ORIGINAL ARTICLE

Effects of Repetitive Electrical Stimulation to Treat Sensory Loss in Persons Poststroke

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ABSTRACT. Smith PS, Dinse HR, Kalisch T, Johnson M, Walker-Batson D. Effects of repetitive electrical stimulation to treat sensory loss in persons poststroke. Arch Phys Med Rehabil 2009;90:2108-11.

Objective: To explore the effectiveness of repetitive electrical stimulation referred to here as tactile coactivation and to improve sensory discrimination and function in the most involved hand of a person recovering from stroke.

Design: Pre-experimental 1-group (n=4) design with multiple measures.

Setting: Outpatient stroke treatment center.

Participants: Subjects with 6 months or longer poststroke with self-reported sensory loss and a mild motor impairment in the most involved hand.

Intervention: Electrical stimulation (coactivation) of the fingers of the involved hand for 90 minutes 4 days a week for 6 weeks.

Main Outcome Measures: Primary-dependent measures included touch threshold, tactile acuity, haptic object recognition, motor tapping task, pegboard activities, and functional tasks from the Wolf Motor Function Test.

Results: Posttreatment assessments revealed improvements in sensory discrimination and motor task performance in all subjects in varying degrees; these results held 4 weeks posttreatment.

Conclusions: The type of repetitive electrical stimulation or tactile coactivation used in this study has not been explored previously in subjects with sensory loss caused by stroke. The results of this pilot study suggest that coactivation may have the potential to be a useful therapeutic modality for this population.

Key Words: Rehabilitation; Stroke; Upper extremity.

IT IS ESTIMATED THAT there are approximately 2.8 million people poststroke who have absent or impaired function in the more involved upper extremity.[1] Feys et al[2] reported that therapeutic interventions targeted at improving function in the more involved upper extremity have mixed results. The most encouraging results come from task-specific practice regimens that demand active engagement by the person for extended periods of time.[3]

Loss of sensory abilities of the more involved upper extremity, particularly the hand, further complicates the individual's ability to use the hand for functional tasks despite the emerging good motor function.[4] For example, a person may have difficulty using his/her hand for writing or pulling correct change from his/her pocket. Over the past decade, tactile coactivation, a form of repetitive sensory stimulation using electrical pulses, has been used successfully to improve discriminatory sensation in the fingertips and motor performance on certain sensorimotor tasks in adults across the age span.[5-7] For this group of healthy subjects, behavioral improvements with physiologic changes have been documented. Functional magnetic resonance imaging after coactivation showed changes in the primary and secondary somatosensory cortex.[8] The purpose of this pilot study was to determine the effectiveness of tactile coactivation to improve sensory discrimination and function of the most involved hand in persons recovering from stroke. The research question was as follows: Do subjects with loss of sensory abilities in the more involved hand after stroke experience an improvement in sensory abilities and function after tactile coactivation to all 5 fingers?

METHODS

Study Design

This study was a pre-experimental 1-group (n=4) design with multiple measures. Within 3 days of the initiation of treatment, multiple-dependent measures of sensory and motor function were assessed. The sensorimotor tasks used in this pilot study were developed for use in the study of the persons without stroke in the Neuroplasticity Laboratory in the University of Ruhr and have been published previously.[5-8] The tasks included touch threshold, tactile acuity, haptic object recognition, motor tapping task, and pegboard activities. In addition, we used 4 functional tasks selected from the Wolf Motor Function Test.[9] Intertester reliability on all dependent measures was established between the clinical evaluator (P.S.) and the senior scientist (H.D.) before the initiation of the study. This exploratory pilot study was unblinded.

Study Sample

Persons recovering from stroke in the postacute and chronic stages were studied. Inclusion criteria specified a single left or right cerebral artery thromboembolic infarction, age 40 to 70, right-hand dominance, entry into the study 6 weeks or longer

List of Abbreviation

NIH	National Institutes of Health

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Table 1: Description of Sensorimotor-Dependent Measures

