Effects of Differences in Touch Height and Touch Load on Postural Control During Static Standing

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Abstract. [Purpose] This study investigated the effects of differences in the touch height and touch load on center of pressure (COP). [Subjects] Subjects were 40 healthy young. [Methods] We measured COP sway at different touch heights and touch loads during tandem standing. [Results] Although the total sway length in light touch contact (LT) was comparable with that of no contact (NC), the environmental area and root-mean-square area in LT were significantly lower than in NC. In addition, the total sway length / environmental area was significantly greater in LT than in NC. The COP sway length was reduced in LT, although the COP sway length was comparable to that of NC. Furthermore, differences in the height at which LT was performed (the greater trochanter, acromion, and midpoint of the trochanter-acromion) did not result in significant differences. [Conclusion] We consider that sway is reduced by feedback from tactile sensations at the fingertips and proprioception. This suggests that LT could be used to increase stability in daily living regardless of the height at which LT is performed between the height of the acromion and greater trochanter.

Key words: Postural control, Touch height, Weight loading

INTRODUCTION

Currently, unforeseen accidents are the fifth most common cause of death. Among such accidents, about 20% of those for seniors of at least 65 years of age are due to falling³. Furthermore, falls account for a high proportion of the conditions that require long-term care. Therefore, the establishment of environments that are safe and easy for seniors to get around is indispensable.

In some instances, handrails are installed in hallways and restrooms as environmental arrangements for fall prevention. However, in the living rooms of Japanese homes, it is difficult to install handrails because household furniture and electrical appliances are often installed on the walls³. However, living rooms are the most common place where house-dwelling seniors fall³. Therefore, we think that in addition to removing steps, environmental arrangements that contribute to stability such as handrails are important for living rooms as well. The use of handrails and canes reduces the weight carried by the lower limbs, and plays a role in increasing physical safety by expanding the base of support. However, in actual settings in daily life, there are also many seniors who gain stability by lightly touching objects such as handrails.

With respect to the involvement of light touch contact (LT) in postural control, Jeka et al.⁴ have reported that the sensory information from lightly touching an immobilized surface with the index finger reduces COP, suggesting the utility of LT. However, in the experimental conditions of Jeka et al., the height of the index finger performing LT was at a comfortable position for the test subjects. The authors did not elaborate on differences in postural sway depending on the height of fingertip placement. In daily life, the height at which LT is performed varies widely depending on the installed furniture, and the LT height that leads to maximum stability has not been clarified. Therefore, in the present study, we aimed to clarify the effects on COP of differences in weight bearing between conditions of no contact (NC) during static standing, LT involving light touch contact with an object, and forceful touch (FT) involving physical support, as well as the difference in the touch height between the LT and FT.

SUBJECTS AND METHODS

The subjects were 40 healthy young adults (20 men, 20 women, average age of 20.3 ± 1.4, average weight of 53.9 ± 6.3 kg, average foot length of 23.8 ± 1.4 cm).

COP measurements were performed with a win-pod (manufactured by Medicapteurs) at a sampling frequency of 100 Hz. An electronic balance (Shimadzu, LIBOR EB-330S) was used to measure the weight bearing on the fingertips during LT, and an analog scale (Tanita, HA-622) was used to measure the weight bearing on the fingertips during FT.

For measurement, the test subjects were asked to stand
with their eyes open in the tandem posture with the left foot forward on the win-pod\textsuperscript{4}. In order to place the foot at the same position for each condition, the position of the foot was marked with tape. The fingertip of the right index finger was used for touching. For the touch height, the three height conditions were those of the greater trochanter, the acromion, and the midpoint between the two (greater trochanter-acromion midpoint). For the touch distance, a distance of 15 cm anterolateral to the right foot was used as the standard, as in the case of setting the height for a T-cane. However, given that conditions were established so that the foot pressure would be positioned as close to the body center as possible at the start of measurements, depending on the test subject there were instances in which the center of foot pressure was posteriorly displaced. For such cases only, the touch position was moved slightly forward. During measurements of COP, the fingertip load was confirmed to be less than 100 g. In addition, the fingertip load for the FT was designated as a load that the test subject felt to be stable. In the NC condition, the subjects let both upper limbs hang at their sides.

For each condition, subjects focused on a fixed target 2 m ahead at eye level without changing the positions of the sole and the fingertip. They were instructed to stay as still as possible. After the position for each test was determined, the test subjects were instructed to signal “yes” when they felt that they were stable, after which measurements were taken for 30 sec. It should be noted that in the LT condition, the experiment was conducted after the subjects had sufficiently learned the sensation for 100 g and below prior to testing. The order of each test was randomized to account for the effects of habituation. In addition, the subjects were given sufficient rest between tests.

We analyzed COP were items of total sway length (TSL), environmental area (EA), root-mean-square area (RMSA), total sway length / time (TSL/t), and total sway length / environmental area (TSL/EA). For data analyses, we performed a two-way analysis of variance (Bonferroni test) comparing touch conditions (3, including NC) as well as the touch height (3) as within-subject factors. The significance criterion was \( p < 0.05 \).

