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Original Article

Effect of fingertip touch on postural sway during static standing in patients with femoral neck or trochanteric fracture

Kohei Minami, RPT, MS,[1] Fumiko Nagatomi, RPT, MS,[2] Susumu Watanabe, RPT, PhD,[3] Akio Tsubahara, MD, PhD[4]

[1]Rehabilitation Center, Kawasaki Medical School Hospital, Kurashiki, Japan
[2]Rehabilitation Center, Kawasaki Hospital, Kawasaki Medical School, Okayama, Japan
[3]Department of Rehabilitation, Faculty of Health Science and Technology, Kawasaki University of Medical Welfare, Kurashiki, Japan
[4]Department of Rehabilitation Medicine, Kawasaki Medical School, Kurashiki, Japan

ABSTRACT

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Objective: Patients with femoral neck or trochanteric fracture (hip fracture) are considered to be at high risk for falling. We investigated whether a light fingertip touch on a stable surface (LT) with a force insufficient to provide mechanical support of the body could stabilize static standing. We also investigated whether the effect differed between LT and heavy fingertip touch (HT) or between ipsilateral and contralateral fingertip touch (relative to the fracture).

Methods: Eleven patients with hip fracture who were hospitalized in a kaifukuki (convalescence) rehabilitation ward participated in the study. The sway of the center of pressure (COP) during static standing was measured and compared under five fingertip touch conditions.

Results: The COP path length was significantly shorter under every fingertip touch condition than for the condition without touch: LT with a finger contralateral to the fracture, 65.5 ± 38.4 cm; LT with a finger ipsilateral to the fracture, 64.5 ± 32.6 cm; HT with a finger contralateral to the fracture, 45.1 ± 23.4 cm; HT with a finger ipsilateral to the fracture, 46.1 ± 26.2 cm; and without touch, 88.4 ± 33.0 cm ($F = 26.9$, $p < 0.01$). It was also shorter for the HT conditions than for the LT conditions. However, there was no difference in the COP path length between fingertip touch with the upper extremity ipsilateral to the fracture versus that contralateral to the fracture.

Conclusions: We attribute the beneficial effect of LT on postural stability during static standing to somatosensory inputs through the fingertip. The additional benefit of HT relative to LT must have stemmed from the addition of mechanical support to this somatosensory feedback.

Key words: femoral neck or trochanteric fracture, hip fracture, sway of center of pressure, fingertip touch

Correspondence: Kohei Minami, RPT, MS
Rehabilitation Center, Kawasaki Medical School Hospital, 577, Matsushima, Kurashiki, Okayama 701−0192, Japan.
E-mail: kohei.m@hp.kawasaki-m.ac.jp
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Introduction

Femoral neck and femoral trochanteric fractures (hip fractures) are typical leg injuries among the elderly. In 2007, approximately 150,000 patients were taken to hospitals in Japan with hip fracture. The incidence is projected to increase gradually until 2043 in parallel with the anticipated increase in the elderly population [1].

Falling is reported to be the most common cause of hip fracture, accounting for 74% of all cases [2]. A decrease in standing balance ability is believed to be one reason for falling [3]. Yamazaki et al. [4] reported that the sway of the center of pressure (COP) was greater in patients with hip fracture at the time of hospital discharge than in general citizens of the same age and also that such patients were at high risk of falling again. Patients with unilateral hip fracture are considered to be at high risk for a contralateral fracture [1]. It is therefore important to study the postural control of patients with hip fracture.

Patients with poor balance ability due to musculoskeletal or cerebrovascular disorders can often stabilize themselves in a standing position by touching a handrail, table, or wall. Jeka [5] reported that light fingertip touch (LT) on a stable fixed point could reduce postural sway in the standing position even when the level of contact force applied was insufficient to support the body mechanically. The stabilizing effect of LT on posture is thought to be mediated by the contribution of somatosensory inputs from the upper extremity used for fingertip touch to postural control [5−7].

Although the ability of LT to reduce postural sway has been observed in normal subjects and in patients with impaired vision, vestibular dysfunction, or sensory impairment [8−11], it has not yet been reported in patients with hip fracture.

There is no consensus regarding the dependence of the postural sway on the level of force of the fingertip touch. Moreover, there has been no report on the relative effects of fingertip touch by the upper extremities ipsilateral and contralateral to a fractured limb.

