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Review

Adding electrical stimulation during standard rehabilitation after stroke to improve motor function. A systematic review and meta-analysis

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ABSTRACT

Background: Clinical studies have shown that sensory input improves motor function when added to active training after neurological injuries in the spinal cord.
Objective: We aimed to determine the effect on motor function of extremities of adding an electrical sensory modality without motor recruitment before or with routine rehabilitation for hemiparesis after stroke by a comprehensive systematic review and meta-analysis.
Methods: We searched databases including MEDLINE via PubMed and the Cochrane Central Register of Controlled Trials from 1978 to the end of November 2017 for reports of randomized controlled trials or controlled studies of patients with a clinical diagnosis of stroke who underwent 1) transcutaneous electrical nerve stimulation (TENS) or peripheral electromyography-triggered sensory stimulation over a peripheral nerve and associated muscles or 2) acupuncture to areas that produced sensory effects, without motor recruitment, along with routine rehabilitation. Outcome measures were motor impairment, activity, and participation outcomes defined by the International Classification of Functioning, Disability and Health.
Results: The search yielded 11 studies with data that could be included in a meta-analysis. Electrical sensory inputs, when paired with routine therapy, improved peak torque dorsiflexion (mean difference [MD] 2.44 Nm, 95% confidence interval [CI] 0.26–4.63). On subgroup analysis, the combined therapy yielded a significant difference in terms of sensory stimulation without motor recruitment only on the Timed Up and Go test in the chronic phase of stroke (MD 3.51 sec, 95% CI 3.05–3.98). The spasticity score was reduced but not significantly (MD – 1.11 points, 95% CI -2.35 – 0.13).
Conclusion: Electrical sensory input can contribute to routine rehabilitation to improve early post-stroke lower-extremity impairment and late motor function, with no change in spasticity. Prolonged periods of sensory stimulation such as TENS combined with activity can have beneficial effects on impairment and function after stroke.

1. Introduction

Hemiparesis is one of the prominent impairments caused by stroke that affects activities of daily living and quality of life [1]. Clinically, the failure to recover motor deficits rapidly within a few months after brain insult reduces the individual's potential to participate in therapy [2,3]. The initial damage to the neuronal pathways followed by functional reorganization halt the motor recovery; however, many stimuli have shown potential therapeutic benefit to improve functional recovery after stroke. Traditionally, in stroke research, potential therapeutic strategies targeting motor recovery emphasize motor stimulation associated with massed motor practice for the recovery of motor skills [4].

Afferent motor stimulation leads to neurological improvements, but the recovery of function varies. The effects of increased sensory input on motor outcomes have been relatively neglected in

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the rehabilitation literature as compared with those of other interventions, even though a number of studies suggested clinical benefits. In 1915, Franz et al. were the first to report success in recovering upper extremity motor function by using simple rehabilitative techniques such as massage and vibration. [5] In particular, cutaneous and proprioceptive afferent information facilitates the improvement of motor performance and promotes effective motor learning because it increases the cortico-motor excitability in areas representing the stimulated body parts [6–10]. Subsequent research has shown that electrical sensory input alters the sensory and motor cortical maps [3,11–13] and clinical studies have shown that sensory input improved motor function when added to active training after neurological injuries in the spinal cord [14].

A recent systematic review and a meta-analysis of the effects of augmenting rehabilitation with sensory stimulation were published in the past 10 years [15,16]. The review by Laufer et al. did not lead to a meta-analysis because of too few studies that met inclusion criteria and the meta-analysis by Veerbeek et al. did not separate sensory stimulations that lead to motor recruitment from pure sensory-level stimulation.

In the current analysis we expanded on these studies. In particular, we used a newer method for the meta-analysis. The random-effects method is commonly used, but it forces the distribution of effect sizes to be independent of the study design, for no relation between a study's effect size and the size of study. This is a strong assumption, which is not necessarily true for all studies, so the estimate of the between-studies variance will have poor precision, limiting investigators' and clinicians' ability to apply the commonly used random-effects method appropriately. Because of major issues with this method [17,18], we used the approach proposed by Shuster et al. to overcome the fundamental limitations of the empirical weighting method. In this approach, "studies-at-random" assumes that studies are drawn from a population of studies that are independent and implies that the weight given to each study's effect size is a random variable [19].

