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Case Report

Impact of Somatosensory Augmentation with AMES on Upper Limb Pain and Spasticity in a Person with Chronic Tetraplegia

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Abstract

The purpose of this case study is to report changes in pain and spasticity in one person participating in a study examining the impact of upper limb (UL) activity-based intervention using a robotic device combining repeated movements with somatosensory augmentation. The participant was a 30 year-old male with chronic (3.5 years post-injury) incomplete tetraplegia due to a motor vehicle accident. He trained on the AMES device (AMES Technology, Inc., Portland, OR), which combines repeated, actively assisted movements of the wrist and hand with muscle vibration, for twenty-five, 1-hour sessions. Prescribed medications pre- and post-training, as well as verbal reports from the participant regarding pain and spasticity, were collected. Following the intervention period, the participant reported decreased pain and spasticity, and that he independently discontinued one pain medication (Gabapentin) and one medication for spasticity/hypertonia (Tizanidine). He also reported functional improvements. Repeated movements combined with somatosensory augmentation may be a useful treatment option for people with pain and/or spasticity due to incomplete tetraplegia, even years after injury. These findings warrant further investigation.

ABBREVIATIONS

ADL: Activities of daily living; AMES: Assisted Movement Enhanced Sensation; C5: Cervical level 5; CUE: capabilities of Upper Extremity; UL: Upper limb; MAS: Modified Ashworth Scale; NSAID: Non-steroidal anti-inflammatory drug; PRN =; QOL: Quality of life; ROM: Range of motion; HZ = Hertz; SCI: Spinal Cord Injury

INTRODUCTION

People with upper limb (UL) dysfunction due to SCI desire greater arm and hand function to improve their participation and to increase their overall quality of life (QOL).[1,2] While weakness or paralysis and somatosensory deficits are expected to negatively impact UL function, pain and spasticity have also been shown to do so in people with tetraplegia [3-8]. Pain and spasticity are known to be particularly difficult to alleviate after SCI, with either medication or physical rehabilitation. Interventions that augment somatosensory input to the nervous system during movement or functional tasks, using vibration or electrical stimulation, show promise for improving arm and hand function in people with tetraplegia [9-11] The effects of these interventions on pain and spasticity, however, have not been adequately described. Some reports show that repeated movement and somatosensory augmentation can lead to decreases in spasticity in people with SCI [12-16] but the effects of such activity-based interventions on pain are not routinely reported.

The purpose of this case report is to present preliminary data demonstrating improvements in pain and spasticity after an activity-based intervention. This case was part of a larger pilot study assessing UL impairment and functional changes following the AMES (Active Movement Enhanced Sensation) intervention.[17] The pilot study was approved by the Research Review Committee at this private, non-profit, long term rehabilitation facility. The participant provided written consent prior to beginning the study.

CASE PRESENTATION

Patient History and Systems Review

The participant was a 30 year old male with motor incomplete (C5 AIS D) [18] traumatic SCI following a work-related motor vehicle accident 3.5 years prior to enrollment in the study. He was not ambulatory at the time of this study, used a power wheelchair for mobility and required some assistance for transfers. The participant reported significant pain and spasticity in both UL's. He described his pain as intermittent, sharp, and shooting in bilateral elbows, wrists, and hands. The clinical description and medication prescribed was consistent with neuropathic pain. He reported that the pain occurred at inconsistent intervals throughout the day and appeared to worsen with increased activity. Spasticity (as measured by the Modified Ashworth Scale [19,20]) was detected in the participant's wrist and finger flexors and extensors, as well as his elbow extensors. This spasticity limited his ability to actively move his elbow, wrist, and hand. This pain and spasticity prevented him from performing activities of daily living (ADLs), like managing zippers, buttons, and laces for dressing, or donning and doffing pants during dressing or personal hygiene, without physical assistance.

The participant reported medication use to manage his pain and spasticity (Table 1), which he and his wife reported made him lethargic, dizzy, and weak, and increased his incidence of headaches. Over the 3.5 years since his injury, the participant had also received Botulinum toxin injections [21-23] to the left flexor carpi radialis, and had intermittently participated in three hours of occupational therapy per week for 2-3 months at a time. Therapy focused on increasing strength, range of motion (ROM), and independence with ADLs, and decreasing pain and spasticity (through use of manual therapy and modalities). Despite these interventions, he continued to report activity-limiting pain and spasticity, and decided to enter this study.

Intervention

The AMES device and training for this study are described in Backus et al. 2014 [17]. Briefly, the AMES device provides repeated active assisted movements of the wrist and hand with coincident vibration (60 Hz, 2 mm) of the antagonist muscle tendons. Flexor tendons were vibrated during extension movements, and extensor tendons were vibrated during flexion movements. The participant elected to train his more functional limb, and thus trained his left UL on the AMES device 1 to 3 sessions per week, on non-consecutive days, until 25 sessions were completed over the course of 12 weeks. Training sessions consisted of 30 minutes of setup/takedown, 20 minutes of active assisted grasp (hand-opening and -closing), and 10 minutes of active assisted wrist flexion and extension (60 minutes total time each session).

Outcome Measures

Several outcome measures were collected in the main study to evaluate changes in strength, somatosensation, and function, and all have been described previously [17]. Of particular interest to this case report is the assessments of pain and spasticity, and the participant's perceived UL function, since he reported that pain and spasticity impeded his function. Pain was assessed at each training session by the trainer, primarily for safety, with the question: "On a scale of 1 to 10, how would you rate your pain today?" Ten indicated the most severe pain. Given that pain was not otherwise planned as an outcome measure in the original study design, no other standardized measures or questions were utilized. Spasticity was grossly evaluated by a trained physical therapist in four muscle groups of the UL (elbow flexors, elbow extensors, wrist and finger flexors, and wrist and finger extensors) using the Modified Ashworth Scale (MAS) [19,20].