The purpose of this study was to examine whether LT on a stable surface increased standing stability in patients with unilateral hip fracture and to compare the effect on postural stability between LT and heavy fingertip touch (HT) with a greater level of force applied. Additionally, we compared the effect on postural stability between fingertip touch by the upper extremities ipsilateral and contralateral to the side of the fracture.

Methods

Eleven patients with hip fracture who were hospitalized in a kaifukuki (convalescence) rehabilitation ward participated in the study. All participants' injuries had been caused by falling. The inclusion criteria were ability to walk independently in the ward with or without a cane; an FIM locomotion score of ≥6 points; and absence of neurological or musculoskeletal disorders, markedly impaired vision, or pain in the posture used for measurement. The patients' demographic data are shown in Table 1.

Prior to the study, each participant received an explanation of the purpose and methods of the study and provided written informed consent to participate. The study was approved by the Research Ethics Committee of the Okayama Central Hokancho Hospital.

The sway of the COP during static standing was measured as an assessment of standing stability, and its value was compared among five different fingertip touch conditions.

The participant was instructed to stand barefoot in the Romberg stance on a portable stabilometer, and to maintain a static standing position as stable as possible by gazing at a round mark located 2 meters in front of the eyes.

A load cell was placed on a greater trochanter-high table beside the participant for confirmation of the force of fingertip touch. When touching the load cell, the participant was instructed to avoid the elbow contacting the trunk. A selected site that was easy for the participant to touch was marked in order to keep it consistent (Fig. 1).

The five fingertip touch conditions were (1) no touch, (2) LT by a fingertip of the upper extremity on the unaffected side (contralateral), (3) LT by a fingertip on the affected side (ipsilateral), (4) HT by the unaffected side, and (5) HT by the affected side. The five conditions were defined as follows:

(1) No touch (NT): The participant stood with his or her arms hanging naturally.
(2) LT by unaffected side (LT-UN): The participant stood with LT by a fingertip of the upper extremity contralateral to the fractured limb.
(3) LT by affected side (LT-AF): The participant stood with LT by a fingertip of the upper extremity ipsilateral to the fractured limb.

Table 1. Demographic data.

Case	Sex	Age (years)	Height (cm)	Weight (kg)	Side and type of fracture	Surgical procedure
1	Female	76	160.0	55.5	Lt・Neck	BHP
2	Female	83	151.5	35.0	Lt・Neck	BHP
3	Female	94	154.0	50.0	Rt・Neck	BHP
4	Female	78	157.0	51.0	Rt・Neck	osteosynthesis
5	Female	88	145.0	52.0	Lt・Neck	BHP
6	Female	75	146.0	52.0	Lt・Trochanteric	osteosynthesis
7	Male	92	154.5	43.5	Rt・Trochanteric	osteosynthesis
8	Female	87	137.0	43.0	Lt・Trochanteric	osteosynthesis
9	Female	78	150.0	41.5	Lt・Trochanteric	osteosynthesis
10	Female	86	146.0	40.5	Lt・Trochanteric	osteosynthesis
11	Female	79	143.0	43.0	Lt・Trochanteric	osteosynthesis

Mean ± SD, 83.3 ± 6.6, 149.5 ± 6.8, 46.1 ± 6.3.
BHP, bipolar head prosthesis.

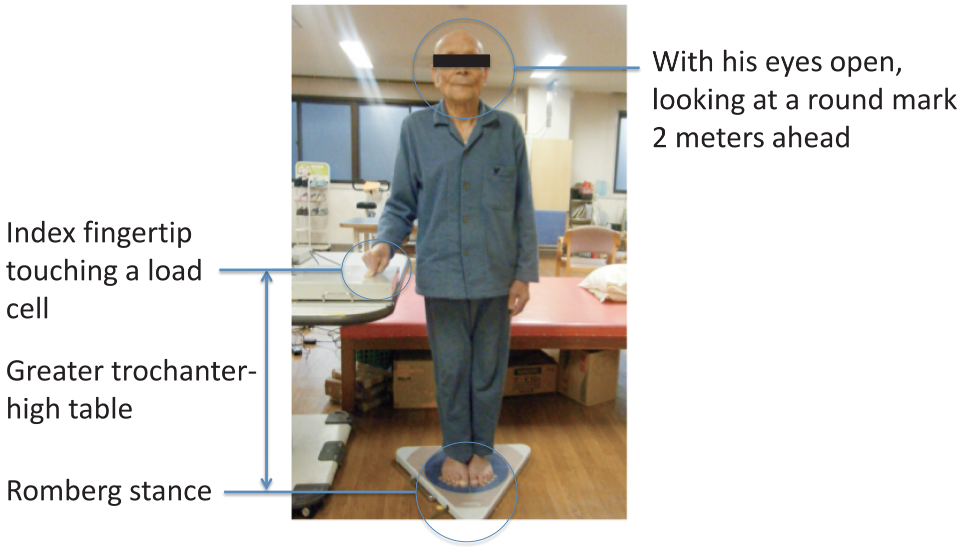

Figure 1. Measurement set-up.

