



Case Study

Lower garment-lifting postural control characteristics during toilet-related activities in healthy individuals and a post-stroke hemiplegic patient undergoing rehabilitation

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Abstract. [Purpose] This study compared lower garment-lifting postural control characteristics during toilet-related activities between healthy participants and a post-stroke patient, and studied changes in the stroke patient's characteristics during rehabilitation. [Participants and Methods] Six healthy individuals and one stroke participant with right hemiparesis were asked to lift a pair of pants with the left arm while on the toilet. During the process, we measured the mean percentage of body weight (%BW) on each leg and the foot center of pressure (COP) using portable force plates. Measurements were conducted twice for the stroke participant during rehabilitation. [Results] In healthy participants, the %BW and respective COP indices for both legs were not different during lifting, but the COP sway velocity and excursion were greater in the anterior-posterior (AP) than the lateral axis in both legs. In the stroke participant, no marked change was seen in the high %BW of the non-paretic leg while lifting during rehabilitation, but both legs' COP positional asymmetry improved on the AP axis and the COP sway velocity and excursion of the non-paretic leg increased. [Conclusion] Facilitating selective COP mobility on the AP axis of the non-paretic leg during lower garment lifting could become an effective intervention for stroke patients.

Key words: Stroke, Hemiparesis, Toilet

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INTRODUCTION

Patients after a stroke often have problems with toilet activities that necessitate toileting care^{1, 2)}. Independent toilet activity in hospitalized patients is a key factor in determining the timing of discharge^{2, 3)}. Stroke patients often have difficulties with lower garment lifting (LGL) during toilet activities^{4, 5)}.

One factor complicating LGL while on the toilet in stroke patients is impaired postural control related to changing and maintaining postures⁵⁾. Postural stability during LGL is needed for reaching and grasping lower garments⁶⁾. Understanding postural control in LGL and the changes during rehabilitation in post-stroke hemiplegic patients could lead to more effective training methods. Studies of stroke patients show reduced weight-bearing in paretic lower limbs and increased postural sway during quiet standing^{7–12)}. However, quiet standing postural control characteristics should not be applied to daily activities,

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such as LGL, which require dynamic and complex postural control.

To understand LGL postural control characteristics during toilet activity in post-stroke hemiplegic patients, this study must clarify these characteristics in healthy participants. Iwata et al.¹³⁾ found that in chronic post-stroke phases, where toileting independence has been achieved, more weight is placed on the non-paretic leg during LGL. However, they evaluated postural control in LGL in an experimental environment, not in an actual toilet. Postural control is influenced by the environment¹⁴⁾; thus, postural control during LGL in an experimental environment, not in an actual toilet. Postural control is influenced by the environment¹⁴⁾; thus, postural control during LGL in the toilet should be studied in an actual toilet environment.

Objectives of this study were to examine the mean percentage of body weight (%BW) on each leg and the foot center of pressure (COP) as postural control characteristics in healthy participants during LGL compared to those of a stroke patient and identified related changes occurring during rehabilitation. The novelty of this research is that to measured lower garment-lifting postural control in an actual toilet environment during rehabilitation of the post-stroke patient.

PARTICIPANTS AND METHODS

Healthy participants were recruited from the rehabilitation hospital staff. The inclusion criteria were: age >18 years and no self-reported motor or cognitive impairments that could interfere with daily activities.

The study stroke participant inclusion criteria were: first episode of unilateral stroke with hemiparesis in the prior 3 months; medically stable; able to maintain independent unsupported stance; requiring medical staff supervision in toilet activities; no other neuromuscular conditions that could interfere with standing/balance; and no cognitive impairments that could hamper the comprehension of instructions.

Posturographic examinations during LGL were performed using portable force plates (GP-6000 Twin Gravicorder, ANI-MA Corp., Tokyo, Japan) on the floor in front of a hospital toilet bowl (180 × 200 cm; distance from toilet bowl to anterior wall, approximately 130 cm) (Fig. 1). The force plate comprised two platforms, each capable of measuring weight-bearing percentages and leg COP. The data were stored at a sampling rate of 100 Hz. Participants placed each leg on the respective force plate and lifted a lower garment with the left arm while standing, without using handrails. For the measurements, the feet were placed at the center of each force plate with the medial aspects of the heels 10 cm apart and toes pointing outward at 10° from the sagittal midline (Fig. 1). LGL involved “lifting a pair of pants from just below the kneecap to the waist (iliac crest).” The lower garments were pairs of pants made of stretchy material with elastic waistbands. The examiners prepared pants in small, medium, and large sizes, and chose the pair most closely matching the height and waist circumference of each participant. Participants were instructed to begin the task from a standing position on the examiner’s signal (“Please begin”). LGL was recorded using a charge-coupled device camera (STC-TC33USB; frame rate, 30 frames/s; Sensor Technologies,