Additionally, the participant completed the Capabilities of Upper Extremity (CUE) Questionnaire [24]. The CUE questionnaire is designed to determine an individual's own perception of how well they can use their arms and hands to perform common daily tasks that are often difficult for individuals with SCI to complete. For example, one question asks them to think about how well they can lift their arm over their head and another asks the individual to think about picking up a small object such as a paper clip or the cap of a tube of toothpaste with the tips of their thumb and first two fingers. Participants are asked to consider whether, on an average day, they have difficulties or limitations performing these actions. "Difficulty" means doing the action, or trouble doing it as often as one would like or need in order to complete everyday activities. Questions are answered on a scale of 1 to 7, where 7 is the best, i.e. the individual has no difficulty or limitation doing the action, and 1 is the worst, i.e. they are totally limited and can't do it at all.

Outcomes

The participant reported regular decreases in pain in his left (trained) UL throughout his 12 weeks of training. He reported he was able to perform functional activities with fewer incidences of sharp, shooting pain in his elbow/wrist, and his pain disrupted his sleep less frequently. While he continued to take Pregabalin and Ibuprofen at the same pre-training dosages, his need for other pain medications diminished. He decreased his use of Oxycodone (prescribed for PRN use) from 2-3 times per week to only once per week to help him sleep. With the consent of his physician, he also discontinued use of one medication for neuropathic pain (Gabapentin) following the 25 training sessions (see Table 1).

The participant also reported decreases in spasticity, and discontinued use of one spasticity/hypertonicity medication (Tizanidine) with the consent of his physician, with no adverse effects. He experienced a decrease in spasticity in the wrist and finger extensors as measured by the MAS (from 1/5 to 0/5), but an increase of spasticity in the elbow extensors (from 2/5 to 3/5). While these changes exceed the minimal detectable change score (1 point) for individuals with stroke, no such cutoffs exist for SCI, and the changes noted could be influenced by the test's limited reliability to assess individual muscle groups [20,25].

The participant and his wife also reported several functional improvements. Within 6 training sessions, he was able to pick up a television remote with his trained left UL; previously he reported that the remote was "too heavy" to manage. Following 10 training sessions, the participant was able to don his pants in standing independently using his left UL; prior to training, he was unable to grasp his pants strongly enough, or maintain that grasp long enough, to fully don pants. This was the first time since

injury that he was able to complete this task without assistance, increasing his independence and easing the burden on his wife.

The CUE questionnaire found that the participant perceived a 65% improvement in function following training, in both the trained and untrained UL. This improvement exceeds the 34-point change required for a minimal detectable change[24]. Changes occurred in unilateral and bilateral movements that are required for many ADL's, including reaching forward or down; pushing, pulling, and grasping light and heavy objects; and performing fine motor activities, like pinching to pick up small items.

DISCUSSION

Our findings suggest that an intervention combining repeated movement and somatosensory augmentation of the wrist and hand with the AMES led to decreases in perception of pain and spasticity that were meaningful to one person with chronic, incomplete tetraplegia. These perceived changes appear to be related to improvements in UL function, participation, and QOL for this individual. Our findings support our hypothesis that positive functional outcomes would result from AMES training, and that these improvements would be secondary to changes in impairments, such as strength and sensation. The findings of reductions in pain and spasticity, however, were unexpected and meaningful to the participant.

One potential mechanism for the observed outcomes is that stimulation of afferent input from muscle spindles in the antagonist muscle(s) augments reciprocal inhibition to the agonist, spastic muscle [26-28] Stimulation of the wrist and finger flexor afferents may elicit an increase in inhibition to the wrist and finger extensors, resulting in an overall decrease in detectable spasticity over time. This does not explain, however, the increase in spasticity observed in the elbow extensors.

Another potential mechanism for the perceived changes in pain and spasticity seen in our participant may be related to the afferent stimulation (vibration) interfering with maladaptive neural circuitry that developed following injury, causing increased excitability including increased tendon reflexes, muscle tone, and muscle spasms [29]. Afferent stimulation to the nervous system, including deep pressure via weight bearing and modalities like heat or cold, have been suggested to modulate input to spinal neurons, resulting in an overall decrease of exaggerated and unwanted neural activity [30-32]. Although many of these results have been seen in the lower extremities, similar effects have not yet been reported for the UL.

While the frequency of training for this study was intended to be 2-3 sessions per week, due to conflicts in the participant's schedule, he actually trained anywhere from 1 to 3 sessions per week (over the course of 12 weeks). Therefore, it is unclear what dose is most appropriate or necessary in order to cause the greatest gains. Further study is necessary to determine the lowest dose necessary to continue to see changes in pain and spasticity.

Although the AMES device is not yet available in many clinics, it is noteworthy that the application of an activity-based intervention combining repeated assisted movement and somatosensory augmentation led to changes in pain and spasticity in an individual with chronic tetraplegia. This has not been previously reported with regard to the UL in people with SCI. In addition, both repeated movements and vibration can be applied in other ways in the clinic, and should be evaluated for their efficacy in decreasing pain and spasticity in individuals with tetraplegia.

This case report represents the results from one individual who was part of a larger cohort. Further study is necessary to determine if and how this can be generalized to others with chronic, cervical SCI.

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Conflict of Interest

[Contents of this manuscript were modified and presented as a poster at the 2012 ACRM (American Congress of Rehabilitation Medicine) Annual Conference in Vancouver. Author Cordo and Oregon Health & Science University (OHSU) both have significant financial relationships with AMES Technology, Inc., a company that may benefit from the work presented in this manuscript; this potential conflict of interest is managed by the OHSU Research Integrity Office.]

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