(4) HT by unaffected side (HT-UN): The participant stood with HT by a fingertip of the upper extremity contralateral to the fractured limb.

(5) HT by affected side (HT-AF): The participant stood with HT by a fingertip of the upper extremity ipsilateral to the fractured limb.

In the LT conditions, the participant touched the selected site on the load cell with the index fingertip at a pressure of less than 1 N, as described in previous studies [5−7]. In the HT conditions, the participant was allowed to push the load cell with the index fingertip with as much pressure as needed to stand steadily.

The fingertip contact force, mean center of pressure (COP) displacement along the X-axis (MCX), COP path length (CPL), and maximum range of COP displacement in the anteroposterior and mediolateral directions (MCD-AP and MCD-ML, respectively) were measured in the present study.

The fingertip contact force was measured with a load cell (P08-1713, Kyowa), and the mean value of the fingertip contact force during each trial was calculated automatically. The other data corresponding to the sway of the COP were measured with a portable stabilometer (Gravicorder GS11, Anima). This study used the CPL as a measure of the postural sway. MCX, i.e., the mean COP displacement in the mediolateral direction, was used as an indicator of COP displacement between the affected and unaffected limbs.

Before the measurements, each fingertip touch condition was explained and the participant allowed to practice until he or she became accustomed to all of the conditions. The examiner ascertained whether the participant could perform LT consistently with a fingertip contact force of less than 1 N. Then, the sway of the COP was measured under each condition, in random order, at 30-second intervals. If the participant came close to exceeding 1 N of contact force, the examiner, watching via a monitor, briefly instructed him or her to keep the contact force at less than 1 N.

The mean values of the fingertip contact force, MCX, CPL, MCD-AP, and MCD-ML under each fingertip touch condition were compared using one-way repeated measures analysis of variance (ANOVA). Tukey's test was used as a post-hoc test for multiple comparisons. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) 15.0J for Windows, and the level of significance was defined as $p < 0.05$ for all tests.

Results

The results of all of the measurements are shown in Table 2.

1. Fingertip contact force

The mean value of the fingertip contact force was less than 1 N for both LT-UN and LT-AF and therefore met the requirement for the LT conditions. There was no significant difference between LT-UN and LT-AF or between HT-UN and HT-AF.

2. Mean COP displacement

Because of technical difficulties with the stabilometer, the MCX data from five participants were severely displaced in the right-hand direction, and these data were therefore excluded from analysis. The MCX was measured precisely for the other six participants. Although the COP was displaced toward the unaffected side under every touch condition, there was no significant difference in the extent of displacement among all touch conditions.

Table 2. Measurement data.

Measurement	Touch condition					ANOVA	F value
	NT	LT-UN	LT-AF	HT-UN	HT-AF		
Fingertip contact force (N)	—	0.6 ± 0.2	0.6 ± 0.3	8.9 ± 3.7	7.1 ± 2.8	$p < 0.01$	36.9
MCX (cm)	0.7 ± 1.0	0.9 ± 1.4	0.0 ± 1.4	0.5 ± 1.2	0.5 ± 1.1	NS	1.6
CPL (cm)	88.4 ± 33.0	65.5 ± 38.3	64.5 ± 32.6	45.1 ± 23.4	46.1 ± 26.2	$p < 0.01$	26.9
MCD-AP (cm)	3.0 ± 1.0	2.5 ± 0.6	2.6 ± 0.8	2.4 ± 0.3	2.3 ± 0.7	NS	1.1
MCD-ML (cm)	3.2 ± 1.0	2.5 ± 1.1	2.5 ± 1.1	1.3 ± 0.3	1.3 ± 0.4	$p < 0.01$	8.8

Mean ± standard deviation.
NT, no touch; LT-UN, light touch by unaffected side; LT-AF, light touch by affected side; HT-UN, heavy touch by unaffected side; HT-AF, heavy touch by affected side; ANOVA, analysis of variance; NS, not significant.
A positive value of MCX indicates deviation of the center of pressure (COP) toward the unaffected limb and a negative value indicates deviation of the COP toward the affected limb.

