Relationship between the Application of TENS to the Lower Limbs and Balance of Healthy Subjects

Mi-Kyung Kang, PT1), Bo-Ra Nam, PT2), Yun-Seob Lee, PT, PhD3), Song-Hee Cheon, PT, PhD3) *

1) Keun Madi Clinic
2) True Love Clinic
3) Department of Physical Therapy, Youngsan University: 288 Joonam-ro, Yangsan, Kyeongsangnam-do, Republic of Korea. TEL: +82 55-380-9438, FAX: +82 55-380-9305

Abstract. [Purpose] The purpose of the present study was to investigate the effect of TENS applied to the skin overlying the bellies of the gastrocnemius muscles of the lower limbs on balance and plantar pressure of healthy adults. [Subjects and Methods] Twenty-eight healthy college students were the subjects of this study. Adhesive transcutaneous electrical nerve stimulation (TENS) electrodes were attached to the medial and lateral belly of the gastrocnemius muscle. Before and after the application of the TENS, subjects' balance ability and maximum plantar pressure were measured and compared. [Results] The scores improved in the balance tests, including the fall risk test and the stability limit test, after the application of TENS, and a statistically significant difference was noted in the stability limit test. The maximum plantar pressure after the application of TENS decreased except beneath the big toe, and statistically significant difference was found under the forefoot. [Conclusion] The results of present study suggest that TENS applied to the skin overlying gastrocnemius muscles is useful strategy that improves the balance ability of healthy adults.

Key words: TENS, Balance, Lower limb

INTRODUCTION

Balance is an essential requirement for the successful performance of an extensive range of human behaviors. Balance efficacy is an individual's confidence in his/her ability to maintain balance and avoid falling when performing behaviors such as standing on a chair to reach for an object or walking in a cluttered environment.

The maintenance of balance depends on the integration of inputs from the somatosensory, visual, and vestibular systems. One of the components of the somatosensory system is cutaneous receptors.

Transcutaneous Electrical Nerve Stimulation (TENS) is a usefully applied and well-tolerated clinical modality. Although stimulation at a sub-motor threshold amplitude is primarily used for reducing pain, other effects are also well established, and TENS at different amplitudes has been shown to affect the excitability of spinal interneurons and motor neurons.

Cho et al.4) reported that TENS improved spasticity and balance of patients with chronic stroke. Guariglia et al.5) noted that the application of TENS to the neck muscles on the paretic side of patients with hemispatial neglect improved postural control and spatial orientation. However, to our knowledge, the relationship between the balance and the application of TENS to the lower limbs has not been established. In addition, the effect of TENS on the muscles of healthy subjects is not well known. Therefore, the purpose of the present study was to investigate the effect of TENS applied to the skin overlying the bellies of the gastrocnemius muscles of the lower limbs on the balance and plantar pressure of healthy adults.

SUBJECTS AND METHODS

Twenty-eight healthy college students were the subjects of this study. Their average age, height, and weight were 21.36 ± 1.81 years old, 166.65 ± 6.47 cm, and 61.99 ± 11.16 kg, respectively. Those who did not have neurological or musculoskeletal abnormality that affected balance were selected. The subjects were forbidden to take medicine or drink alcohol in the 24 hours prior to the study. A sufficient explanation about this study was given and only those who consented to participation were included.

In this study, in order to measure balance ability, Biodex Balance System SD (Biodex Inc., Shirley, NY, USA) was used for the stability limit test and the fall risk test. The base of support was connected to a computer running proprietary software (Biodex, ver 0.0, Biodex, Inc.) which computes an objective balance evaluation.

The subjects took off their shoes, stepped on the foot-plate, folded their arms on the trunk comfortably, and maintained their body in an upright position while staring at the...
monitor in front of them. The location of the feet was where the line of gravity that passed through the ankle joint vertically met the marked line on the footplate, and a reference point was marked on the foothold in order to minimize changes in the reference point in the repeat measurement.

An F-scan System (Teckscan Inc., USA) was used to measure the distribution of plantar pressure. The F-scan System consists of an insole sensor that measures plantar pressure, a converter that is attached to the legs, cables that connect the converter to a computer, and software for the analysis of plantar pressure. In this system, the thickness of the mat measuring pressure is 0.88 mm, and it has 128 resistance sensors of 9 × 16 mm are arranged in an 8 × 16 array; data is sampled at 3.072 Hz. Its measurement range is from 0 to 30 psi. We used three different sizes of pressure mats: 230 × 100 mm, 250 × 100 mm, 270 × 100 mm. The subjects put suitably-sized mat on their feet. Their soles were divided into regions in order to analyze the pressure distribution characteristics of each region rather than obtaining information on pressure on the soles as a single number. In this study, the foot was divided into eight different regions for the measurement of pressure: two toe regions, three forefoot regions, one midfoot region (M), and two heel regions (H1 and H2). The toes were divided into the great toe region (T1) and the second to fifth toe region (T2). Among the three forefoot regions, the medial forefoot region was below the first caput metatarsalis (F1), the middle forefoot region was below the second and the third caput metatarsalis (F2), and the lateral forefoot region was below the fourth and fifth caput metatarsalis (F3). The maximum pressure of each region of the foot during the performance of a task was measured. The signal input was delivered to a computer interface via a 10 m attached to the subjects’ waists. Data were collected and analyzed using F-Scan research TAM/STAM 6.00 software (Tekscan Inc., South Boston, MA, USA).

