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Original article

Effects of sit-to-stand training combined with transcutaneous electrical stimulation on spasticity, muscle strength and balance ability in patients with stroke: A randomized controlled study

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ABSTRACT

Sit-to-stand is a fundamental movement of human being for performing mobility and independent activity. However, Stroke people symptoms experience difficulty in conducting the sit-to-stand due to paralysis and especially ankle spasticity. Recently, transcutaneouselectrical- stimulation (TENS) is used to reduce pain but also to manage spasticity. The purpose of this study was to determine (1) whether TENS would lead to ankle spasticity reduction and (2) whether sit-to-stand training combined with TENS would improve spasticity, muscle strength and balance ability in stroke patients. Forty-stroke patients were recruited and were randomly divided into two groups: TENS group (n = 20) and sham group (n = 20). All participants underwent 30-sessions of sit-to-stand training (for 15-min, five-times per week for 6-weeks). Prior to each training session, 30-min of TENS over the peroneal nerve was given in TENS group, whereas sham group received non-electrically stimulated TENS for the same amount of time. Composite-Spasticity-Score was used to assess spasticity level of ankle plantar-flexors. Isometric strength in the extensor of hip, knee and ankle were measured by handheld dynamometer. Postural-sway distance was measured using a force platform. The spasticity score in the TENS group (2.6 ± 0.8) improved significantly greater than the sham group (0.7 ± 0.8, $p < 0.05$). The muscle strength of hip extensor in the TENS group (2.7 ± 1.1 kg) was significantly higher than the sham group (1.0 ± 0.8 kg, $p < 0.05$). Significant improvement in postural-sway was observed in the TENS group compared to the sham group ($p < 0.05$). Thus, sit-to-stand training combined with TENS may be used to improve the spasticity, balance function and muscle strength in stroke patients.

1. Introduction

Sit-to-stand, which is a movement required for standing and walking, is essential for independent daily life [1]. The time required for stroke patients to perform sit-to-stand increases compared to the age-matched control due to damaged postural control ability and muscle weakness [2–4]. In stroke people, 37% of falls occurred during the transfer or posture changing from sitting to standing [5]. Also, as the reliability of the paretic side decreases, weight bearing on the paretic side also decreases [6], showing tendency for the trunk tends to laterally deviate toward the nonparetic side during the sit-to-standing [7,8].

To enhance body symmetry in regard with performing sit-to-stand, auditory feedback or visual feedback was used [6], or method of modifying or correcting foot position was employed [7,9]. Roy et al. [9] reported that weight bearing on the paretic side increases during sit-to-stand conducted with the paretic foot placed behind; which also increased the activity of paretic lower limb muscles. A study [10] showed that sit-to-stand training with their paretic feet behind improved postural sway and weight bearing asymmetry in stroke patients. However, the extensibility of plantar flexors is important in order to stand in a backward foot position [1], when spasticity of plantar flexors is present, it is

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difficult to stabilize the feet on the ground as the spasticity causes tightness and eventually disturbs stretching of the muscles [11].

Transcutaneous electrical stimulation (TENS) is a type of electrical therapy and has been used to treat and modulate pain perception in clinic. Interestingly, TENS is recently used to manage spasticity in patients with CNS disorder [12]. TENS has a short-term inhibitory effect on the abnormal stretch reflex activity caused by stroke [13,14], and also several studies demonstrated that TENS with/without exercise training is effective in decreasing spasticity [13,15,16] and enhancing postural stability in stroke patients [17–19]. Also, a review study for effects of the TENS has found that TENS with task related training is applied either individually or simultaneously, which could be more effective for improving spasticity and activity relative to the single therapeutic modality [20]. However, to date, studies on effects of TENS application with task training in lower limb is lacking and the most effective parameter of TENS application with task training is unclear.

Thus, the purpose of the study was twofold: (1) to investigate whether TENS application into ankle plantar-flexor with spasticity is effective to manage spasticity, and (2) to determine the effects sit-to-stand training with a status of decreased spasticity following TENS has on muscle strength as well as balance, and spasticity in patients with stroke.

