

Original Paper

# Influence of Active Fingertip Contact with a Stable Surface on Postural Sway and Electromyographic Activities of the Lower Extremity Muscles Immediately after Turning

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## Abstract

Recent studies have shown that active contact cues from a fingertip provide information that leads to reduced postural sway during static standing. Although the risk of falling increases immediately after turning, little is known about the influence of active fingertip contact with a stable surface. The purpose of this study was to investigate the influence of fingertip contact on the sway and the electromyographic (EMG) activities of the lower extremity muscles immediately after turning 180°. Twelve healthy male volunteers participated in this study. Sway was measured by the center of pressure (COP) and was compared under two conditions: (1) standing without touching a stable surface and (2) standing with the right index fingertip lightly touching a stable surface (<1N). The EMG activities associated with sway under the two conditions were measured and compared. More areas of COP were observed during standing without touching compared to standing with light touching. No significant differences in the length of COP and EMG activities were observed between the two conditions. These results suggest that active fingertip touch contact with a stable surface decreases sway immediately after turning by finely controlling the lower extremity muscles.

## 1. Introduction

Standing balance decreases in elderly people because of age-related physiologic diminution of vestibular function and in many kinds of neuromuscular, musculoskeletal, and sensory disorders. Accordingly, the incidence of falling increases in these cases. Fear of falling in these people creates a psychological barrier that makes them reluctant to leave their homes, leading to an inactive life.

Recent studies have shown that active contact cues from the fingertip provide information that leads to reduced postural sway while standing [1-6]. Clinicians have observed that subjects with poor balance control

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use light touch contact with surrounding objects, such as a desk or a wall, to stabilize themselves while standing and walking. Some investigators have described the effect of light touch and forceful contacts with horizontal surfaces, such as a bar or a desk, on postural sway while standing [4, 5, 7].

Turning has been identified as more challenging than quiet standing or straight-line walking for mobility-impaired subjects, such as people with Parkinson's disease [8, 9]. During clinical observation, these subjects exhibit difficulty turning and an increased risk of falling while turning. Although sway and the risk of falling increase during or immediately after turning, little is known about the influence of light contact with a stable surface, such as a desk, on postural sway and the electromyography (EMG) activities of the lower extremity muscles [10]. The first purpose of this study was to investigate the influence of active light fingertip contact with a stable surface on postural sway while standing upright immediately after turning.

It is well known that lower extremity muscles such as the quadriceps femoris, the biceps femoris, the tibialis anterior, the gastrocnemius, and the soleus muscles play important roles in maintaining a standing upright position against gravity. Jeka et al. [5] evaluated changes in EMG activity in the peroneus longus muscle with different levels of fingertip contact force. The authors investigated the EMG activity of the soleus muscle, which plays a very important role in controlling the ankle joint and standing balance, while subjects stood quietly [11]. However, little is known about the influence of fingertip contact with a stable surface while standing upright immediately after turning on the EMG activities of other lower extremity muscles according to the soleus muscle. The second purpose of this study was to investigate the influence of fingertip touch on the EMG activities of the lower extremity muscles. Our findings provide basic information on the influence of light fingertip touch on standing balance immediately after turning in subjects with poor balance.

## 2. Methods

### 2.1. Participants

Twelve healthy male volunteers who did not have any musculoskeletal, neuromuscular, or sensory disorders or any general systemic diseases participated in this study. Their mean ( $\pm$  standard deviation) age, height, and weight were  $20.8 \pm 0.7$  years,  $170.5 \pm 4.8$  cm, and  $63.1 \pm 8.0$  kg, respectively. Informed consent was obtained from all of the participants.

### 2.2. Evaluation of postural sway

Standing balance or postural sway was measured by the sway of the center of pressure (COP). Each subject was asked to stand upright and quietly on a gravicorder (P07-1712, Kyowa Electronic Instruments Co., Ltd., Japan) in the standard Romberg position immediately after turning  $180^\circ$  under two conditions: (1) standing while simulating the act of touching of a stable surface without actually touching it and (2) standing with the right index fingertip lightly touching ( $<1\text{N}$ ) a stable surface. The stable surface used in this study was a force plate (P08-1713, Kyowa Electronic Instruments Co., Ltd., Japan). The first position served as the control. In the second position, subjects were instructed to touch the stable surface, which was positioned at a 30-cm distance external to the right foot, with the right index fingertip. Each subject stood for 10 s under each condition while watching a round, 2-cm-diameter mark that was placed 2 m in front of their eyes. The two experimental conditions were randomly arranged for each subject. Each subject was asked to turn  $180^\circ$  on the gravicorder for 4 s with four steps. The amount of COP sway was calculated by measuring the length, the rectangular area, and the environmental area of the COP for 4 s immediately after turning. We selected a measurement period of 4 s according to a previous study, in which Miyoshi et al. [7] demonstrated that greater sway continued for 4 s immediately after sit-to-stand movement from a chair in elderly subjects. Before the force-contact trial, each subject was given verbal feedback about the level of applied fingertip force until it was close to 1N. The subject was instructed to maintain this force level throughout the trial, and the applied force level was monitored by one experimenter during the trials. The trial was stopped and rejected if more than 1N was applied at any moment. The rest period between

the two conditions was approximately 1 min.

