35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

Effects of light finger touch to the upper legs on postural sway and muscle activity during quiet standing

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Abstract— **The purpose of the present study was to investigate the effects of light finger touch (LT) to one's own body on postural sway and ankle muscle activity during quiet standing. In the first part of the present study, 24 healthy men (19±1 years) stood upright with their eyes closed on a pneumatic balance disk under 3 different conditions. In the first condition, the participants kept their hands in loose fists, and contact between the fingers/palms and the legs was avoided. In the second condition, the participants touched the lateral sides of upper legs lightly (without applying force for mechanical support) with all fingers. In the third condition, the participants again held their hands in loose fists. Postural sway was significantly decreased during second condition compared to first condition. Further, it also tended to decrease in third condition (*P* = 0.08). The second part of the present study was designed to investigate the mechanisms underlying the association between postural sway and LT by analyzing electromyographic data. Data were obtained from 12 healthy men (20±1 years). During quiet stance on the stable surface, soleus activity did not significantly change by LT. However, tibialis-anterior activity significantly decreased with LT. These results suggest that LT to the upper part of one's own legs decreases postural sway (during and after touching) during a still stance by decreasing co-activation of the ankle muscles.**

I. Introduction

Independent mobility is an important factor that affects quality of life, and good balance control is required to decrease the incidence of falls during locomotion. Because postural swaying during standing is believed to play an important role in balance control, many indicators for evaluating postural sway have been suggested. These indicators are most commonly based on the excursions of the body's center of mass (COM; determined using an accelerometer [1-3] or displacement sensor [4,5]) or center of pressure (COP; determined using a force plate [6-12]). Further, various procedures to improve COM or COP sway have been suggested by numerous researchers.

Some researchers have observed that providing additional tactile sensory input through the hand or finger decreases postural sway during standing [6-11]. Jeka and Lackner [6,7] showed that a light touch with the tip of the index finger on a surface at waist height (producing insufficient force to have any appreciable mechanical effect on stability) resulted in decreased postural sway during the Romberg stance (tandem) with the eyes closed. Holden et al. [8] reported that the resultant postural sway when the eyes are closed was equivalent to sway the eyes were open, but that it occurs at contact force levels that are insufficient for providing mechanical body support (<1 N). Therefore, lightly touching an external object can provide additional information regarding the alignment of the finger, hand, and arm with respect to the environment.

Although exerting a light touch on an external object decreases postural sway, Nagano et al. [9] studied whether the same was true for a light touch on one's own body. They found that lightly touching a finger to the upper part of the legs significantly decreased postural sway during a quiet stance on an unstable surface (standing upright on a pneumatic balance disk). This finding showed that a light touch on one's own body primarily provides information about the relative movement of the body segments; in short, it helps an individual sense the movements of the trunk, arms, and legs relative to one another.

Although postural sway decreases during light touch, changes in postural sway after a light touch to the upper part of the legs have not yet been thoroughly examined. The association between postural sway and light touch is scientifically interesting. However, it is unusual for an individual to stand and lightly touch the upper part of his/her legs while performing daily activities. If indeed the postural sway decreases after light touch (relative to that without light touch), this finding would be helpful in the development of a useful application. Therefore, the purpose of the first part of the present study was to investigate the effect of a light finger touch to one's own body (Study 1).

When an individual stands still on a stable surface, the plantar flexor muscles are recruited as antigravity muscles at the ankle joint. Therefore, ankle muscle activity during the upright stance differs depending on various factors such as age [12-14], visuomotor condition [14,15], and the supporting surface condition [15]. However, the effects of light touch (especially to one's own body) on ankle muscle activity are yet to be thoroughly examined. In Study 1, we investigated the effect of a light finger touch to one's own body on postural sway. Furthermore, the second part of the present study was designed to investigate ankle plantar flexor and dorsiflexor activity during an upright stance with a light finger touch to the upper part of one's legs by analyzing electromyographic (EMG) data (Study 2).

*This work was supported by Grant-in-Aid for Young Scientists (B) (25870988), and Grant-in-Aid for Scientific Research (C) (23500651).

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978-1-4577-0216-7/13/$26.00 ©2013 IEEE

II. Methods

A. Study 1

Data were obtained from 24 healthy men (age, 19 ± 1 years) with no current or previous medical history of neural, muscular, or skeletal disorders. Participants were randomly assigned to a light-touch (LT-group; n = 12) or a no-touch (NT-group- n = 12) group. Before initiating the study, all participants were informed of the purpose of the study and informed consent was obtained from each of them. Further, this study was approved by Human Ethics Committee of Graduate School of Human Development and Environment, Kobe University.