2. Materials and methods

2.1. Participants

We used G*power 3.1.9.2 software to calculate the sample size. In present study, the mean power was set at 0.8 and the alpha error at 0.05. Also, the effect size was set to 0.8148 based on the pilot study (10 subjects). The analysis of G*power software shows that at least 20 participants should make an acceptable group sample size for each group; thus 42 participants were recruited in consideration of drop-out.

Participants were recruited from a rehabilitation centers after attaining a full understanding of the purpose and method of the research, and signing the consent form. Inclusion criteria were as follows: (1) first episode of unilateral stroke with hemiparalysis caused by hemicerebrum damage; (2) MRI to confirm stroke (3) able to understand and follow verbal commands; (4) able to independently stand up from a chair without using hand (5) moderate to severe spasticity in the affected ankle plantar flexors with composite spasticity score ≥ 10 [14,16,21] (6) motor recovery of the lower extremity by Brunnstrom stage is at 3 (7) National Institute of Health Stroke Scale (NIHSS) score <20 [7]. Exclusion criteria included: (1) hemianopia, dizziness, or other symptoms indicating vestibular impairment; (2) medical history of lesion of peroneal nerve (3) neglect and sensory loss [12] (4) orthopedic disease influencing sit-to-stand movement (5) contraindications of TENS (6) previous experiences with TENS therapy.

This study was approved by the Institutional Review Board of Gachon University. Table 1 shows the characteristics of subjects in the TENS and sham groups. Subjects were randomly assigned to the TENS group (n = 20) or the sham group (n = 21) using a selection envelope. Due to a change of address, one subject in the control group dropped out prior to completion of the training. All subjects were evaluated on their spasticity, muscle strength, and postural sway after the six-week training period (Fig. 1).

2.2. Intervention

Subjects in both the TENS and sham groups conducted sit-to-stand training. The training lasted for 15 min a day, five times a week for six weeks. Prior to each training session, subjects in the TENS group received electrical stimulation for 30 min while those in the sham group received non-electrically stimulated TENS for same time. All of the subjects received conventional therapy for an hour a day, five times a week for six weeks. All interventions were performed under the supervision of two licensed therapists to prevent the complications of the rehabilitation protocol or TENS stimulation.

TENS electrodes were attached over the peroneal nerve on the affected side. In the TENS group, electrical stimulation was applied to the peroneal nerve using a TENS machine (TENS-7000, Koalaty Products Inc., USA). The intensity of stimulation delivered by the TENS stimulator was two times the sensory threshold without muscle contraction. Pulses width of 200 μs was delivered at a frequency of 100 Hz. Sensory threshold, defined as the minimal tingling sensation felt by the patients. The subjects were asked to inform the mediator if they felt any discomfort or involuntary muscle contraction following TENS. Also, the mediator was asked to observe whether motion due to muscle contraction occurred in the subject. Electrodes were attached at the same location, but electrical stimulation was not applied in the sham group.

Subjects seated on an armless, height adjustable chair during the sit-to-stand training. The chair should be support for half of the

Table 1
Common and clinical characteristics of subjects.

Variable	TENS group (n = 20)	Sham group (n = 20)	p-value[a]
Sex			
Male	11	12	0.550[a]
Female	9	8	
Age	56.2 ± 10.4[a]	56.3 ± 10.2	0.316[b]
Weight (kg)	63.2 ± 7.6	64.3 ± 8.8	0.688[b]
Height (cm)	164.6 ± 9.0	167.1 ± 9.7	0.405[b]
Stroke type			
Ischemic	12	11	0.749[a]
Hemorrhagic	8	9	
Affected side			
Left	10	11	0.977[a]
Right	10	9	
Post-stroke Duration (Month)	6.5 ± 2.7	6.6 ± 2.5	0.856[b]
MMSE	26.5 ± 1.7	27.0 ± 1.4)	0.316[b]

MMSE, Mini-Mental Status Examination.
Values are expressed as mean ± standard deviation (SD).
[a] Chi-square test Independent t-test.
[b] Independent t-test.