Measure	Equipment	Procedure
Touch threshold	Five Semmes-Weinstein Monofilaments for testing sensation in the hand (0.07, 0.4, 2.0, 4.0, and 300mN)	Participant is blindfolded. 1. Tip of index finger touched with filaments in an increasing order of pressure until the person recognized touch. Value recorded. 2. Tip of index finger touched with filaments in a decreasing order of pressure until the person can no longer recognize touch. 3. Procedure repeated 3 times to validate amount of pressure discernable.
Tactile acuity	For testing spatial discrimination performance, we used a grating orientation task in a 2-alternative forced-choice paradigm.[14,15] The stimuli consisted of 8 hemispherical plastic domes with gratings cut into their surfaces, resulting in parallel bars and grooves of equal width. Spatial frequency was varied between 6mm and 2.5mm in steps of 0.5mm. With the help of a custom-built device, the domes were manually applied by the experimenter perpendicularly to the surface of the skin of the tip of the right and left index finger for a duration of approximately 1.5 second and indenting the skin by about 1.5mm. A calibrated spring inside the device ensured that a defined force of 150mN was applied. The gratings discrimination threshold was defined as the level at which 75% of the responses were correct.	Participant is blindfolded. 1. Tip of index finger touched with a specific dome 10 times using a predetermined random orientation of the grooves. 2. The participant identified the direction of the grooves "up and down" or "across." 3. The test was performed with a series of descending dome widths starting with the largest grating (6mm) and ending when the subject scored less than 75% correct responses within 1 block.
Haptic object recognition	3 different objects made from LEGO[a] bricks that differed in the overall shape and configuration (3 items of each configuration).	Participant is blindfolded. 1. Nine LEGO objects: 3 items of the 3 configurations are placed in a soft cloth bag. 2. The participant placed the more involved hand in the bag and felt the LEGO figure, brought it out of the bag, and placed it by the like test item. 3. The participant was given 5 minutes to complete this task, and numbers of items correctly matched and time needed to complete the task if faster than 5 minutes were recorded.
Pegs placed in pegboard	12 wooden pegs (0.5-cm diameter) and board	1. The participant moved the pegs from 1 side of the pegboard to the other. 2. The time to complete the task was recorded. 3. The participant did the task 2 times, and the mean time was used for further analysis.
Motor tapping task	Electronic device that records the number of motor taps in 3 blocks of 10 seconds each for a total time of 30 seconds.	1. The participant used a stylus to tap on a base plate as quickly as possible for 30 seconds. 2. The mean number of taps averaged across the 3 blocks of 10 seconds was used for further analysis.

poststroke, upper-extremity motor performance of 46 to 60 points on the Fugl-Meyer Assessment of Physical Performance,[10] and the ability to exhibit grasp in the paretic hand. This Fugl Meyer scale is recognized to be a valid and reliable assessment tool for persons recovering from stroke.[11] There are 66 points allotted to motor function of the upper extremity on this assessment.[11] Exclusion criteria specified no other coincident neurologic condition including seizures or terminal medical condition (eg, acquired immune deficiency syndrome, cancer).

Four subjects, a sample of convenience, aged 57 to 67 years were recruited from The Stroke Center-Dallas to participate in

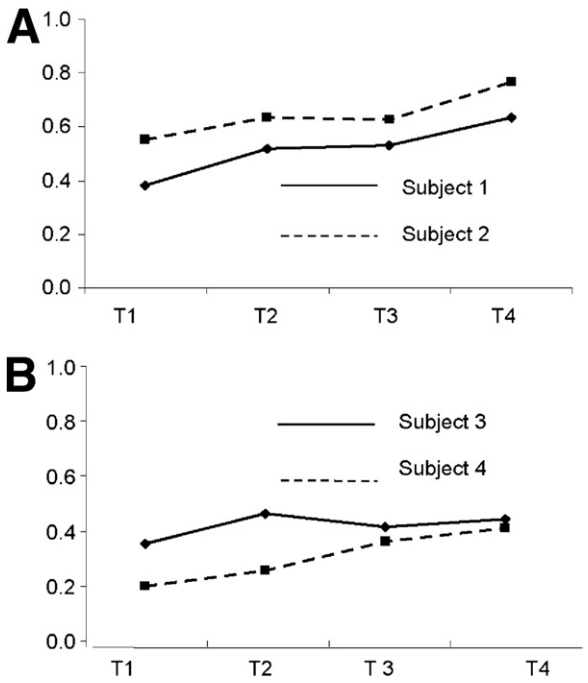

Fig 1. The average of all tasks across time; the task performance is expressed as the ratio of the lesser involved hand to the more involved hand. (A) Subjects (S) with right hemisphere brain lesions (S1: 6 months; S2: 1.5 years after stroke). (B) Subjects (S) with left hemisphere brain lesions (S3: 3 years; S4: 6 years after stroke). Abbreviations: T1, baseline; T2, midtreatment; T3, end of treatment; T4, follow-up.

this study. The Edinburgh Handedness Inventory[12] was administered, and all participants were determined to be strongly right-handed. All participants reported an inability to use their more involved hand for functional activities secondary to a sensory loss and scored "0" or "1" on the sensory portion of the NIH Stroke Scale.[13] The Institutional Review Boards at The University of Texas Southwestern Medical Center and Texas Woman's University approved this study. All participants signed a consent form before commencing the study.

Data Collection

The study compared sensory and motor abilities in both hands at baseline (T1), midtreatment (T2), at the end of treatment (T3), and at follow-up (T4) 1 month after the final treatment session. The participants performed all tests with the left and right upper extremities. To ensure a stable baseline, all T1 assessments were performed twice 24 hours apart, and the participant's performance was averaged. The 4 motor tasks adopted from the Wolf Motor Function Test included the following: stacking 3 checkers, turning over 3 cards, picking up and placing down a standard pencil, and attempting to drink from a full 12-oz soda can. Table 1 provides a detailed description of the sensorimotor-dependent variables.

