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Effects of a new sensory re-education training tool on hand sensibility and manual dexterity in people with multiple sclerosis

Alon Kalron[a,*], Michal Greenberg-Abrahami[a], Simona Gelav[a] and Anat Achiron[a,b]
[a]*Multiple Sclerosis Center, Sheba Medical Center, Tel – Hashomer, Israel*
[b]*Sackler Faculty of Medicine, Tel-Aviv University, Israel*

Abstract.
OBJECTIVE: To describe and evaluate the effects of a new home-based sensory re-education training tool on hand sensibility and manual dexterity in people with MS experiencing upper limb sensory deficits.
METHODS: Twenty-five people with relapsing-remitting MS (18 women), mean age 50.6 years (SD = 11.4), volunteered to participate. Participants were initially assigned to a 7-week control phase followed by a 3-week home-based sensory re-education phase. Measurements used were the nine-hole peg test, the two point discrimination test, the monofilaments test and the functional dexterity test. Measurements were collected at baseline, following the control phase and at the end of the trial.
RESULTS: Participants demonstrated an improvement in the nine-hole peg (26.8 (SD = 3.5) vs. 22.6 (SD = 3.2); mean difference (95% CI) 4.9 (0.9, 7.1), $P = 0.03$) and functional dexterity tests (38.6 (SD = 4.4) vs. 33.8 (SD = 4.9); mean difference (95% CI) 4.8 (1.8, 7.0); $P = 0.02$) at the end of the sensory re-education phase compared to the end of the control phase. No differences were observed as to the monofilaments and two-point discrimination tests.
CONCLUSIONS: Sensory re-education training does not affect the level of sensory impairment in the hand but may lead to improvement in select measures of manual dexterity.

Keywords: Multiple sclerosis, sensory deficits, sensory retraining, manual dexterity

1. Introduction

Sensory impairments, a typical symptom of multiple sclerosis (MS), affect almost all people with this progressive disease. Prevalence rates of 30% to 82% have been demonstrated in several studies with a significant number of people with MS identifying sensory complaints as their worst symptoms [2]. Sensory impairments range from just one type of sensation, such as a light touch to impairment of all sensory abilities. Sensory deficits are of particular concern in light of neurophysiological research demonstrating the importance of sensory input in maintaining normal cortical representations in both the sensory and motor cortices [19]. Furthermore, fine motor control in the upper limb has been shown to be affected by sensory impairment, in particular, the ability to sustain an appropriate level of force when grasping an object and object manipulation [5].

Sensory re-education combines several techniques of physical and occupational therapy, thus assisting

*Address for correspondence: Alon Kalron, Multiple Sclerosis Center, Sheba Medical Center, Tel Hashomer, 60 Habanim Street, Herzlia, Israel, Tel./Fax: +972 9 9512726; Tel.: +972 52 2436839; E-mail: alkalron@gmail.com.

individuals with sensory impairments to decode the altered neural impulses created by the affected hand [21]. Sensory re-education does not induce axonal regeneration or re-innervations, but takes advantage of and maximizes the full sensory potential obtained by the existing sensory nerve receptors and somatosensory spinal tracts. Principles of sensory re-education training include repeated presentation of targeted discrimination tasks (e.g defining weight and texture of objects or materials placed in the affected hand); progression from easy to more difficult discriminations; attentive exploration of stimuli with occluded vision; and use of anticipation trials and feedback on salient sensory features of the stimuli. The rationale for the following training principles were based on perceptual learning consistent with "learning dependent" neural plasticity [5] designed to facilitate transfer of training effects to greater improvement in sensory capacity [6].

Although various sensory re-education techniques have been used in patients suffering from pathologies of the central nervous system [7, 20], this method has never been documented in people with MS. Carey et al. [4] examined the effects of a 3-week (60 minute session, 3 times a week) sensory re-education program in 50 hemiplegic patients in the chronic phase of recovery. The program was oriented and designed to retrain 3 sensory discrimination functions: texture discrimination, limb position sense, and tactile object recognition. Compared to the control group, who received passive movements of the upper limb, patients in the training group demonstrated significant gains in functional sensory capacity.

Given this knowledge, the purpose of our study was to evaluate the effect of a new home-based sensory re-education training tool on sensory and motor hand capabilities in people with MS suffering from upper limb sensory deficits.

2. Methods

2.1. Subjects and materials

All participants were diagnosed as clinically definite MS patients based on McDonald's revised criteria, [16] and confirmed by an experienced neurologist. They also complained of sensory deficits in one or both hands, confirmed by a neurological examination, concluding with an expanded disability status scale score, an accepted method of quantifying disability in MS [14].