To assess COM fluctuations during experiments, the anteroposterior (COM-AP) and mediolateral (COM-ML) positions of a lumbar point at L3 were measured using a triaxial accelerometer (MPU-6050, InterSense, USA). Signals were acquired at a sampling frequency of 500 Hz by using a wireless sensor interface (TSND121, ATR-Promotions, Japan) and stored on a computer hard disk for later analysis.

The participants stood upright on a pneumatic balance disk (model DK 380, Hata Sporting Goods Ind., Ltd., Japan) for approximately 10 min before the experiment. This 10 min period functioned as a practice session to allow the participants to familiarize themselves with standing on the balance disk. Participants were instructed to remove all footwear before stepping on the disk and to then find a comfortable placement on the disk, which was then marked with adhesive tape. The amount of air in the disk was adjusted for each participant so that the thickness of the balance disk with a participant standing still on it was 63 mm.

After a 5 min rest period, the participants in the LT-group were asked to stand upright on a pneumatic balance disk under 3 different conditions for 20 s each (Figure 1). In the first and third conditions (before- and after-touch condition), the participants held their hands in loose fists. Arms were kept straight and the fingers/palms did not touch the legs. At the same time, this position prevented the participants from swinging their arms for balance recovery. In the second condition (light-touch condition), the participants were told to let all of their fingertips lightly touch the lateral sides of the upper parts of their legs but to not apply force for mechanical support. The participants were carefully observed by the experimenters during the trials to ensure compliance with this instruction. The participants in the NT group were asked to stand upright on the pneumatic balance disk and perform 3 "no-touch condition" tasks for 20 s each. Each participant was given a 1 min rest period between tasks.

For the stored COM accelerometer signals, the data were processed using the waveform analysis software SPCANA and Microsoft Excel. The data for an 8 s (4,000 sample) period in the middle portion of each phase were selected for analysis of individual trials since body motion is not immediately stabilized when participants close their eyes. After low-pass filtering (<100 Hz), the standard deviation (SD) of COM acceleration in each direction was calculated to evaluate the amplitude of the postural sway.

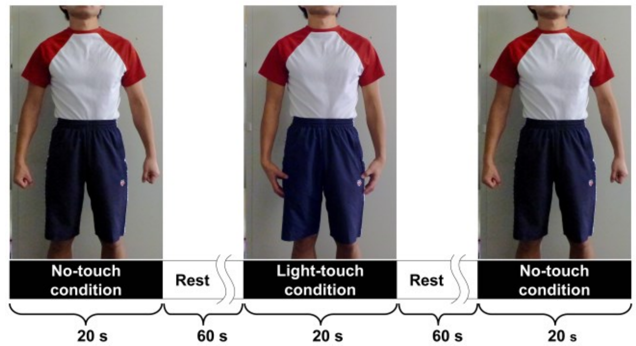

Figure 1 The position of the arms used in the present study

B. Study 2

Data were obtained from 12 healthy men (age, 20 ± 1 years) with no current or previous medical history of neural, muscular, or skeletal disorders who took part in this study. Before initiating the study, all participants were informed of the purpose of the study and informed consent was obtained from each of them. Further, this study was approved by Human Ethics Committee of Graduate School of Human Development and Environment, Kobe University.

To assess ankle muscle activity during the experiment, EMG data were collected from the tibialis anterior (TA) and the soleus (SOL) muscles. In the right lower leg, bipolar surface electrodes (ID2PAD, Oisaka Electronic Equipment Ltd., Japan) were placed over the TA and SOL with a 2 cm interelectrode distance. Skin impedance to the electrical signal was decreased by gently abrading the skin with a skin preparation gel and wiping the area with isopropyl alcohol swabs. The signals were acquired at a sampling frequency of 1,000 Hz by using a data logger with an analog-to-digital converter (LP-MS1002, Logical Product Corporation, Japan). After the experiments, the stored signals were transferred to a computer hard disk for later analysis.