Intervention

Participants received the intervention at The Stroke Center-Dallas. The intervention protocol for the coactivation has been previously described[14] and consisted of a high-frequency electrical stimulation of the fingers. For this study, 90 minutes of coactivation was applied per day (20-Hz single pulses in bursts of 1s with 5-s interburst intervals) for 4 days a week for 6 weeks, resulting in a total stimulation time of approximately 36 hours. Pairs of small adhesive electrodes were attached to the base of the proximal and tip of the distal phalanx for all fingers on the volar surface of the most involved hand by using 2 leads connected to the coactivation device. The intensity of the stimulation was set at the highest threshold the participant could easily tolerate for the extended period of time. The participant was encouraged not to pay attention to the stimuli but rather to engage in a quiet secondary task such as reading or watching television. The clinical investigator remained on site to troubleshoot any malfunction of the device, adjust the intensity if requested, and monitor any adverse reaction from the participant. The highest intensity for each session was recorded at the end of the session. Given the research question, no additional general exercises or task-specific interventions were done with any of the participants.

Data Analysis

To collapse the results of the many different tasks used into a single figure, we decided to provide a condensed illustration of the overall changes induced by coactivation (fig 1). The data were normalized to the healthy hand. This was done by dividing the performance measured for the less affected hand by the performance measured with the more affected hand. The ratio score is between 0 and 1. A score of 0 means no performance with the most affected hand, whereas a score of 1 would depict the participant was able to perform the task equally well with both hands. For this aim, we calculated the percent changes of the ratio scores for each task, which subsequently were averaged across tasks. This was done separately for the percent changes found for baseline measurement (T1) versus midtreatment (T2), for T1 versus the end of treatment (T3), and for T1 versus follow-up (T4).

RESULTS

All 4 participants completed the study inclusive of the 4 testing sessions. Table 2 details the demographics for the participants including age, sex, side of the brain lesion, months poststroke, baseline Fugl-Meyer score, and range of current intensity of the coactivation. Because all of the participants were strongly right-handed, 2 of the subjects had involvement in their nondominant hand. The subjects with right hemisphere brain lesions were 6 months and 1.5 years poststroke and had

Table 2: Subject Demographics

Subject No.	Age/Sex	Lesion Side	Months Poststroke	FMM	NIH Sensory	Current Range
1	67/male	Right	6	60	0	5–15
2	57/female	Right	18	60	0	5–20
3	57/male	Left	60	60	1	5–25
4	67/male	Left	36	56	1	15–45

Abbreviations: Current Range, lowest to highest current (mA) used on each subject during the coactivation intervention period; FMM, Fugl-Meyer Motor assessment score of the more involved upper extremity; NIH Sensory, NIH Stroke Scale Score, sensory section.

only a mild to moderate sensory loss (NIH Stroke Scale-sensory score 1) in their involved hand. The subjects with left hemisphere brain lesions were 3 and 6 years postinsult and had profound sensory loss (NIH Stroke Scale-sensory score 0) in their involved hand. There were no recorded adverse reactions to the treatment, and all participants tolerated gradual increases in the current stimulation. Figure 1 displays the average of all task performance across time for each participant. In this exploratory pilot study, the trend of the data showed improvement after 6 weeks and 36 hours of coactivation intervention in all 4 participants. These improvements in average task performance continued to hold 4 weeks after the intervention ceased. There were no negative effects of electrical stimulation reported by the participants.

DISCUSSION

This was the first application of tactile coactivation in subjects suffering from sensory deficits as a result of a stroke. In this initial study, it was important to determine that the subjects studied could tolerate the length of treatment and the increases in the intensity of the stimulation that occurred during each session. All subjects showed improvement in varying degrees across all tasks.

Whether these findings extend to other persons suffering sensory deficits caused by stroke cannot be determined from this study. This study was exploratory in nature. We had a small number of subjects, and the time poststroke varied considerably. There was no comparison group; therefore, the study was unblinded. These factors limit the generalizability of our findings.

Other confounds include the side of the lesion. We had 2 subjects with left-hemisphere lesions and 2 with right-hemisphere lesions, although all subjects were strongly right-handed. How this may have affected the response cannot be determined with such limited numbers. Another topic requiring clarification is the question of dosing of the tactile coactivation. Would increasing the amount and intensity of the stimulation show greater benefits in subjects with more profound sensory losses? These confounding areas along with the demonstrated functional improvements for the person after coactivation need to be shown in future studies before this approach can be considered a useful therapeutic intervention for sensory deficits subsequent to stroke.

CONCLUSIONS

We found changes in sensory function in varying degrees in all subjects studied after 36 hours of coactivation. Additionally, there were no negative effects from the coactivation reported by any of the subjects studied with increasing levels of intensity of the stimulation. Although we are cautious regarding these preliminary findings, we believe the results justify exploration of coactivation under more controlled conditions in a larger number of subjects; we are currently undertaking this.

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Suppliers

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