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Effect of Sensory Impairment on Hand Functional Improvement with Therapy and Sensory Stimulation

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Abstract

Background: Sensory impairment severity may impact individual stroke survivors' motor recovery as well as their response to peripheral sensory stimulation treatment.

Objective: To determine the effect of sensory impairment level of individual stroke survivors on motor improvement with therapy and peripheral sensory stimulation.

Methods: A secondary analysis of a pilot triple-blind randomized controlled trial. Twelve chronic stroke survivors participated in 2 weeks of hand task-practice therapy. They were randomly assigned to the treatment group receiving peripheral sensory stimulation or the control group receiving no stimulation during the therapy. Sensory impairment level was quantified as the pre-intervention sensory threshold. Motor improvement was assessed as change in the Box and Block Test score from pre to post-intervention. The association between sensory impairment level and motor improvement was examined using a regression analysis, accounting for groups.

Results: Participants with better sensation (*i.e.*, with lower sensory threshold) had better motor improvement than patients with worse sensation (*i.e.*, with higher sensory threshold). Sensory impairment level did not alter the effect of peripheral sensory stimulation.

Conclusion: The level of sensory impairment can be utilized to predict recovery potentials and direct rehabilitation treatment for stroke survivors.

Keywords: Stroke rehabilitation • Upper extremity • Neurologic rehabilitation • Subliminal stimulation• Sensory function • Afferent pathways • Neural pathways • Wearable technology

Introduction

Stroke affects more than 795,000 people per year in the U.S. and is a major cause of long-term disability [1] More than two thirds of stroke survivors have hand impairment [2] which limits their ability to perform activities of daily living [3,4]. In addition to motor impairment, sensory impairment is a common consequence of stroke. An estimated 50%-85%of chronic stroke survivors have sensory impairment, [5-7] with 37% of all stroke survivors experiencing long-term sensory deficits in the hand alone [8]. Sensory impairment significantly hinders motor learning9 and thus, may impede motor recovery [10-12]. However, sensory impairment level is not typically considered as a covariate for rehabilitation intervention outcome.

Peripheral sensory stimulation can be used to supplement manual therapy during rehabilitation since adding peripheral sensory stimulation enhances upper extremity motor recovery post-stroke [13,14]. Peripheral sensory stimulation activates not only the afferent pathway but also the motor cortex as seen by changes in neurophysiologic measures, thus priming the motor cortex for motor activities [15-17]. However, sensory impairment may curtail the effect of peripheral sensory stimulation due to disruption in the sensory processing pathways [18,19]. Yet, the impact of patients' sensory impairment on the extent of hand functional recovery from therapy with peripheral sensory stimulation has not been examined. The objective of this study was to determine the effect of sensory impairment level of individual stroke survivors on motor improvement with therapy and peripheral sensory stimulation.

Materials and Methods

Study design

This secondary exploratory study is based on a triple-blind randomized controlled trial. Twelve chronic stroke survivors were randomly assigned to either the treatment group or control group (n=6/group). Both groups received hand task-practice therapy while wearing a peripheral sensory stimulation device on the paretic wrist for 2 hours/session, 3 times a week for 2 weeks. The device delivered imperceptible random-frequency vibration at 60% of the participant's sensory threshold for the treatment group and no vibration for the control group. This vibration stimulates skin mechanoreceptors and elevates cortical neuronal firing for hand tasks 20, 21 to improve sensorimotor function [22-26] and recovery in stroke survivors. Further description of this particular peripheral sensory stimulation and task-practice therapy used in this study can be found.

Participants

Participants were adult (age ≥ 18 years) chronic stroke survivors (≥ 6 months post-stroke) with mild-to-moderate upper limb impairment (Fugl-Meyer Upper Extremity Assessment (FMA-UE) scores 30-60/66 points) with cognitive ability to participate in task-practice therapy. None of the participants had botulin toxin injection in the paretic upper limb within 3 months of enrollment or concurrent upper limb therapy other than the study intervention. Participants had the mean age of 62 (SD=8) years, mean time post-stroke of 5 (SD=5) years, and mean FMA-UE score of 48 (SD=8). Demographic characteristics, including age, time post-stroke, and FMA-UE scores, were not significantly different between groups. All participants provided written informed consent. The study protocol was approved by the Medical University of South Carolina's Institutional Review Board.

Assessments

The level of sensory impairment was quantified as the sensory threshold in this study. The sensory threshold was measured before the intervention as the lowest vibration amplitude at which the participant could feel the vibration at the wrist, determined using the staircase method [28]. The sensory threshold was expressed as percent of the maximum possible vibration amplitude (root mean square velocity of 68 mm/sec). Motor improvement following therapy was quantified as change in box and block test scores from pre to post-intervention. The post-intervention box and block test was completed on average 6 (SD=3.6) days after the last intervention day [14].