The participants were instructed to remove all footwear and then maintain a quiet stance on a stable platform, because postural sway during a quiet stance on an unstable surface moves in various directions, making the identification of agonist and antagonist muscles difficult. The plantar flexor muscles play a significant role in stabilizing the body during a bipedal quiet stance on a stable surface [5,16]. Further, the activity of the SOL during a bipedal quiet stance is coherent with both a spontaneous body sway [5,17] and a mechanically induced body sway [18]. Therefore, the second part of the present study was conducted on a stable surface. The participants stood upon the platform, aligned their feet with marks placed 15 cm between the centers of the heels, and closed their eyes. The participants then stood quietly on the platform as upright as possible and kept their eyes closed during the measurement. The participants were first requested to stand on the platform for approximately 30 s as a practice session and for the recording of reference EMG data.

After a 5 min rest period, the participants were requested to stand for 60 s, a period that was divided into 3 equal phases. In the first (before-touch) phase, the participants held their hands in loose fists. The participants were asked to keep their arms straight and avoid contact between the fingers/palms and the legs to prevent them from swinging their arms for balance recovery. In the second (light-touch) phase, the participants were instructed to allow all of their fingertips to lightly touch the lateral sides of the upper part of their legs without applying force for mechanical support. The participants were carefully observed by experimenters during the trials to ensure that they complied with this instruction. In the third (after-touch) phase, the participants again held their hands in loose fists.

The stored EMG data for an 8 s (8,000 sample) period in the middle portion of each phase were selected for the analysis of individual trials since body motion is not immediately stabilized after changes in arm position. After band-pass filtering (1–500 Hz), the root mean square of the EMG signal (RMS-EMG) in each phase was calculated. Further, all RMS-EMS values were normalized to the practice period data (unitless) for the muscle activity evaluation.

C. *Statistical analysis*

Statistical analysis was performed using one-way analysis of variance (ANOVA), and significant differences between touch conditions were evaluated with post-hoc multiple comparisons using Tukey's test. Values of $P < 0.05$ were considered statistically significant. These analyses were performed using EZR software (Saitama Medical Center, Jichi Medical University) [19], a graphical user interface for R (The R Foundation for Statistical Computing, version 2.13.0).

III. RESULTS

A. *Study 1*

In the NT-group, the mean COM-AP and COM-ML values did not differ significantly among the 3 conditions (Figure 2). In the LT-group, the mean COM-AP and COM-ML values were significantly different among the 3 conditions (Figure 2). Further, multiple analysis revealed that the COM-AP and COM-ML values were significantly decreased during the light-touch condition compared to the before-touch condition. The differences in COM-AP values between the before- and after-touch conditions were not large enough to exhibit statistical significance ($P = 0.08$). These results indicate that although postural sway significantly decreased during the light-touch condition, it also tended to decrease after the light touch.

B. *Study 2*

During the participants' performance of the 3 different quiet stance phases, the mean values of normalized RMS-EMG of the SOL did not significantly change (Figure 3). Therefore, SOL activity was not influenced by light touch. The mean values of normalized RMS-EMG of the TA significantly changed during the 3 different quiet stance phases (Figure 3). Multiple analysis revealed that the normalized RMS-EMG of the TA significantly decreased during the light-touch phase compared to the before-touch phase.

IV. DISCUSSION

In the first part of the present study, postural sway significantly decreased by a light finger touch to the upper part of one's legs. This finding is consistent with that of the previous study [9]. However, changes in postural sway after a light touch have not been thoroughly examined until now. An

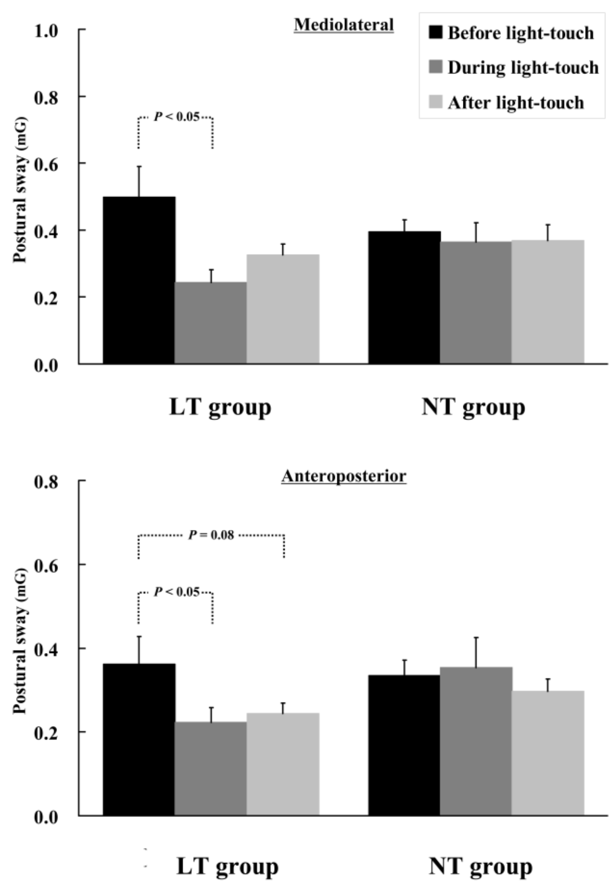

Figure 2 Change in postural sway, evaluated by standard deviation of center of mass acceleration