Participants were excluded if they had trouble communicating, were prone to emotional disturbances, had experienced a prominent cognitive decline which prevented learning or had orthopedic disorders negatively affecting hand movement. The study was approved by the Institutional Review Board of the hospital. Rights of the human subjects were protected. All participating subjects signed an informed consent form.

2.2. Sensory training tool

The sensory training tool, a relatively short hollow tube, 2 cm in length and 1 cm in diameter, comprised twelve tactile stimulation elements. Each tube was constructed from plastic, rubber or metal and designed with its own particular texture. Consequently, each element was differentiated by tactile stimulation. The tube had to be large enough to be comfortably handled by the patients, who needed fine-motor skills for manipulation. The sensory training tool tactile stimulation elements are shown in Fig. 1.

Participants were initially allocated to a 7-week control phase occupational therapy session, twice a week, consisting of non-specific repeated exposure to stimuli varying in texture, shape, size, weight, hardness, and temperature, via grasping of common objects. Exposure was selected as the control intervention because previous studies had indicated that most stroke survivors do not improve with repeated exposure alone [4]. Following the control phase, patients commenced a 3-week home-based sensory re-education phase.

The sensory re-education intervention phase included an initial familiarization session carried out by an occupational therapist specialized in MS rehabilitation. The rationale was to introduce the sensory training tool, explain its usage and provide guidance as to self-practice. The therapist presented each sensory element to the participant by its official name and described its texture (Fig. 1). Simultaneously, participants were encouraged to palpate the elements in order to feel its specific sensory tactile sensation. Palpation was performed with eyes open; the objects were separately manipulated by the right and then the left hand.

Following familiarization, the participants practiced two different sensory tasks. They were blindfolded during the first task, and then the therapist randomly placed a single element into their hand, asking for identification through palpation and to state its official name. Upon completion, the therapist informed the participant as to the accuracy of his identification.

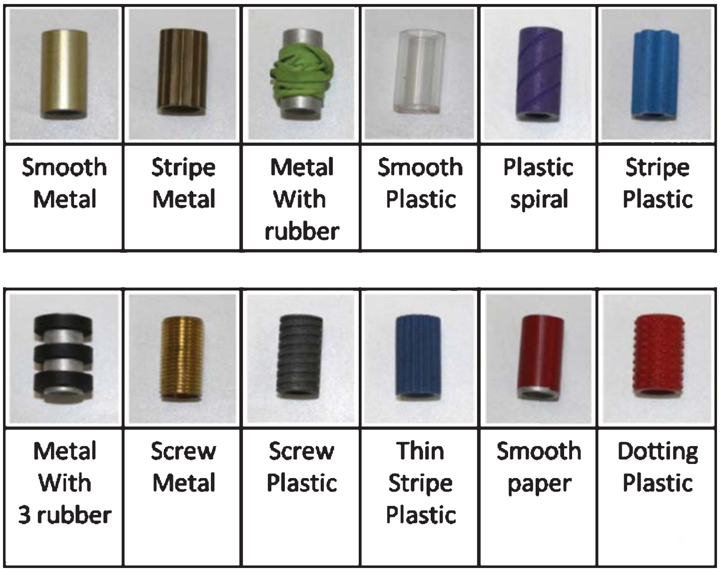

Fig. 1. Sensory training tool.

In the second task, all elements were placed in a pouch. Participants were unable to see the tubes. They then placed their affected hand into the pouch picking out a single element described by the therapist, relying solely on palpation. Both tasks were performed by each hand. The total session lasted approximately 30 minutes. Upon completion of this task, participants received the sensory training tool for practice at home. Task instructions were identical to those implemented in the clinic session.

Participants were encouraged to practice 20 minutes a day, 5 days a week, for three consecutive weeks. An occupational therapist phoned each person at the end of each week in order to detect possible difficulties encountered with the sensory training tool. Additionally, participants were requested to fill out an attached self-reporting sheet recording hours of daily practice.

3. Outcomes measurements

Outcome measurements were assessed on three occasions over a period of 10 weeks: at the beginning of the experiment (baseline), after 7 weeks following the control phase and at the end of the trial following the three week home-based sensory re-education therapy. Evaluation tests measuring motor hand abilities were the nine-hole peg test for finger dexterity [15] and the functional dexterity test [1]. The two-point discrimination test was used to determine tactile sensation [8]. Light-touch and pressure-sensation thresholds were determined using the Semmes-Weinstein monofilaments [3]. The last two measurements were standardized tests commonly used in research and sensory evaluation of peripheral and central nerve lesions, usually used as a criterion standard of touch-pressure threshold and tactile sensation.