Analysis

A regression analysis was used to determine the relationship between sensory impairment level and motor improvement. The regression analysis included the between participant groups (treatment and control) and the interaction between sensory impairment level and group. All statistical analyses were performed using SAS (SAS Institute Inc., Cary, NC, USA).

Results

Sensory impairment level significantly predicted motor improvement (p=0.006) (Figure 1). Specifically, participants with better sensation (*i.e.*, with lower sensory threshold) had greater motor improvement than participants with worse sensation (*i.e.*, with higher sensory threshold). The treatment group had a greater motor improvement than the control group (p=0.0117). The interaction between group and sensory impairment level was not significant (p=0.949), indicating that the motor improvement decreased similarly in the two groups as the sensory impairment increased.

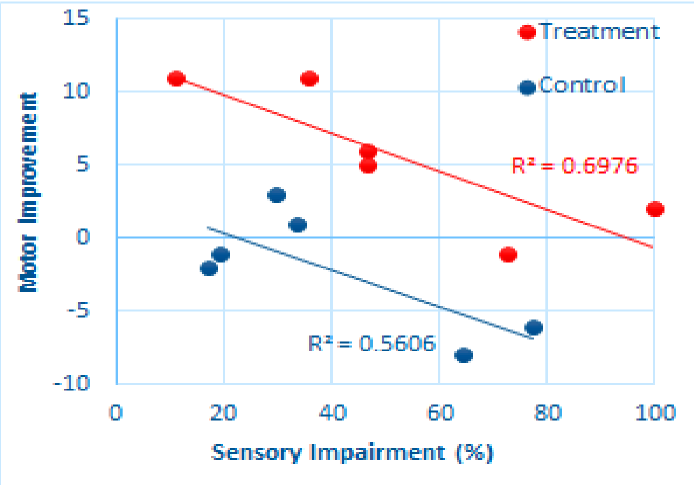

Figure 1. Association between sensory impairment level and motor improvement. Sensory impairment level was quantified as the pre-intervention sensory threshold. The motor improvement was quantified as change in the Box and Block Test score from pre- to post-intervention.

Discussion

Sensory impairment is rarely considered in post-stroke motor rehabilitation [10,18]. However, sensation is essential to enable feedback motor control [29,30]. Longer feedback loops and direct projections from the cortical hand sensory areas to motor areas exist as evidenced by the cutaneomuscular reflex in humans [31,32] and intracortical micro stimulation studies in animals [33-36]. These projections enable sensory feedback to affect motor output [37]. Thus, it follows that impaired sensation results in impaired motor function [38-41]. Many cross-sectional studies exist to show that stroke survivors with sensory deficits tend to have poor motor function [11,12,42-48]. More importantly, sensory deficits hamper motor learning. Motor learning relies on development of an internal model to output motor commands that are appropriate for the motor state informed by the sensory feedback [49-51]. Sensory deficits, and thus impaired sensory feedback, likely interfere with development of an accurate internal model, thereby motor learning [52,53]. The significant contribution of the present study is the presentation of longitudinal clinical data to suggest that greater severity of sensory impairment may diminish upper extremity motor recovery following intervention in chronic stroke survivors.

The present study provides insight into the importance of considering sensation for motor recovery. For example, sensory impairment level may be considered as a prognostic means to predict motor recovery. Improved prognosis may assist clinicians with determining appropriate rehabilitation goals, rehabilitation treatment, and discharge planning for individual stroke survivors. In addition, sensory intervention [54,55] may be a prerequisite to or in conjunction with motor intervention to promote motor recovery.

Interestingly, sensory impairment level did not alter the effect of the peripheral stimulation. All but one participant had some residual sensation, as seen by the sensory threshold less than 100% of the maximum possible amplitude. In addition, the peripheral stimulation was adjusted to be 60% of the sensory threshold for individual participants. Thus, it is possible that the residual sensory pathway, together with the individually adjusted peripheral stimulation amplitude, was able to yield the benefit of the peripheral sensory stimulation.

Conclusion

The primary limitation of this study is that it is exploratory and consequently has the small sample size. Larger studies are warranted, where additional covariates such as baseline motor function level, sex as a biological variable, age, and time since stroke could be examined. Other future research directions include investigation of the relative contributions of the sensory versus motor pathway integrity to post-stroke motor recovery as well as reorganization of these pathways with sensorimotor intervention.

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Authors' contribution

Dr. Na Jin Seo is the Principal Investigator of the study. Dr. Na Jin Seo and Jenna Blaschke conceived this study. Dr. Na Jin Seo, Jenna Blaschke, and Dr. Amanda Vatinno contributed to analysis. Drs. Amanda Vatinno and Viswanathan Ramakrishnan performed statistical analysis/interpretation. All authors contributed to result interpretation and writing of this manuscript. All authors reviewed and approved the final manuscript.