3. COP path length

The mean value of the CPL was significantly lower under every fingertip touch condition relative to the no-touch condition ($p < 0.01$). In addition, the CPL was shorter for HT-UN and HT-AF than for LT-UN and LT-AF ($p < 0.01$) but did not differ between HT-UN and HT-AF or between LT-UN and LT-AF (Fig. 2).

4. Maximum COP displacement range

The MCD-AP did not differ significantly among all touch conditions. The MCD-ML was significantly shorter for HT-UN and HT-AF than for NT, LT-UN, and LT-AF.

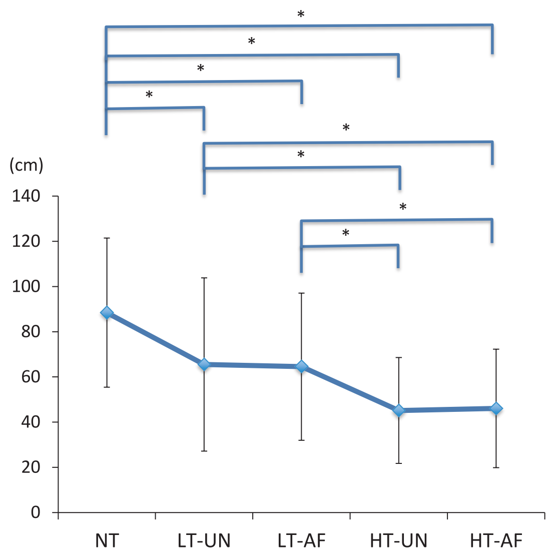

Figure 2. Center of pressure path length.
NT, no touch; LT-UN, light touch by unaffected side; LT-AF, light touch by affected side; HT-UN, heavy touch by unaffected side; HT-AF, heavy touch by affected side.
*: $p < 0.01$ (Tukey's test)

Discussion

The present study examined the effect of LT on postural sway in patients with hip fracture. The fingertip contact force was less than 1 N for LT conditions, consistent with the force used in previous studies [5, 8, 10, 11]. Although we anticipated differences in the distribution of weight between the right and left feet according to whether the touch was provided by the upper extremity ipsilateral or contralateral to the fractured limb, the MCX did not differ among all touch conditions. Therefore, we concluded that the postural sway was not affected by displacement of weight to the unaffected or affected limb. As the CPL, a measure of the postural sway, decreased significantly under the LT conditions compared with the no-touch condition, LT with force of less than 1 N can clearly stabilize static standing in patients with hip fracture as in other individuals.

The postural stability provided by LT is attributable to the contribution of the somatosensory input from the touch to postural control. This seems the likeliest explanation because a fingertip contact force of less than 1 N is insufficient for mechanical support of the body [6], the time phase patterns of the fingertip touch and sway of the COP differ between LT and HT [5], and the sway of the COP is not diminished by the touch of a finger with sensory dysfunction [7]. Therefore, we must also attribute the ability of LT to decrease the CPL observed in this study to the somatosensory input provided by the fingertip touch.

We also examined the difference in the postural sway between the LT and HT conditions. The CPL was significantly smaller under the HT conditions than under the LT conditions. Therefore, HT stabilized standing balance more effectively than did LT.

The ability of HT has been attributed to control of postural sway by the mechanical support of the body provided by fingertip touch [5]. We consider the