In order to reduce errors at the arch, the subject wore the F-Scan mat on their bare feet and walked in a straight line for 10 seconds three times; the average value was calculated.

Adhesive transcutaneous electrical nerve stimulation (TENS) electrodes were attached to the medial and lateral bellies of the gastrocnemius muscle. After the attachment of the electrodes, subjects’ balance ability and plantar pressures were measured as described above. SPSS ver. 17.0 was used for the analysis of the data. The independent t-test was conducted in order to compare balance test and plantar pressure results prior to and after the application of TENS.

All data was expressed as mean ± SD and statistical significance was accepted for values of p<0.05.

RESULTS

The fall risk test result and the stability test result measures of balance ability were 0.77 ± 0.31 and 48.85 ± 14.18, respectively. These values increased after the application of the TENS, but only the stability limit test showed a statistically significant result (p<0.05) (Table 1).

According to the analysis of the maximum plantar pressure, T1 was 1.67 ± 0.81, T2 was 0.87 ± 0.58, F1 was 3.94 ± 1.77, F2 was 5.83 ± 2.00, F3 was 2.32 ± 1.36, M was 1.93 ± 1.10, H1 was 10.16 ± 4.03, and H2 was 4.11 ± 3.00. Maximum plantar pressure after the TENS application decreased in all regions except for T1, and the decrease was statistically significant at F2 and F3 (p<0.05) (Table 2).

DISCUSSION

Balance control in an upright position is required for independence in activities of daily living (ADL)7). In addition, the definition of human balance, dynamic postural control to prevent falling8, implies that balance performance is necessary to avoid falls9.

The principal objective of this study was to evaluate the effects of TENS application to the skin overlying the bellies of the gastrocnemius muscles of the lower limbs on the balance and plantar pressures of healthy adults. The fall risk test and stability limit test were used to assess balance ability. Our results show that balance scores improved in the fall risk test and stability limit test after the application of TENS, and a statistically significant difference was noted in the stability limit test.

Citaker et al.10 reported that light touch-pressure, vibration, and two-point discrimination of sensations on the foot sole decreased in mild to moderately disabled patients with multiple sclerosis (MS), and as a result, one-leg standing balance ability decreased. Decrease in the sensitivity of the foot sole is related with imbalance in the MS population. Pèrennou et al.11 found that TENS reduced neglect-related postural instability after stroke, but no effect was observed in patients without neglect.

TENS was used in this study with a view to improving the balance of healthy subjects. TENS is a safe and well-established procedure that can be delivered over prolonged periods, via cutaneous electrodes glued to the skin. This intervention consists of stimulating superficial cutaneous

| Table 1. Fall risk test and stability limit test results (unit: score) |
|---|---|---|
| Pre-TENS | Post-TENS |
| Fall risk test | 0.72 ± 0.26 | 0.77 ± 0.31 |
| Stability limit test | 35.78 ± 16.89 | 48.85 ± 14.18* |

mean ± SD, *p<0.05

| Table 2. Plantar pressure results of each foot region |
|---|---|
| T1 | 1.59 ± 1.28 | 1.67 ± 0.81 |
| T2 | 0.97 ± 0.64 | 0.87 ± 0.58 |
| F1 | 4.29 ± 2.92 | 3.94 ± 1.77 |
| F2 | 7.41 ± 3.55 | 5.83 ± 2.00* |
| F3 | 3.20 ± 1.97 | 2.32 ± 1.36* |
| M | 2.40 ± 1.52 | 1.93 ± 1.10 |
| H1 | 11.63 ± 5.35 | 10.16 ± 4.03 |
| H2 | 5.17 ± 2.70 | 4.11 ± 3.00 |

mean ± SD, *p<0.05
nerve fibers of large diameter\(^2\), by an electric current of relatively short-pulse duration and intensity below the motor threshold\(^3\).

Plantar pressure measurement is being increasingly used in both research and clinical practice to compare gait patterns of different clinical groups and to evaluate the effects of footwear, and orthotic and surgical interventions\(^4\)\(^5\)

In the present study, the maximum plantar pressures of the different foot regions after the application of TENS decreased, except that of T1, and statistically significant differences were found at F2 and F3.

Walking speed has been shown to linearly influence the loading patterns beneath the hallux and the rearfoot. However, increase in walking speed has less of an effect on forefoot loading patterns. Medial and middle forefoot loading initially increases at slower walking speeds, but remains constant or decreases as subjects began to walk faster, and this has been attributed to a decrease in contact time as walking speed increases\(^3\). While changes in loading patterns have been observed at the rearfoot, hallux, and forefoot, the forces beneath the medial and lateral midfoot are not significantly altered by increases in walking speed\(^6\).

Our results suggest that TENS applied to the skin overlying gastrocnemius muscles improves the balance ability of healthy adults. Although the mechanisms of postural control after the application of TENS to the lower limbs in healthy adults are not well known, the results of this study indicate that cutaneous stimulation increases postural stability. Therefore, we can conclude that TENS application to the skin overlying the gastrocnemius muscle is a useful strategy that enhances the balance ability of healthy adults. Furthermore, cutaneous stimulation of the lower limbs may help to improve the balance of older people. However, more study will be needed to establish its clinical application.

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