The two sensory tests were performed on the anterior aspect of the finger pads and a modified 4, 2 and 1 stepping algorithm [10] was employed to evaluate the threshold point. The subjects sat in a quiet room, blindfolded. The monofilaments test began with a 4.17 filament; the two-point discrimination test began with the 5 mm distance gap. Depending on the subject's response, the changes in stimulus intensity/distance gap were made in three increments until their response changed and a turnaround point was reached. Changes were then made in two increments until another turnaround point, at which point all stimuli were presented in one increment.

The tactile sensation threshold was determined to be the lightest filament experienced >50% of the time. In the same manner, the two-point discrimination threshold was determined as the smallest distance gap recognized >50% of the time. For each location tested, the examiner performed two null trials randomly placed throughout the algorithm. If the subject responded to both null trials at any given location, the test was halted and the subject reinstructed. The final score, given separately for both the monofilaments test and the two-point

Table 1
Sensory evaluation test scores according to the study phase

Sensory motor tests	Mean scores (SD)			Mean difference (95% CI), *P*-Value	
	Base line	After control phase	After STT phase	Base line-Control	Control phase- STT
Mono	17.7 (5.1)	17.5 (6.3)	17.1 (4.7)	0.2 (−1.5, 1.8), 0.85	0.6 (−1.0, 2.2), 0.38
TPD (mm)	40.1 (6.5)	39.3 (7.2)	38.5 (6.9)	0.8 (−1.2, 2.8), 0.67	1.6 (−0.9, 4.1), 0.47
NPH (sec)	27.5 (3.1)	26.8 (3.5)	22.6 (3.2)	0.7 (−1.3, 2.7), 0.55	4.9 (0.9, 7.1), 0.03*
FDT (sec)	40.3 (5.2)	38.6 (4.4)	33.8 (4.9)	1.7 (−2.1, 3.9), 0.61	4.8 (1.8, 7.0), 0.02*

*$P < 0.05$. Mono: threshold Semmes Weinstein monofilaments test, TPD: two point discrimination test, NHP: nine-hole peg test for finger dexterity test, FDT: functional dexterity test, STT: sensory training tool.

discrimination test, was calculated as the total sum of the separate thresholds demonstrated by each digit. All clinical evaluations were performed by a trained occupational therapist specialized in MS.

3.1. Data analysis

Descriptive statistics were performed to determine distributions of demographic, clinical, sensory and motor hand parameters. All sensory and motor hand data were normally distributed and the assumptions of homogeneity of variance were not ignored. Furthermore, Mauchly's sphericity test was used to examine the covariance.

In order to determine whether the intervention phase affected outcome variables, a repeated measure analysis of variance (ANOVA) test was performed. All analyses were performed using the SPSS software (Version 15.0 for Windows, SPSS Inc. Chicago, IL, USA). All reported *P*-values were two-tailed with the level of significance set at $P < 0.05$.

4. Results

Twenty-five people with relapsing-remitting MS (18 women and 7 men), mean age 50.6 years (SD = 11.4, range 20–60) with a disease duration of 13.4 (SD = 5.8) years, volunteered to participate. The expanded disability status scale score was 5.3 (SD = 1.7) representing moderate neurological disability; mean pyramidal score was 3.6 (SD = 1.2); mean cerebellar score 1.9 (SD = 1.1) and mean sensory score was 1.6 (SD = 1.3). All participants complained of sensory deficits in one or both hands, identified during the initial neurological examination. Although, intervention programs usually focus on both hands, our data analysis included only one hand of each individual. In the event of bilateral sensory hand deficits, the hand that was negatively affected on the initial examination was included. Therefore, a total of 25 hands were involved.

Participants demonstrated an improvement in the nine-hole peg (26.8 (SD = 3.5) vs. 22.6 (SD = 3.2), mean difference (95% CI) 4.9 (0.9, 7.1), $P = 0.03$) and functional dexterity tests (38.6 (SD = 4.4) vs. 33.8 (SD = 4.9), mean difference (95% CI) 4.8 (1.8, 7.0); $P = 0.02$) at the end of the sensory re-education phase compared to the end of the control phase.

