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Vibration Applied to the Lateral Muscle of the Neck Induces Ipsilateral Body Sway during Sit-to-Stand Exercise in Healthy Adults – A Pilot Study

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Abstract

Background: The aim of this study was to investigate whether vibration that is applied to the lateral muscles of the neck induces the illusion that the body is swaying and compensatory body sway during sit-to-stand movements.

Methods: Ten healthy adults participated in this examination. The center of pressure's position during the sit-to-stand exercise was measured immediately after the participant sat for 1 minute with their eyes closed, with or without vibration applied to the right side of the neck. The average center of pressure position in the anterior-posterior and left-right directions during the sit-to-stand exercise after the vibration was compared with and without vibration. After the task, we asked the participants about their sensation of body sway during the sit-to-stand movement, and the ratio of the appearance of the body sway and direction were compared between vibration conditions.

Results: The sensation that the body swayed to the right due to vibration was significantly higher than that without vibration. The center of pressure's position in the vibration condition was significantly deviated to the left compared with that without vibration.

Conclusion: Our findings indicate that vibration applied to the right side of the neck induces the sense that the body is swaying to the right, although the body is actually swaying to the left. This actual body sway during the sit-to-stand motion may compensate for an illusion that is induced by muscle vibrations, and this technique is possibly effective for posture control training.

Key words:

Vibration; Illusion; Body sway; Aftereffect; Sit to stand; Lateral sway; Center of pressure

Abbreviations: COP: Center of Foot Pressure; AP: Anterior-Posterior

Introduction

Cognition of the subjective vertical axis is important for controlling posture in humans [1]. Cognition consists of visual information [2], vestibular sensation [3,4], and somatosensory information [5]. Vibratory stimulation of the muscle activates the muscle spindle and increases the firing rate in ascending group Ia neurons, likely because of the stretching of the muscles [6,7].

Therefore, although the joint does not move, the subject senses the motion; this sensation is called an illusion [6,7]. Furthermore, this muscle vibration acts compensatively to move backwards against the direction in which motion is sensed [8].

This illusion-induced movement of the whole body results in a postural response because the forward sway of the body during the sensation of illusion to backward body sway induced by vibration on neck dorsal muscle in standing human [9]. These findings indicate that vibration can modulate the subjective vertical axis that is caused by the illusion, and the body can sway into the sagittal plane to compensate for illusionary body sway.

However, task dependency in relation to vibratory body sway in both a static upright standing position, and gait, have been reported previously [10]; thus, it is unclear whether this vibratory effect on body sway in the coronal plane has an effect on the dynamics of standing-up position.

Vibration effects not only occur during vibration; they have also been reported to occur after vibration [6,7]. However, it is unclear as to whether effects after vibration can induce lateral body sway during movement from a sitting to a standing position. Furthermore, these after effects provide us with an advantage during examinations in that confounding factors, such as auditory stimulation and the burden imposed by the weight of the vibration stimulation equipment, can be eliminated as much as possible.

If the vibration-induced lateral body sway during sitting to standing originates from the sensation of deviation to the subjective vertical axis, then this method can be a useful interventional method for stroke patients with contraversive pushing, because this phenomenon originates from the deviation of sensation related to the subjective vertical axis [11].

However, sensation of the subjective vertical axis cannot be measured during dynamic stand-up movement, because such measurement should be conducted in a static sitting position [12].

Therefore, in this study, the subjective vertical axis during stand-up was measured using a questionnaire as body sway during stand-up after the task. If the direction of the sensation of body sway opposes the direction of the actual movement of body, then that sensation represents an illusion and motion can be interpreted as a compensatory response of that sensation.

Based upon these concepts, this study investigated whether vibration that is applied to the lateral muscle of the neck induces the body to sway in the coronal plane with the illusion of body sway during a stand-up exercise, immediately after vibration was applied.

Materials and Methods

Ethical considerations

The ethics committee of Shijonawate Gakuen University approved the experimental procedures, and this study was conducted according to the ethical principles and guidelines of the Declaration of Helsinki. After we explained the experimental protocol to the participants, they provided written informed consent to participate in these experiments.

Participants

Ten healthy volunteers (6 men and 4 women; mean age: 20.6 ± 0.8 years) with no history of epilepsy or other neurological diseases were recruited for this study.