Values are mean for twelve subjects in each group (Error bars are ± 1 standard error of mean). G = 9.8 m/s²

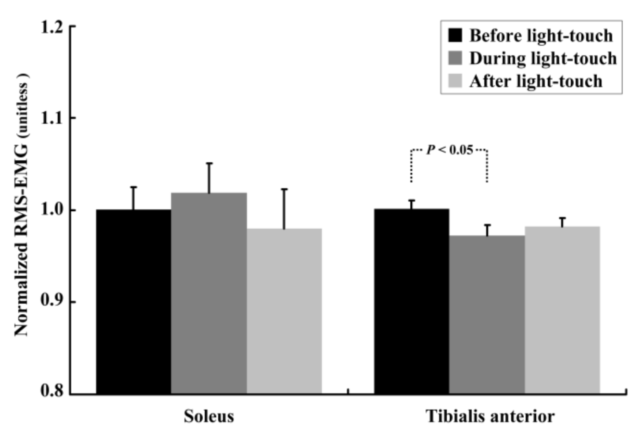

Figure 3. Change in RMS-EMG (root mean square of electromyographic signals) for the soleus and the tibialis-anterior

Values are mean for twelve subjects (Error bars are ± 1 standard error of mean). All RMS-EMG values are normalized to the practice (reference) period.

interesting finding of present study is that although postural sway decreased during light touch, it also tended to decrease after light touch. This result suggests that the association between postural sway and light touch might have an immediately effect on perceptual-motor learning. The present study also investigated the mechanisms underlying the association between postural sway and light touch by analyzing ankle muscle activity. The interesting finding of the present study was that although the SOL (agonist) activity did not significantly change by the light finger touch to the upper part of the legs, the TA (antagonist) activity significantly decreased with light finger touch.

SOL activity during a quiet upright stance differs under various conditions; it is greater in the elderly than in young adults [12-14], greater with eyes closed than with eyes open [14,15], and greater on an unstable surface than on a stable surface [16]. However, the results of the present study suggest that light touch did not influence SOL activity. During the Romberg stance (feet together), SOL activity was not significantly changed by light touch on a wall [11]. The authors suggested that plantar flexors contract continuously at a constant level to maintain a quiet stance [11]. Therefore, other leg muscles might play a role in adjusting the quiet stance.

Plantar flexors are recruited as anti-gravity muscles at the ankle joint during a quiet stance, while dorsiflexor activity usually remains low. However, dorsiflexors also influence postural stability as antagonist muscles. During the bipedal stance, muscle co-activation of the ankle joint increased with age [12,13], and persons with less physical function during postural control tasks showed higher muscle co-activation of the ankle joints [12,20]. Therefore, in some cases, the maintenance of postural stability is accomplished by greater co-activation of antagonists with resultant ankle joint stiffness. The results of the present study suggest that although a light touch did not influence SOL (agonist) activity, TA (antagonist) activity significantly decreased. Therefore, the findings of the present study suggest that a light touch to the upper part of one's own legs decreases postural sway (during and after touching) during a still stance by decreasing co-activation of the ankle muscles.

However, further studies are needed to clarify the direct relationship between muscle activity and joint kinematics. In addition, if this change is relevant during various motions, such as dynamic or perturbed conditions or even walking, light touch may help improve human movement. The extent to which co-activation may be affected by self-contact and the mechanisms responsible for such changes are issues of great interest and are worthy of further attention.

V. Conclusion

The purpose of the present study was to investigate the effects of a light finger touch to one's own body on postural sway and ankle muscle activity during quiet stance. Postural sway during quiet stance decreases by a light touch to the upper part of one's legs. Furthermore, postural sway also tends to decrease after a light touch. EMG data revealed that although the SOL (agonist) activity did not significantly change by the light touch, the TA (antagonist) activity significantly decreased with light touch. Therefore, change in postural sway may be caused by decreased co-activation of the ankle joint.

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