No differences were observed as to the monofilaments and two-point discrimination tests. Differences were not observed between baseline and termination of the control phase in all four evaluation tests. Sensory evaluation scores according to different trial phases are presented in Table 1.

5. Discussion

To the best of our knowledge, the present study is the first report investigating the effects of sensory re-education training on people with MS with upper limb sensory impairments. The results of the present study imply that sensory capabilities of people with MS cannot be improved solely by home based sensory re-education training. However, this intervention can have beneficial effects on manual dexterity. As opposed to the control phase, an overall improvement of 15% in manual dexterity measurements was shown upon completion of the sensory re-education phase, as demonstrated by the nine-hole peg and functional dexterity tests.

According to healthy adults norms, subjects within an age range of 41 to 51 should be able to perform the nine-hole peg test between 17 to 19 seconds (small differences according to gender and hand dominance) [11]. Participants in the present study improved their performance from an average 27.5 seconds recorded on baseline to 22.6 seconds at end of the sensory re-education phase. These results are promising since the nine-hole peg test has a high discriminative and predictive ability in discerning active daily living independence, upper extremity functional status and participation in social and lifestyle activities in people with MS [13].

Changes were not observed on the level of sensory abilities, determined by the two-point discrimination and monofilaments tests. It is worth noting that the two-point discrimination and monofilaments tests are sensory outcome measures at the impairment level, thus it is possible that changes occurring at the impairment level were more difficult to detect. In contrast, the outcome measurements of the nine-hole peg and functional dexterity tests are at the functional level and tend to be affected by combined improvements in sensation, proprioception and motor function rather than the result of improvements in one component. Therefore, the choice of outcome measures may have contributed to the study results.

A recent systematic review reported on "passive" and "active" approaches to sensory re-education training [17]. The authors emphasized that currently there is insufficient evidence as to "active" approaches to sensory rehabilitation for retraining the upper limb. Similarly, a recent Cochrane review focusing on interventions for sensory impairment in the upper limb, reported a relative lack of high-quality randomized controlled trials [9]. The sensory re-education intervention used in our study applied an "active-cognitive" approach. In addition to recruitment of sensory neural pathways, completion of re-education tasks depended on cognitive abilities and imagery skills. During practice, participants were required to concentrate and utilize cognitive resources in their attempt to differentiate between the tactile elements. Although we speculated that a beneficial effect on sensory abilities would be achieved when cognition challenge and imagery aspects were integrated into training strategy sessions, our results do not confirm this hypothesis. Furthermore, in people with MS suffering from cognitive fatigue, defined as a slowing in mental ability during performance of repeated cognitive tasks, the sensory re-education training tasks can be frustrating and tiresome. Nevertheless, Heremans et al. [12] demonstrated significant correlations between imagery abilities, cognitive functioning and motor performance of the hand in thirty patients with MS. Moreover, according to studies examining neuronal plasticity and interconnection brain networks on people with MS, a relationship was found between cognitive function, motor function, and cortical activation [18]. Future studies should address these reservations by differentiating study groups according to basic cognitive functions.

An encouraging aspect of this report related to patient characteristics. The participating group consisted of MS patients with average disease duration of 13 years, suffering from moderate to severe functional abilities. While many clinicians doubt the capability of chronic hand impairments to improve at this stage, it was encouraging to discover that progress in manual dexterity has been achieved in chronic MS patients. We can only question whether sensory re-education training at an earlier phase of the disease may slow down the progression of manual dexterity deficits in the hands. Future studies should address this issue.

6. Study limitations

The present pilot study has several limitations. Firstly, although there was a control phase, the present research was not a randomized controlled trial (RCT) with an equally plausible control intervention. Secondly, additional functional measurements tools such as the Michigan Hand or Disabilities of the Arm, Shoulder and Hand questionnaire's could have expanded the interpretation of the present study results.

Additionally, although both intervention phases included a similar number of training sessions, 14 in the control phase vs. 15 in the sensory intervention phase, there was a variance in the duration of the different phases, 7 weeks vs. 3 weeks, respectively. Perhaps the intensity of the intervention, rather than the training tool, impacted the outcome measurements. Finally, there was no follow up assessment; therefore, we are unable to determine whether the improvements in manual dexterity were maintained for a period of time following the termination of sensory re-training.

We believe that the new home-based sensory re-education training tool should be introduced to people with MS suffering from impaired functional hand abilities. Nevertheless, future studies examining the extent of sensory re-education practice and identifying patients who could benefit the most from this intervention are certainly warranted.

Declaration of interest

None.

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