Procedures

The participants sat on a chair without a backrest with their eyes closed. Their knee and hip joints were set at 90° parallel to the floor. Their feet were positioned on a force plate (Gravicorder G5500, Anima Inc., Tokyo, Japan) to calculate the position of the center of pressure (COP) from the ground reaction force. A vibrator (YCM-08, Yamazen Corp., Osaka, Japan) was set laterally at one-sixth the length of the circumference of the neck, at the C7 vertebra; consequently, the resulting vibration occurred on the Trapezius muscle.

The frequency was set at 60 Hz and the vibration stimulus was applied for 1 minute with the participant in a static sitting position. The participant was asked to stand up immediately after the vibration. The COP was recorded for 20 seconds after the participant began to stand up.

In the control trial, the participant sat on the same chair with their feet in the same position as in the vibration trial. The vibrator was set at the same position as in the vibration trial but the vibration stimulus was not applied. The COP was recorded while the participant stood up, after being cued to start. After each trial, the participant was asked about whether they sensed their body sway and the direction their body swayed while standing up.

COP analysis

To calculate the deviation, we used the direction of the lateral and anterior-posterior (AP) projection. The right and forward directions were described as having positive values. The mean of COP position during sit to stand was calculated in lateral-medial and anterior-posterior direction in vibration condition and no-vibration condition.

To determine the amount of deviation of the COP position that was induced by the neck vibration, we subtracted the average COP position in the no-vibration trial from that of the vibration trial.

Statistical analysis

To test the difference in the COP position between the vibration and no-vibration trials, we conducted a one-sample t-test. Furthermore, a chi-squared test was conducted to test the difference in the probability of the body sway sensation while standing up. The alpha level was set at 0.05 in all statistical analyses.

Results

Figure 1 shows the mean of COP's position in lateral direction, and Figure 2 shows the mean of COP's in AP projection in vibration condition and no-vibration condition. A paired t-test revealed that there was significant difference between the mean of COP in lateral direction (t=-4.4, d.f.=9, p=00017) and no significant difference in AP direction (t=0.02, d.f.=9, p=0.98).

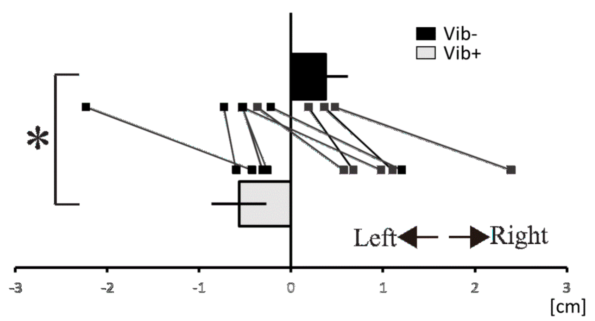

Figure 1: The position of the COP in the medial-lateral direction. Dots indicate the mean of each subject connected by lines to show within-subject changes. Bars indicate the mean, and error bars indicate the standard error within groups. The asterisk (*) indicates a significant difference. COP: center of foot pressure.

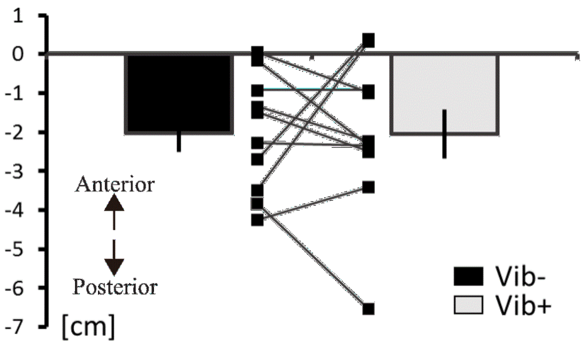

Figure 2: The position of the COP in the anterior-posterior direction. Dots indicate the mean of each subject connected by lines to show within-subject changes. Bars indicate the mean, and error bars indicate the standard error within groups. COP: center of foot pressure.

Table 1 shows the probability that the participant could sense their body sway and direction. In the vibration trial, the probability that the participant would feel their body sway to the right was 70%, that for the left side was 10%, and that of no sensation was 20%. In the no-vibration trial, the probability that the participant could sense their body sway was 0%. The chi-squared test revealed that there was a difference in the probability that the participant could sense their body sway between the vibration and no-vibration trials (chi-square value=13.3, df=2, p=0.001).