### 2.3. Measurement of EMG activities

Each subject's skin was thoroughly prepared for EMG measurement by cleansing with alcohol and by using a skin abrasion technique. Thereafter, disposable silver/silver chloride surface electrodes with a recording diameter of 1 cm (Blue Sensor N-00S, Medicotest A/S, Denmark) were placed over the right rectus femoris, biceps femoris, tibialis anterior, gastrocnemius, and soleus muscles to measure the EMG activities associated with sway. Although many muscles are involved in maintaining an upright standing position, these muscles mainly serve to control standing posture. Bipolar electrode pairs were placed longitudinally over the muscle belly at an inter-electrode distance of 3 cm. The grounded electrode was placed over the head of the fibula. EMG signals were recorded during all postural sway tasks. Signals were amplified, band-pass filtered (10-500 Hz), digitized, and stored by a data acquisition system (VitalRecorder2, Kissei Comtec Co., Ltd., Japan) at a sample frequency of 1000 Hz. The average EMG activity values for 4 s immediately after each turning task were normalized to maximal voluntary contractions (MVC), which were obtained in isometric maximal exertion tasks by using the standard manual muscle test described by Hislop et al. [12] (%MVC). Each MVC was held for 5 s and the average EMG activity was used to determine the MVC. All experiments were carried out in an air-conditioned laboratory maintained at approximately 24°C.

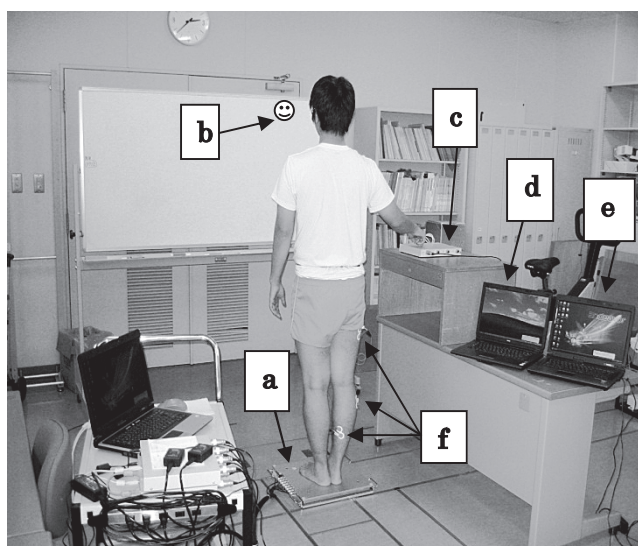


Fig. 1 Each subject was asked to turn 180° on a gravicorder (a).

Immediately after turning 180° on the gravicorder (a), each subject was asked to stand upright quietly on it watching a mark (b) in the standard Romberg position under two conditions : (1) standing without touching a stable surface, that is, a force plate (c) simulating touching it, and (2) standing with the right index fingertip lightly touching ( $1 < N$ ) the stable surface. The level of applied fingertip force was monitored using a force plate system (d). EMG signals at the right rectus femoris, the biceps femoris, the tibialis anterior, the gastrocnemius, and the soleus muscles were recorded while standing (e, f).

### 2.4. Statistical analysis

The Wilcoxon test was used to validate statistical differences between the two experimental conditions by using the SPSS statistical package 16.0 for Windows. A high level of  $p < 0.05$  was considered significant for these comparisons.

## 3. Results

Comparisons of the parameters of postural sway under each condition are shown in Table 1. The

length of the COP did not differ significantly between the two conditions. However, the rectangular and environmental areas of COP were significantly smaller when the subjects were standing with a light touch rather than when the subjects were standing without touching a stable surface.

The %MVC results from each condition are shown in Table 2. No significant differences were observed between the two conditions.

Table 1 Comparisons of parameters of postural sway under each condition

	NT	LT
LNG (cm)	96.0 ± 10.0	93.8 ± 11.0
REC (cm <sup>2</sup> )	104.3 ± 66.7	65.0 ± 60.7*
ENV (cm <sup>2</sup> )	38.6 ± 15.6	27.5 ± 17.6*

Values are means ± SD (standard deviation).

\*; p<0.05 (compared with NT)

NT: No touch

LT : Light touch

LNG : Length of COP (Center of Pressure)

REC : Rectangular area of COP (Center of Pressure)

ENV : Environmental area of COP (Center of Pressure)

Table 2 Electromyographic activities normalized as a percentage of maximal voluntary contraction (%MVC) for the five lower extremity muscles under each condition

	NT	LT
RF	3.8 ± 1.3	4.5 ± 1.2
BF	3.6 ± 3.7	3.5 ± 2.7
TA	1.9 ± 0.9	2.9 ± 2.0
GA	9.5 ± 5.5	8.2 ± 4.7
SO	20.7 ± 9.2	20.8 ± 10.7

Values are means ± SD (standard deviation).