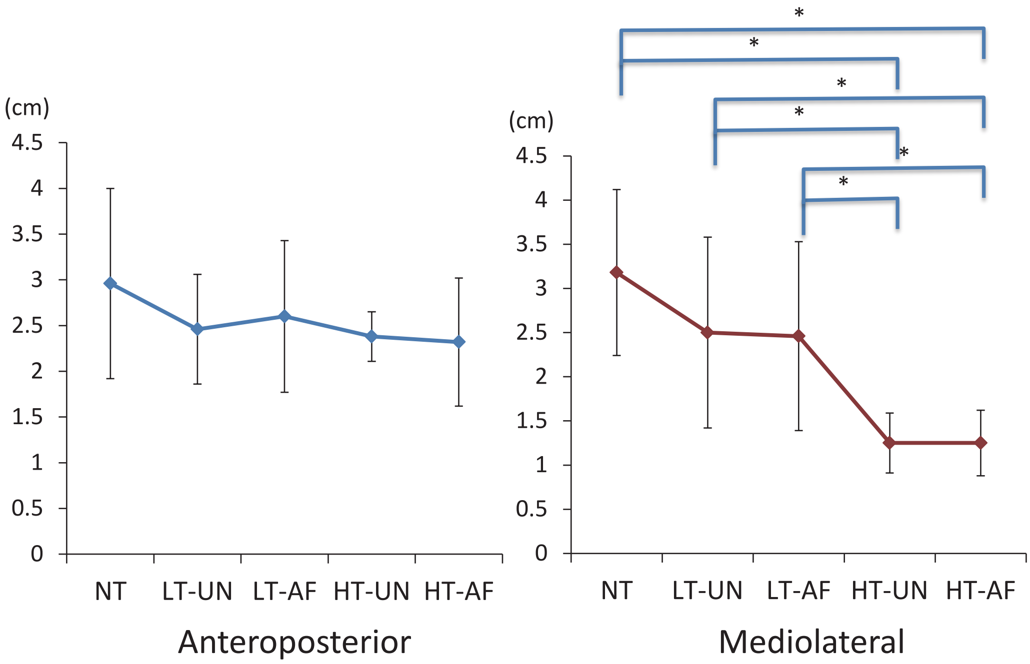

Figure 3. Maximum range of center of pressure displacement.
NT, no touch; LT-UN, light touch by unaffected side; LT-AF, light touch by affected side; HT-UN, heavy touch by unaffected side; HT-AF, heavy touch by affected side.
*: $p < 0.05$ (Tukey's test)

decrease in the CPL by HT in the present study to have the same cause.

Jeka [5] reported that the sway of the COP in the frontal plane decreased equivalently under the LT and HT conditions. In contrast, Dickstein et al. [10] and Baccini et al. [11] reported that HT significantly decreased the sway of the COP relative to LT. There is no consensus as to whether the magnitude of the decrease in the postural sway differs between LT and HT. Our results showed that the CPL was remarkably smaller under the HT conditions than under the LT conditions. One possible explanation for this discrepancy is the difference in the fingertip contact force defined as HT, which was approximately 7−9 N in the present study versus approximately 4 N in Jeka's report. Therefore, the HT might have provided greater mechanical support in the present study.

Neither MCD-AP nor MCD-ML decreased in response to LT relative to the no-touch condition. However, MCD-ML was significantly smaller under the HT conditions than under the no-touch condition, whereas MCD-AP did not decrease under the HT conditions. We attribute the decrease in the CPL under the HT conditions to a combination of the somatosensory feedback effect posited for the LT conditions and mechanical control of the lateral sway of the COP by the placement of the load cell beside the subject.

Finally, we examined the effect of the side of the upper extremity providing the touch relative to the fractured lower limb (i.e., ipsilateral versus contralateral) on the postural sway. There was no significant difference in the CPL with respect to which upper extremity provided the touch. As we have reported previously, the decrease of the postural sway under the LT conditions is most likely due to somatosensory input via the fingertip touch [5−7]. As the fingertip ipsilateral to the fracture and the one contralateral to the fracture provide equivalent somatosensory input, the decrease in the CPL was equivalent between ipsilateral and contralateral LT. The same is true for the HT conditions. Because the mechanical support of the body provided by HT was equivalent between the affected and unaffected sides, the decrease in the CPL was also equivalent.

The present study clarified the effects of fingertip touch on the sway of the COP in patients with an anticipated decrease in balance ability due to hip fracture. In conclusion, LT on a stable surface clearly decreased the postural sway during static standing and improved postural stability. In addition, HT stabilized standing more effectively than did LT. For an equivalent fingertip contact force, the postural stabilizing effect of fingertip touch was equivalent between the upper extremities ipsilateral and contralateral to the fractured limb.

It was recently reported that environmental and emotional changes can influence postural sway. The present study did not investigate whether differences in the measurement environment and fingertip touch conditions might have had psychological effects. Although the postural sway is a measure of balance ability, the relationship between the postural sway during static standing and falling has not been clarified. Therefore, the decrease of the postural sway by fingertip touch may not correspond to prevention of falling. Future investigation is warranted concerning the relationship between the postural sway and falling as well as the effects of fingertip touch on dynamic balance during such activities as standing up and walking. We are interested in determining whether fingertip touch could be a simple and useful method for the prevention of falling.

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