Thus, this current study extended the previous work by:

- potentially broadening the available literature that could be reviewed;
- using a method suitable for pooling a small number of studies with a small number of participants;
- examining the effects of electrical sensory stimulation without motor recruitment across levels of function.

The primary questions driving this current analysis were as follows:

- Is there evidence for the efficacy of augmenting rehabilitation with sensory input using electrical stimulation (e-stim) to improve motor function in a person after stroke?
- What are the specific effects of adding an electrical sensory modality before or along with routine rehabilitation on motor impairment, activity, and participation outcomes after stroke?

2. Methods

2.1. Identification and selection of studies

We extracted key words associated from relevant articles and used Medical Subject Heading (MeSH terms) and Major Headings to search for human studies in any language in the databases MEDLINE via PubMed, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Web of Science, SPORTDiscus, and Cumulative Index to Nursing and Allied Health Literature (CINAHL), Google, and WorldCat from 1978 to the end of November 2017. We also hand-searched the reference lists of published reviews and narrative review articles. In addition, abstracts published in relevant conference proceedings were polled.

The search terms included "cerebrovascular accident" OR "stroke" OR "hemiplegia" OR "hemiparesis" OR "hemiparetic," AND "vibration," "pressure" OR "haptics," "kinesthetic*," "stretch," "weight," "joint angle," OR "tactile," "touch," OR "texture," OR "transcutaneous electrical nerve stimulation," "TENS," "neuromuscular training," AND "motor," "movement," OR "motion," OR "mobility," OR "function," OR "performance". Although each database used differing syntax, this set of search terms was the basis for the searches in each of those databases.

We included reports of randomized controlled trials or controlled trials with parallel or crossover designs. In studies with more than 2 arms, the values related to e-stim or placebo interventions combined with the routine therapy were recorded.

All reports of sensory modalities investigated such as vibration, pressure, haptics, stretch, weight, proprioception, tactile, touch, texture, thermal, and transcutaneous electrical nerve stimulation (TENS) as adjunct therapy to routine rehabilitation to improve post-stroke motor function were included. However, the primarily sensory modality of interest was e-stim. Different e-stim interventions such as repetitive electrical nerve stimulation, acupuncture or muscle stimulation have common sensory nerve axon stimulation at specific peripheral sites. The comparison groups included active treatment (active or passive exercise, e-stim over different sites), placebo (sham, sub-sensory threshold stimulus intensity), and no treatment.

The outcome measures were any measurable activity-based motor function. To increase the generalizability of the results to the population of interest, we included studies of participants with all durations of stroke-related sequelae (acute, sub-acute, and chronic) and severity of stroke-induced hemiparesis. The International Classification of Functioning, Disability and Health (ICF) allowed us to document functioning and disability outcomes reported by the included studies across the levels of function (the body, the person, the society).

2.2. Assessment of quality of studies

Two independent raters (SSh and MDB) assessed the methodological quality of the included articles by using the standardized validated PEDro scale for the quality of controlled clinical trials [20], an 11-item scale [21] previously used in systematic reviews [22], with total scores ranging from 0 to 10. Agreement in quality assessment on PEDro rating between evaluators was measured by the Kappa statistic, with 95% confidence intervals (CIs). A kappa of 1 ndicates perfect agreement, and a kappa of 0 indicates agreement equivalent to chance.

2.3. Data analysis

The initial screening step involved examining the article title and major key words, then abstracts and full texts.

One author (SSh) extracted the relevant data from each article and recorded them on standardized Microsoft Excel spreadsheets. To ensure accurate copying of the data, a second reviewer (MDB) independently checked the information in the forms with the related articles. The data recorded were the study design, participant characteristics, type of intervention and co-intervention, region of the body to which the stimulus was applied, and the mean pre-and post-intervention values for each measure.