NT : No touch

LT : Light touch

RF : Rectus femoris muscle

BF : Biceps femoris muscle

TA : Tibialis anterior muscle

GA : Gastrocnemius muscle

SO : Soleus muscle

#### 4. Discussion

In this study, the rectangular and environmental areas were greater when the subjects were standing without touching a stable surface compared to when the subjects were standing with a light touch immediately after turning. This result is similar to those reported by Holden et al. [13] and Jeka et al. [5]. They asked a subject to touch his or her index fingertip to a horizontal bar. Holden et al. [13] found that postural sway was reduced by over 60% when a standing subject applied 5-8N of force to the bar with his or her index fingertip compared to the control condition, in which subjects stood with their arms hanging passively by their sides. When the subjects were limited to applying a very small contact force level (<1N), postural sway was also attenuated by over 60% compared to the control condition. Holden et al. [13] performed a systematic physical analysis of the amounts of passive and dynamic stabilization of posture that can be achieved with different fingertip contact force levels. Passive stability or direct active stabilization is not possible under a condition involving less 1N of applied fingertip force. The maximum sway reduction attributable to actively applied contact force is 2.3%. However, 5-8N of applied contact force is estimated

to attenuate sway through passive and dynamic stability by 20-40%, indicating that biomechanical factors play a significant role in this process [13]. Jeka et al. [5] reported that sensory input to the hand and arm through contact cues at the fingertip or through a cane can reduce postural sway in individuals who have no impairments as well as in patients without a functioning vestibular system, even when the contact force levels are inadequate to provide physical support of the body.

In elderly subjects with visual impairment, Maeda et al. [10] reported that the greatest degree of sway occurred when subjects stood unsupported; the second largest was recorded while they stood with a cane; and the smallest sway occurred when they stood touching a wall. Although they did not record the force touch level, the results were similar to ours. Maeda et al. [10] proposed that the increase in somatosensory input achieved by touching a wall adequately compensates for the lack of visual information, similar to the case of body support using a cane. Furthermore, they hypothesized that touching a wall for body support is more effective than holding a cane for visually impaired persons because the fixed plane of the wall effectively suppresses body sway [10]. They did not measure the contact force level, but the authors measured the force level. We previously showed that a light or forceful touch to a vertical surface, such as a wall, led to a decrease in body sway as the touch to a horizontal surface, such as a desk [11]. We concluded that the increase in somatosensory input achieved by touching a wall was enough to decrease body sway.

Although the rectangular and environmental areas were greater when the subjects were standing without touching a stable surface compared to when they were standing with a light touch immediately after turning, no significant difference in COP length was observed between the two conditions. This result suggests that COP sway was more finely controlled in the smaller areas in the light touch condition compared to the no-touch condition. Thus, we propose that body sway was controlled more finely by the touch cue, even after turning. We were interested in understanding how the sensory input from a fingertip on a stable surface is interrelated with proprioceptive information about the configuration of the arm and the body to stabilize standing balance. When the contact force is too small to counteract body sway biomechanically, fingertip stimulation presumably provides cues about torso motion that can be used to activate the lower extremity muscles to attenuate the sway. Jeka et al. [5] reported that both light and forceful touch contacts led to decreased levels of EMG activity in the peroneal muscles relative to a no-contact condition in the tandem Romberg stance, and the EMG activity was significantly lower under the forceful-touch condition than under the light-touch condition. These authors postulated that the level of EMG activity in the peroneal muscles and the timing of the relationship between fingertip forces and the body sway was an indication that "long-loop reflexes" involving postural muscles were stabilizing sway [5]. In a previous study, no significant change in the EMG activity level at the soleus muscle was observed when subjects stood with the right index finger lightly (<1N) or forcefully touching (5-10N) and without touching the stable surface [11]. The authors suggested that both light and forceful fingertip touch contact led to a decrease in the sway but did not influence the EMG activity level of the soleus muscle because this muscle contracts continuously at a constant level to maintain static standing balance. In the present study, we investigated how EMG activity in the lower extremity muscles changed with light fingertip touch contact compared to no-touch contact. No significant differences in the %MVC were observed under the two conditions. This result suggests that lower extremity muscles were activated more finely to control sway in the smaller area under a light touch condition and were activated grossly to control sway in the large area under the no-touch condition. Thus, we believe that the contact cue from the fingertip on the stable surface may have decreased sway and controlled it more finely, even immediately after turning.

The sample of 12 subjects is small and limits the explanatory power of this study. Future studies will require one to investigate not only the rectangular area of COP but also anterior-posterior and right-left sway distances. It will also require one to detect muscles that control sway in the frontal plane and to investigate the muscle activity pattern immediately after turning.

## 5. Conclusion

The results of this study suggest that light fingertip contact with a stable surface decreases sway and

controls it more finely, even immediately after turning.

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