years; (5) discharged from all forms of physical rehabilitation; and (6) electrical stimulation neuroprosthetic orthosis fits on the paretic UE properly.

Exclusion criteria were as follows: (1) excessive pain in the paretic UE, indicated by a score $\geq 5$ on a 10-point visual analog scale; (2) excessive spasticity at the paretic elbow, wrist, or digits as defined by a score $\geq 2$ on the Modified Ashworth Spasticity Scale; (3) participating in any experimental rehabilitation or drug studies; (4) moderate to severe apraxia ($<2.5$ on the Alexander Scale); (5) severe language deficits (score $<2$ on National Institutes of Health Stroke Scale question 9); (6) history of neurologic disorder other than stroke; (7) received botulinum toxin injection to any portion of the paretic UE within the past 4 months, or phenol injections $<12$ months before participation; and (8) other conditions or circumstances that, in the opinion of the investigators, would preclude safe or effective participation, or both, including severe sensory deficits, skin conditions, and/or other sequelae that may be contraindicated for electrical stimulation, as well as personal circumstances (eg, distance from center) that may affect full participation.

***List of abbreviations:***

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|---|---|
| **BBT** | **Box and Block Test** |
| **FM** | **upper extremity section of the Fugl-Meyer Impairment Scale** |
| **MAL** | **Motor Activity Log** |
| **RTP** | **repetitive task-specific practice** |
| **UE** | **upper extremity** |

## Testing and instruments

After signing consent forms approved by the local ethics board, the following instruments were administered twice before intervention, approximately 1 week apart.

### UE section of the Fugl-Meyer Impairment Scale

Because of the moderately impaired nature of our subjects' paretic UEs, subjects would likely be unsuccessful attempting items on distally based measures that we and others have used in poststroke UE trials[3,4,14,15] with minimally impaired subjects. Thus, the upper extremity section of the Fugl-Meyer Impairment Scale (FM)[18] was used as the primary outcome to assess UE impairment. Data arise from a 3-point ordinal scale (0, cannot perform; 2, can perform fully) applied to each item, and items are summed. The FM has high test-retest reliability, interrater reliability, and validity.[19,20]

### Box and Block Test

To examine how UE motor impairment changes conspired to affect paretic UE gross manual dexterity, the Box and Block Test (BBT) was used. During the test, subjects were seated in front of a wooden box with a partition in the middle, and asked to move colored blocks from 1 side of the box, over the partition, to the other side. The number of blocks moved in 1 minute was recorded. The test's test-retest reliability and validity have been shown in stroke.[21]

### Motor Activity Log

While important, the above measures do not ascertain UE use, which is fundamental to plasticity and motor return,[6] and speaks to carryover of the intervention to the subjects' real-world environments. Thus, we also administered the Motor Activity Log (MAL)[22] to examine the amount of paretic UE use in laboratory and community-based activities, as well as how well subjects carried out these activities.

## Apparatus

The Bioness H-200 system[a] is a U.S. Food and Drug Administration–approved electrical stimulation device administered as part of the RTP program described later. It consists of a forearm-hand–molded prosthesis that contains an array of 5 surface electrodes ranging from $2\times2$cm to $6\times4$cm positioned over the extensor digitorum, extensor pollicis brevis, flexor digitorum superficialis, flexor pollicis longus, and adductor pollicis muscles, and a programmable controller that signals the electrodes to activate. Electrode position within the prosthesis is custom-fitted for each patient to optimize the contraction of the digit flexors and extensors. The programmable controller, which wirelessly controls the electrodes, delivers alternating current using a sinusoidal, balanced waveform with a frequency of 11kHz and the pulse bursts at 36Hz ranging from .01 to 0.5 milliseconds.