Conflict of interest

Dr. Na Jin Seo is an inventor of a patent regarding the investigated sub threshold vibratory stimulation. The other authors report no conflicts of interest.

References

1. Virani SS, et al. Heart disease and stroke statistics-2021 update: A report from the american heart association. *Circulation.*143 (2021):e254-e743
2. Lawrence ES, et al. Estimates of the prevalence of acute stroke impairments and disability in a multiethnic population. *Stroke.* 32 (2001): 1279-1284.
3. Nakayama H, et al. Recovery of upper extremity function in stroke patients: The copenhagen stroke study. *Arch Phys Med Rehabil.* 75.4 (1994):394-398.
4. Stewart JC, et al. Patient-reported measures provide unique insights into motor function after stroke. *Stroke.* 44.4 (2013):1111-1116.
5. Semrau JA, et al. Examining differences in patterns of sensory and motor recovery after stroke with robotics. *Stroke.* 46.12 (2015):3459-3469.

6. Carey LM, Matyas TA. Frequency of discriminative sensory loss in the hand after stroke in a rehabilitation setting. *J Rehabil Med*. 43.3 (2011):257-263.

7. Kim JS, et al. Discriminative sensory dysfunction after unilateral stroke. *Stroke*. 27.4 (1996):677-682.

8. Bowden JL, et al. The prevalence and magnitude of impaired cutaneous sensation across the hand in the chronic period post-stroke. *PLoS One*. 9.8 (2014):e104153.

9. Vidoni ED, et al. Preserved motor learning after stroke is related to the degree of proprioceptive deficit. *Behav Brain Funct*. 5 (2009):36.

10. Kessner SS, et al. Somatosensory deficits after stroke: A scoping review. *Top Stroke Rehabil*. 23.2 (2016):136-146.

11. Tyson SF, et al. Sensory loss in hospital-admitted people with stroke: Characteristics, associated factors, and relationship with function. *Neurorehabil Neural Repair*. 22.2 (2008):166-172.

12. Meyer S, et al. How do somatosensory deficits in the arm and hand relate to upper limb impairment, activity, and participation problems after stroke? A systematic review. *Phys Ther*. 94.9 (2014):1220-1231.

13. Conforto AB, et al. Repetitive peripheral sensory stimulation and upper limb performance in stroke: A systematic review and meta-analysis. *Neurorehabil Neural Repair*. 32.10 (2018):863-871.

14. Seo NJ, et al. Therabracelet stimulation during task-practice therapy to improve upper extremity function after stroke: A pilot randomized controlled study. *Phys Ther*. 99.3 (2019):319-328.

15. Schabrun SM, et al. Primary sensory and motor cortex excitability are co-modulated in response to peripheral electrical nerve stimulation. *PLoS One*. 7 (2012):e51298.

16. Kaelin-Lang A, et al. Modulation of human corticomotor excitability by somatosensory input. *J Physiol*. 540.2 (2002):623-633.

17. Celnik P, et al. Somatosensory stimulation enhances the effects of training functional hand tasks in patients with chronic stroke. *Arch Phys Med Rehabil*. 88.11 (2007):1369-1376.

18. Bolognini N, et al. The sensory side of post-stroke motor rehabilitation. *Restor Neurol Neurosci*. 34 (2016):571-586.

19. Reding MJ, Potes E. Rehabilitation outcome following initial unilateral hemispheric stroke. Life table analysis approach. *Stroke*. 19.11 (1998) : 1354-1358.

20. Seo NJ, et al. Effect of imperceptible vibratory noise applied to wrist skin on fingertip touch evoked potentials - an eeg study. *Physiol Rep*. 3.11(2015):e12624.

21. Seo NJ, et al. Use of imperceptible wrist vibration to modulate sensorimotor cortical activity. *Experimental brain research*. 237.3 (2019) :805-816.

22. Seo NJ, et al. Effect of remote sensory noise on hand function post stroke. *Front Hum Neurosci*. 8 (2014) :934.

23. Enders LR, et al. Remote vibrotactile noise improves light touch sensation in stroke survivors' fingertips *via* stochastic resonance. J *Neuroeng Rehabil*. 10 (2013):105.

24. Lakshminarayanan K, et al. Application of vibration to wrist and hand skin affects fingertip tactile sensation. *Physiol Rep*. 3.7 (2015):e12465.

25. Wang F, et al. An mri-compatible hand sensory vibrotactile system. *Physiol Meas*. 36 (2015):N15-21.

26. Hur P, et al. Investigating the role of vibrotactile noise in early response to perturbation. *IEEE Transactions on Biomedical Engineering*. 61.6 (2014): 1628-1633.