	No-Vibration	Vibration
Sway to the right	0	7
Sway to the left	0	1
No sensation	10	2

Table 1: The direction of the sensation of body sway during the stand-up exercise.

Discussion

The aim of this study was to investigate whether a vibration that was applied to the muscle of the side of the neck induced the body to sway to the contralateral side during a sit-to-stand exercise and induced the illusion that the body swayed to the contralateral side. We found that the COP immediately after the vibration was applied to the muscle of the right side of the neck significantly shifted to the left side while the participant stood up. This finding indicates that lateral neck vibration can induce the body to sway to the contralateral side while standing up. On the contrary, the probability that the participant could sense the body sway to the right side was significantly higher in the vibration trial than in the no-vibration trial. This finding indicates that lateral neck vibration can cause the participants to feel their body sway to the ipsilateral side during the sit-to-stand exercise immediately after the vibration was applied.

The reason why vibration creates the illusion that the body is swaying was considered in previous studies. To induce the sensation that the body is swaying without actual movement, participants experienced illusory movements toward the direction at which the vibrated muscle would be stretched [6,7]. Vibration activates the muscle spindles and increases the firing rate of group Ia neurons in the muscle spindles [2-3]. The primary endings of the muscle spindles play an important role in the illusion of kinesthetics, because the primary endings are the most sensitive to muscle vibration [6,7]. Activation by vibration can induce the sensation of motion without actual movement. Therefore, in this study, the vibration of the muscles in the side of the neck induced the sensation that the body was swaying.

The sensation that the body is swaying backward is induced by vibration on the Trapezius in the neck muscle of the neck and the actual forward sway of the body during static standing and gait with eyes closed. In this study, sensation and body sway were not induced when the participant had their eyes open, because sensation is not induced when the eyes are open [9]. This finding indicates that the body sway is a compensational response that is associated with the sensation that the body is swaying, which is induced by muscle vibration. In this study, the participants sensed that their bodies swayed to the right, although they actually swayed to the left. Therefore, the sway to the left side induced by vibration that was applied to the muscle of the right side of the neck may have compensated for the sensation that the body swayed to the right side.

Vibration that is applied to the biceps of the upper limbs induces the sensation of elbow extension during vibration, but the sensation of elbow flexion is induced immediately after the vibration [8]. Furthermore, actual elbow extension is elicited during the sensation of elbow flexion after vibration is applied [10]. The reversals and aftereffects of the vibration that was used in this study may have been due to the vibration that was applied to the muscles of the side of the neck, because the direction of sensation of body sway and actual body movement corresponded with the results of this previous study [10].

Previous studies have shown that vibration can induce body sway during standing or gait [11]. However, there have been no previous reports relating to vibration-induced body sway during sitting to standing movement. Stroke patients with contraversive pushing have impairment of the subjective vertical axis and lateral body sway, resulting in difficulty in controlling posture, even while sitting and standing [13]. Our vibration technique, in which vibration was applied to the muscles of the side of the neck and induced the body to sway to the contralateral side, is a possible intervention for stroke patients with contraversive pushing resulting in a disturbance in the ability of sit to stand. In the present study, we identified and characterized the effect of vibration-inducing body sway during movement from a sitting to a standing position. Consequently, our current data, for the first time, provide a foundation for the development of an effective intervention for contraversive pushing. Therefore, a further study is needed to investigate the effect of this vibration technique on contraversive pushing.

This study was limited in terms of some of the methodology employed. While the CoP position is useful in estimating the human body's center of gravity, it does so only in an indirect manner. Therefore, more directly method such as three-dimensional motion analysis may be applied to estimate the body motion after neck vibration in future study.

Conclusion

Although it is well known that lateral and dorsal neck vibration can induce lateral body sway during upright standing or gait, it remains unclear how this form of stimulation can induce lateral body sway during sitting to standing movement. Furthermore, it was not clear whether the after effects of such vibration can influence lateral body sway during sitting to standing movement. Our results indicate that vibration that is applied to the muscles of the side of the neck induces the illusion that the body is swaying and the body sways compensationally to the contralateral side during sit-to-stand exercises. This technique may be effective to control posture in patients with postural disorders such as contraversive pushing.

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