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Effects of Local Muscle Vibration on the Displacement of Center of Pressure during Quiet Standing

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Abstract. [Purpose] The purpose of this study was to investigate the effect of local vibration stimuli on body balance (trace area, trace length, and velocity) in healthy adults during double-leg standing. [Subjects and Methods] Thirty-nine subjects (10 male, 29 female) participated in this study. They were asked to keep their balance while holding four positions: standing with their eyes open, with and without vibration stimuli, and standing with their eyes closed, with and without vibration stimuli. The vibration stimuli, which had a duration of 30 sec, and a frequency of 60–80 Hz, were applied to the tibialis anterior and gastrocnemius muscle belly during double-leg standing. Balance measurement was performed using the Balance Trainer 4 (HUR Labs Oy, Tampere, Finland). All subjects provided informed consent prior to participation in this study. [Results] In the open-eyes position, there were no significant differences in trace area, trace length, and velocity of the center of pressure (COP) either with or without vibration stimuli. However, in the closed-eyes position, the vibration stimuli significantly decreased trace area, trace length, and velocity of the COP compared with when no vibration stimuli were applied. [Conclusion] These results suggest that vibration stimuli applied to the lower leg improve balance when a person's eyes are closed during double-leg quiet standing.
Key words: Vibration, Center of pressure, Quiet standing

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INTRODUCTION

Posture control is necessary to regulate the body's position in space for the purposes of orientation and balance[1)]. The body maintains its center of gravity (COG) on the base of support (BOS) against internal and external forces through the interaction of sensory input, motor responses, and cognitive processes. Normal balance is characterized by the body's ability to maintain its COG within postural sway using information and motor responses. In addition, balance involves reaction to disordered power, and prediction and adaptation based on a previous experience or specific task[2, 3)]. Healthy adults try to maintain their center of pressure (COP) in relation to the center of mass of their bodies and general coordination systems[4)]. Maintenance of equilibrium is needed to ensure the accuracy of the somatosensory, vestibular, and visual systems during standing[5, 6)].

Adjustment of pressure and motor responses requires visual observations, the vestibular system, and the information gained by the proprioceptors through the central nervous system (CNS). The senses required for adjustment of postural balance are the tactile (superficial senses) and proprioceptive senses (deep sense). Tactile senses include the sensations of touch, pressure, vibration, and temperature[7)], while the proprioceptive sense is composed of sensory input from several sources, including the muscle spindles, joint capsules, ligaments, and skin[8)]. The proprioceptive sense helps to maintain the posture of a limb in the static state and to move when it is in a dynamic state. Therefore, the proprioceptive and tactile senses play an essential role in the development and maintenance of adjustments of postural balance[9, 10)].

A vibration stimulus (50–60 Hz; 1.5–1.8 mm) is powerful enough to stimulate tendons and regenerate the important Ia concentric contracture of muscle spindles[11)]. Suitable vibration is an effective method that increases bony mechanical function and body balance, muscle strength[12)].

There have been many studies that have investigated the effect of vibration using variable interventions. However, to the best of our knowledge, no study has addressed the effects of vibration stimuli on postural balance while simultaneously applying vibration to the agonists and antagonists of both lower extremities. Therefore, this study investigated the effect of vibration stimuli on the COP while applying vibration to the anterior tibialis and gastrocnemius muscles during quiet standing.

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SUBJECTS AND METHODS

Thirty-nine subjects (29 females, 10 males; 25.3 ± 6.2 years old) voluntarily participated in this study. They had no neuromuscular or musculoskeletal disorders. Approval for the study was obtained from the institutional review board of the National Evidence-based Healthcare Collaborating Agency (PIRB11-015-1), and written informed consent was obtained from each patient before starting the study.

A custom-made vibrator was used, and eight electrodes were placed over the belly of each subject's anterior tibialis and gastrocnemius. Vibration stimulation (60–80 Hz; 1.5 mm) was applied during double-leg standing. Balance was measured using the Balance Trainer 4 (HUR Labs Oy, Tampere, Finland). Information regarding each subject's COP balance (trace area, trace length, and velocity) was gathered. Subjects were asked to stand on a force plate with their feet shoulder-width apart and to keep their balance for 30 sec while holding four positions: standing with their eyes open, both with and without vibration stimuli, and standing with their eyes closed, with and without vibration stimuli.. Measurements were randomly taken for each of the four positions, and information was gathered regarding COP balance. Subjects took a break of 30 minutes to prevent muscle fatigue. The data used for descriptive statistics were means and standard deviations. The Wilcoxon signed-rank test was used for all outcomes to determine the different effects of balance on the visual senses and of the vibration stimuli. SPSS version 19 was used for statistical analysis. The level of significance was set at $p<0.05$.

RESULTS

The mean age of the subjects was 20.7 years, mean height was 165.2 cm, and mean weight was 55.71 kg. In the open-eyes position, there were no significant differences in trace area, trace length, and velocity of the COP either with or without vibration stimuli ($p>0.05$) (Table 1). However, in the closed-eyes position, vibration stimuli significantly decreased trace area, trace length, and velocity of the COP compared with when no vibration stimuli were applied ($p<0.05$) (Table 2).

Table 1. Comparison of balance variables with and without vibration with open eyes (mean±SD)

Variables	No vibration	With vibration
C90 area (mm^2)	231.1±166.5	195.9±114.2
Trace length (mm)	289.4±86.7	277.3±74.1
Trace velocity (mm/s)	5.5±1.9	5.3±1.9

[a] Based on positive ranks
C90 area: Minor ellipse area including 90% of COP

Table 2. A comparison of the balance variables with and without vibration with closed eyes (mean±SD)

Variables	No vibration	With vibration
C90 area (mm^2)	377.8±241.9*	252.3±131.1*
Trace length (mm)	368.8±124.9*	300.9±80.4*
Trace velocity (mm/s)	7.2±2.9*	5.7±1.5*

* Significant difference ($p<0.05$) between with and without vibration
[a] Based on positive ranks
C90 area: Minor ellipse area including 90% of COP

DISCUSSION

The present study confirmed the effects of vibration stimuli on balance during double-leg quiet standing. In this study, there was no significant difference in trace area, trace length, and velocity of COP with and without vibration in the open-eyes position. However, in the closed-eyes position, trace area, trace length, and velocity of COP with vibration stimuli decreased significantly compared with or without vibration stimuli. In previous research, subjects showed a greater increase in the area and velocity of the COP during one-leg standing without visual information than one-leg standing with visual information[13]. Furthermore, it has been established that somatosensory stimulation can decrease postural sway in normal subjects when their eyes are closed[14]. Ivanenko et al.[15] reported that subjects tilted when vibration was applied to the anterior tibialis, and Thompson et al.[16] reported that vibrations applied to both Achilles tendons during quiet standing extended the trunk and lower extremities. These results were similar to our results. However, some studies have reported that vibration stimuli increases postural disturbance and induces falling[17]. On the other hand, there have been reports that stimulation of the afferent fiber of the muscle spindles results in maintenance of proper postural balance[18].

The present study examined the influence of vibration stimuli on lower-limb muscles during standing. It shows that there is no difference in static balance either with or without visual information. Until now, the effect of vibration has been a controversial issue. But, in the current study, the researchers found that vibration positively affects postural balance. The present study also suggests that visual information is an important element and that vibration, particularly without visual information, helps to improve postural balance by stimulating the proprioceptors of the body. It is thought that vibration may have a positive effect in maintaining static balance by activating the proprioceptors.

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