27. Vatinno AA, et al. Using subthreshold vibratory stimulation during poststroke rehabilitation therapy: A case series. OTJR (Thorofare N J). 42 (2022):30-39.

28. Ehrenstein WH, et al. Psychophysical methods. In: Windhorst U, Johansson H, eds. Modern techniques in neuroscience research. *Springer*.(1999):1211-1241.

29. Baker SN. Oscillatory interactions between sensorimotor cortex and the periphery. *Curr Opin Neurobiol*. 17.6 (2017) :649-655.

30. Scott SH. Optimal feedback control and the neural basis of volitional motor control. *Nat Rev Neurosci*. 5.7 (2004):532-546.

31. Jenner JR, et al. Cutaneous reflex responses and their central nervous pathways studied in man. *J Physiol*. 333 (1982):405-419.

32. Chen R, et al. Reflex responses in upper limb muscles to cutaneous stimuli. *Can J Neurol Sci*. 20.4 (1993):271-278.

33. Kaneko T, et al. Information processing within the motor cortex. Ii. Intracortical connections between neurons receiving somatosensory cortical input and motor output neurons of the cortex. *J Comp Neurol*. 345.2 (1994):172-184.

34. Kaneko T, et al. Information processing within the motor cortex. I. Responses of morphologically identified motor cortical cells to stimulation of the somatosensory cortex. *J Comp Neurol*. 345.2 (1994):161-171.

35. Lemon RN. Functional properties of monkey motor cortex neurones receiving afferent input from the hand and fingers. *J Physiol*. 311 (1981): 497-519.

36. Matyas F, et al. Motor control by sensory cortex. *Science*. 330.6008 (2010):1240-1243.

37. Ridding MC, Rothwell JC. Afferent input and cortical organisation: A study with magnetic stimulation. *Exp Brain Res*.126 (1996):536-544.

38. Monzee J, et al. The effects of digital anesthesia on force control using a precision grip. *J Neurophysiol*. 89 (2003):672-683.

39. Augurelle AS, et al. Importance of cutaneous feedback in maintaining a secure grip during manipulation of hand-held objects. *J Neurophysiol*. 89 (2003):665-671.

40. Shim JK, et al. Tactile feedback plays a critical role in maximum finger force production. *J Biomech*. 45 (2012):415-420.

41. Hur P, et al. Muscular responses to handle perturbation with different glove condition. *J Electromyogr Kinesiol*.24.1 (2014):159-164.

42. Enders LR, et al. Effects of sensory deficit on phalanx force deviation during power grip post stroke. *J Mot Behav*.49.1 (2017):55-66.

43. Blennerhassett JM, et al. Impaired discrimination of surface friction contributes to pinch grip deficit after stroke. *Neurorehabil Neural Repair*. 21.3 (2007):263-272.

44. Enders LR, et al. Altered phalanx force direction during power grip following stroke. *Exp Brain Res*.233.6 (2017):1677-1688.

45. Campfens SF, et al. Poor motor function is associated with reduced sensory processing after stroke. *Exp Brain Res*.233.4 (2015):1339-1349.

46. Dukelow SP, et al. The independence of deficits in position sense and visually guided reaching following stroke. *J Neuroeng Rehabil*.9 (2012): 72.

47. Sommerfeld DK, et al. The impact of somatosensory function on activity performance and length of hospital stay in geriatric patients with stroke. *Clin Rehabil*.18.2 (2014):149-155.

48. Hill VA, et al. Relationship between touch sensation of the affected hand and performance of valued activities in individuals with chronic stroke. *Top Stroke Rehabil*. 21 (2014):339-346.

49. Wolpert DM, et al. An internal model for sensorimotor integration. *Science*. 269.5232 (1995):1880-1882.

50. Ito M. Control of mental activities by internal models in the cerebellum. *Nat Rev Neurosci*. 9 (2008):304-313.

51. Kawato M, et al. Internal models for motor control. *Novartis Found Symp*. 218 (1988):304-297.

52. Vidoni ED, et al. Role of the primary somatosensory cortex in motor learning: An rtms study. *Neurobiol Learn Mem*.93.4 (2010):532-539.

53. Pavlides C, et al. Projection from the sensory to the motor cortex is important in learning motor skills in the monkey. *J Neurophysiol*. 70 (1993):733-741.

54. Yekutiel M, et al. A controlled trial of the retraining of the sensory function of the hand in stroke patients. *J Neurol Neurosurg Psychiatry*. 56 (1993):241-244.

55. Carey LM, et al. Same intervention-different reorganization: The impact of lesion location on training-facilitated somatosensory recovery after stroke. *Neurorehabil Neural Repair*. 30.10 (2016):988-1000.

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