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

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Abstract

Sensory impairment may impact individual stroke survivors' motor recovery as well as their response to peripheral sensory stimulation treatment. 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. A secondary analysis of a pilot triple-blind randomized controlled trial was used. Twelve chronic stroke survivors were randomly assigned to the treatment group receiving peripheral sensory stimulation or the control group receiving no stimulation during 2-week hand task practice 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. This study found that 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. These findings suggest that the level of sensory impairment may predict recovery potentials and direct rehabilitation treatment for stroke survivors.

Keywords

Stroke Rehabilitation; Upper Extremity; Neurologic Rehabilitation; Subliminal Stimulation; Sensory Function

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Introduction

Stroke affects approximately 795,000 people per year in the U.S. and is a major cause of long-term disability (Virani et al., 2021). More than two thirds of stroke survivors have hand impairment (Lawrence et al., 2001), which limits their ability to perform activities of daily living (Stewart & Cramer, 2013). In addition to motor impairment, sensory impairment is a common after stroke. An estimated 50–85% of chronic stroke survivors have sensory impairment (Carey & Matyas, 2011; Kim & Choi-Kwon, 1996). Sensory impairment significantly hinders motor learning (Vidoni & Boyd, 2009) and thus, impedes motor recovery (Meyer, Karttunen, Thijs, Feys, & Verheyden, 2014; Tyson, Hanley, Chillala, Selley, & Tallis, 2008). However, sensory impairment is not typically considered in predicting rehabilitation outcomes (Bolognini, Russo, & Edwards, 2016).

Peripheral sensory stimulation can supplement manual rehabilitation therapy and enhance upper extremity motor recovery post-stroke (Conforto et al., 2018). Peripheral sensory stimulation not only activates the afferent pathway but also primes the motor cortex for greater motor improvement (Celnik, Hummel, Harris-Love, Wolk, & Cohen, 2007; Kaelin-Lang et al., 2002). However, sensory impairment may curtail the effect of peripheral sensory stimulation due to disruption in the afferent pathways. 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.

Methods

The study design is secondary analysis of a triple-blind randomized controlled trial (Seo, Woodbury, et al., 2019). Twelve chronic stroke survivors were randomly assigned to either the treatment or control group (n=6/group). Both groups received standardized hand task-practice therapy while wearing a stimulation device on the paretic wrist for 2 hours/session, 3 times/week for 2 weeks. The device delivered imperceptible random-frequency vibration at 60% of sensory threshold for the treatment group and no vibration for the control group. This vibration elevates cortical neuronal firing (Schranz, Vatinno, Ramakrishnan, & Seo, 2022; Seo, Lakshminarayanan, Bonilha, Lauer, & Schmit, 2015; Seo, Lakshminarayanan, et al., 2019) to improve sensorimotor function (Enders, Hur, Johnson, & Seo, 2013; Hur, Wan, & Seo, 2014; Lakshminarayanan, Lauer, Ramakrishnan, Webster, & Seo, 2015; Seo, Kosmopoulos, Enders, & Hur, 2014; Wang, Lakshminarayanan, Slota, Seo, & Webster, 2015) and recovery in stroke survivors (Seo, Woodbury, et al., 2019; Vatinno, Hall, et al., 2022). The device usability and feasibility have been demonstrated (Lakshminarayanan, Wang, Webster, & Seo, 2017; Seo et al., 2020). Full descriptions of this stimulation and task-practice therapy are in Seo, Woodbury, et al. (2019).

Participants were adult chronic stroke survivors (> 6 months post-stroke) with mild-to-moderate upper limb impairment (Fugl-Meyer Upper Extremity Assessment (FMA-UE) 30–60/66) with cognitive ability to participate in task-practice therapy. None of the participants had botulinum toxin injection in the paretic upper limb within 3 months of

enrollment or concurrent other upper limb therapy. Participants had the mean age of 62 (SD = 8) years, time post-stroke of 5 (SD = 5) years, and FMA-UE score of 48 (SD = 8). Demographic characteristics, including age, time post-stroke, and FMA-UE, were not significantly different between groups. All participants in both groups completed the study. All participants provided informed consent approved by the local Institutional Review Board.

Sensory impairment was quantified as the sensory threshold. The sensory threshold was measured before intervention as the lowest vibration amplitude that the participant could feel on the wrist using the staircase method (Ehrenstein & Ehrenstein, 1999) and expressed as percent of the maximum amplitude (RMS velocity 68 mm/sec). Motor improvement was quantified as change in Box and Block Test scores from pre-intervention to on average 6 days after the last intervention day.