**RESULTS**

The results of each parameter are shown in the Table. For TSL, significant differences were found between NC and FT at all touch heights, as well as between LT and FT at each touch height (\( p < 0.01 \)). However, there were no significant differences between the NC and LT at any touch height. Furthermore, there were no significant differences within LT or FT. For EA, there were significant differences between the NC and LT at all touch heights, as well as between the NC and FT at all touch heights (\( p < 0.01 \)). Additionally, there were significant differences between LT and FT at each touch height (\( p < 0.01 \)). However, there were no significant differences within LT or FT. For RMSA, there were significant differences between the NC and LT at all touch heights (\( p < 0.01 \)). In addition, there were significant differences between LT and FT at each touch height (\( p < 0.01 \)). However, there were no significant differences within LT or FT. For TSL/t, there were significant differences between NC and FT at all touch heights (\( p < 0.01 \)). In addition, there were significant differences between LT and FT at each touch height (\( p < 0.01 \)). However, there were no significant differences within LT or FT. For RMSA, there were significant differences between the NC and LT at all touch heights as well as between the NC and FT at all touch heights (\( p < 0.01 \)). However, there were no significant differences between the NC and LT at any touch height. For TSL/EA, there were significant differences between the NC and LT at all touch heights as well as between the NC and FT at all touch heights (\( p < 0.01 \)). However, there were no significant differences, either between LT and FT at any touch height, or within LT or FT.

**DISCUSSION**

The present study aimed to clarify the effects of LT on COP sway during static standing and the LT height that minimizes COP sway. Postural stability during static standing is the ability to maintain the COP sway, which expresses the degree of fluctuation in the COP line within the base of support, at a small value, as well as the center-of-mass in a smaller range within the stable region\textsuperscript{5}. Therefore, a state can be considered more stable if the TSL (expressing the COP movement) is short, and EA (expressing the COP movement range) and RMSA (expressing the variation in COP sway) are small. We found differences between the NC, LT, and FT condition for EA and RMSA in that order, despite the fact that TSL and TSL/t were comparable under the NC and LT conditions and significantly greater than those the FT conditions. Additionally, TSL/EA\textsuperscript{3}, a parameter that indicates the fineness of postural control, was comparable in LT and FT and significantly lower than in NC.

In FT, TSL was lower than in NC or LT. In addition, EA was high only in NC, and was significantly lower not only

| Table 1. The results for each parameter under the different touch conditions |
|-----------------------------|-----------------|-----------------|-----------------|
| TSL (mm) | EA (mm²) | RMSA (mm²) | TSL/t (m/sec) | TSL/EA (1/m) |
| NC | 827.0 ± 214.4 | 250.7 ± 119.5 | 2.9 ± 2.3 | 28.3 ± 7.9 | 3.9 ± 1.7 |
| LT | 779.1 ± 150.3 | 111.6 ± 62.4 | 1.6 ± 2.0 | 26.4 ± 7.3 | 9.2 ± 4.8 |
| FT | 303.7 ± 124.7 | 60.2 ± 61.0 | 1.0 ± 1.2 | 10.8 ± 5.3 | 8.9 ± 6.6 |
| acromion | LT | 753.1 ± 136.3 | 107.8 ± 57.4 | 1.2 ± 0.8 | 25.7 ± 5.2 | 8.9 ± 4.2 |
| FT | 318.5 ± 144.2 | 52.9 ± 47.1 | 0.8 ± 0.8 | 11.4 ± 6.3 | 9.8 ± 7.0 |
| Midpoint of GT-AC | LT | 756.2 ± 139.2 | 111.2 ± 54.5 | 1.5 ± 2.0 | 26.6 ± 6.7 | 8.2 ± 3.3 |
| FT | 287.5 ± 136.2 | 49.0 ± 57.0 | 0.8 ± 1.1 | 10.4 ± 6.1 | 10.3 ± 7.5 |
in FT but also in LT. Similarly, RMSA was clearly high only in NC and significantly lower in FT and LT. These results reveal that COP sway is lower in FT than in LT and NC. In previous studies of the effects of the touch target on COP sway\textsuperscript{7)}, tests of the effects of LT and FT on rough non-slippery and smooth slippery surfaces for the touched area found no significant difference in COP sway between the rough and smooth surfaces in LT. On the other hand, there was a significant difference in COP sway between rough and smooth surfaces in FT. It has been stated that during FT with a smooth surface, stability is strengthened using a postural adjustment strategy similar to that used during LT\textsuperscript{7}). The FT condition in the present study did not involve a smooth surface. This suggests a fixed action resulting from the expansion of the support base due to weight loading with the index finger, as well as involvement of the fingertip as a weight-loading limb in stability during static standing.

In LT, EA and RMSA were significantly lower than in NC despite the fact that TSLs were comparable in the two conditions. This reveals that in LT, the COP sway range was small even though the COP movement was comparable to that in NC. Additionally, TSL/EA was significantly larger in FT and LT than in NC. Unlike FT, in which fixed stability was obtained as a result of expansion of the support base, this suggests the influence of the somatosensory system (touch, proprioception) on postural control in the LT.

Regarding the reduction of COP sway though LT, Jeka et al. have also suggested this is the result of sensory information from the fingertips acting as feedback and feed-forward inputs to adjust posture in a precise manner\textsuperscript{7,8}). From these observations, it is likely that stabilization of COP by LT is due to an increased amount of feedback, especially from the somatosensory system, among the systems (visual, vestibular, and somatosensory) required for postural adjustment. In other words, we speculate that despite there being COP sway in LT, the COP sway range was controlled by an increase in sensory feedback from the fingertips.

With respect to the effects of differences in the height of objects touched on the COP sway, there were no significant differences between the different height conditions for any of the parameters in FT or LT. This reveals that differences in the height at which LT is performed have no effect on COP sway under conditions of static standing. In other words, regardless of the touch height, COP sway is reduced so long as there is something to touch. This suggests the possibility of using LT in daily life.

The present experiment was conducted in the tandem position, and only measured COP sway in the static standing posture with the eyes open. In future, we hope to carry out experiments under conditions that tax the ability to maintain posture, such as with the eyes closed and dynamic conditions, and test the practical utility of LT in daily life under conditions such as walking while holding onto an object.

REFERENCES