Regression was used to determine the relationship between sensory impairment and motor improvement. The regression analysis included group (treatment/control) and the interaction between sensory impairment and group. Statistical analysis was 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 (with lower sensory threshold) had greater motor improvement than participants with worse sensation (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 with increasing sensory impairment similarly in the two groups.

Discussion

Sensory impairment is rarely considered in post-stroke motor rehabilitation (Bolognini et al., 2016). However, sensation is essential to enable feedback motor control (Scott, 2004) via feedback loops from the cortical hand sensory areas to motor areas (Chen & Ashby, 1993; Matyas et al., 2010). These projections enable sensory feedback to affect motor output (Enders & Seo, 2011; Seo, Shim, Engel, & Enders, 2011). It follows that impaired sensation results in impaired motor function (Hur, Motawar, & Seo, 2014; Monzee, Lamarre, & Smith, 2003; Shim et al., 2012). Many cross-sectional studies show that stroke survivors with sensory deficits tend to have poor motor function (Blennerhassett, Matyas, & Carey, 2007; Campfens et al., 2015; Enders & Seo, 2015, 2017; Hill, Fisher, Schmid, Crabtree, & Page, 2014; Meyer et al., 2014; Tyson et al., 2008). More importantly, sensory deficits hamper motor learning (Vidoni & Boyd, 2009). Motor learning relies on the internal model to adjust motor commands appropriately per sensory feedback (Wolpert, Ghahramani, & Jordan, 1995). Sensory deficits, and thus impaired sensory feedback, likely interfere with development of an accurate internal model, thereby motor learning (Vidoni & Boyd, 2009).

The significant contribution of this study is the longitudinal data suggesting that more severe sensory impairment may diminish upper extremity motor recovery in stroke survivors.

Clinically, this study suggests considering sensory impairment as prognosis for motor recovery. Improved prognosis may guide appropriate rehabilitation goals, treatment, and discharge planning. Sensory intervention (Schabrun & Hillier, 2009) may be used as 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 residual sensation, as seen by the sensory threshold less than the maximum amplitude. The stimulation was adjusted to 60% of sensory threshold for individual participants. Thus, it is possible that the residual sensory pathway, together with the individually adjusted stimulation amplitude, could yield the benefit of the peripheral sensory stimulation.

The limitation of this study is that it is secondary analysis using a small sample size from the trial. Larger studies are warranted, where additional covariates of baseline motor function level, age, and time post-stroke could be examined (Seo et al., 2022). Future directions include investigation of the contributions of the sensory versus motor pathway integrity to post-stroke motor recovery and reorganization of these pathways with intervention (Vatinno, Schranz, et al., 2022).

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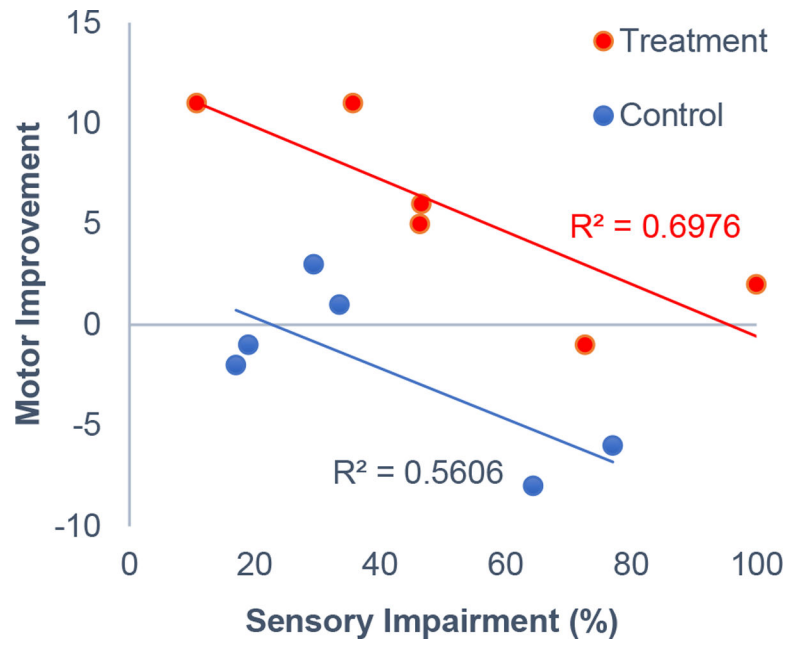


Figure 1. Association between sensory impairment level and motor improvement. Sensory impairment level was quantified as the pre-intervention sensory threshold. The motor improvement was quantified as change in the Box and Block Test score from pre- to post-intervention.