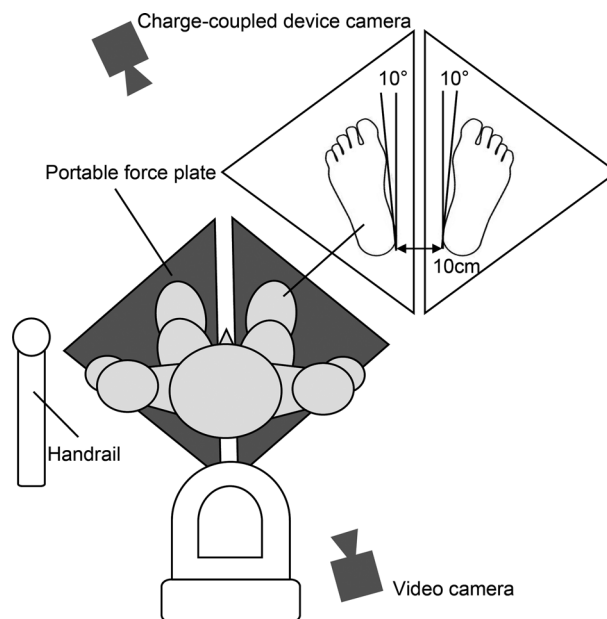


Fig. 1. Experimental setting.

Portable force plate placed on the floor in front of the toilet bowl in the hospital toilet (180×200 cm) equipped with handrails for right hemiplegic patients. The act of LGL was recorded using a charge-coupled device camera and a video camera. The feet were placed at the center of each force plate platform with the medial aspect of both heels 10 cm apart and each foot placed with toes outward at an angle of 10° from the sagittal midline.

Kanagawa, Japan) synchronized with the force plate, and a video camera placed behind the participant (HDR-XR550; Sony, Tokyo, Japan). The set-up was the same for all participants.

The weight-bearing, total length of COP movement (COP LNG), and environmental area of the COP movement (COP ENV area) for the left and right legs were measured during 30 s of quiet standing before measuring LGL. This set-up was the same as for the LGL measurements. During the measurements, the participants were asked to focus on a black circular mark (width, 10 cm) placed at eye level on a wall approximately 1 m in front of them.

Data analysis included importing video footage onto a computer and extracting data related to weight-bearing and COP during LGL. The start of LGL was defined by the participant's first movement of the left arm or head, and the end was defined by completing LGL to the waist and removing the hand from the garment. The recorded video footage was used to measure the time required for LGL and count the number of garment pulls.

Postural control indices included: %BW of each leg, COP ENV area, average COP position (PCOP), average COP fluctuation velocities (VCOP), and COP excursion (ECOP; maximum PCOP minus minimum PCOP) on the mediolateral (ML) and anteroposterior (AP) axes of each foot. For PCOP, the force plate platforms centered on the ML axis were the origin points. A (+) value indicated right-sided displacement (paretic side), while a (-) value indicated left-sided displacement (non-paretic side). On the AP axis, the center of the heel to toe length along the AP axis was the origin point. The (+) values indicated forward displacement and (-) values indicated backward displacement.

Data from healthy participants were analyzed using t-testing to identify differences in the %BW of the left and right legs, differences in COP indices (PCOP, VCOP, and ECOP) in left and right legs based on axis, and differences in VCOP and ECOP on each axis based on leg. $P < 0.05$ was considered significant. Analyses were performed using SPSS version 19 software (IBM, Tokyo, Japan).

The stroke participant measurements were conducted twice, once with supervision (T1: stroke participant could carry out toilet activities alone, but supervision was necessary for safety and fall prevention), and once in the independence phase (T2: stroke participant could carry out toilet activities alone, with no assistance/supervision). Motor recovery of the paretic limbs and paretic finger was assessed using the Brunnstrom recovery stage (BRS)¹⁵. Paretic triceps surae muscle spasticity was assessed using the Modified Ashworth Scale (MAS)¹⁶. Sense of touch and position of the paretic foot were assessed using the Stroke Impairment Assessment Set (SIAS)¹⁷. Gait was assessed using the Functional Ambulation Categories (FAC)¹⁸. ADLs were assessed using the Functional Independence Measure (FIM)¹⁹.

This study was approved by the Institutional Review Board of Hyogo University of Health Sciences (approval number: 14011-2). All participants provided informed consent after receiving both verbal and written information about the study, which was conducted between April 2014 and March 2017.

RESULTS

Participants were six healthy individuals with no physical dysfunction (mean age: 38.7 ± 6.3 years; all men; mean height: 169.8 ± 3.4 cm; mean weight: 63.7 ± 11.1 kg; all right-handed) and one post-stroke hemiplegic, hospitalized patient (early 50s; male; height: 176 cm; weight: 87 kg; right-handed). His right hemiplegia was caused by a left putaminal hemorrhage. He underwent initial measurements 64 days after stroke onset and had no noticeable cognitive dysfunction (Mini-Mental State Examination score, 25)²⁰. He could lift his lower garments without needing staff or handrails for toileting. He was in rehabilitation with physical therapy and occupational therapy for 40–60 min/day, 5–7 days/week.

Table 1 presents the participants' demographic and clinical characteristics. The period between T1 and T2 measurements was approximately 1.5 months. The stroke participant's COP LNG and COP ENV area during quiet standing were greater than those of the healthy participants in T1 and T2. The stroke participant also placed a greater %BW on the non-paretic leg during quiet standing, which was more pronounced in T2.

Table 2 presents the data for postural control indices of LGL while on the toilet. In LGL by healthy participants, %BW of each leg and PCOP, VCOP, and ECOP of each leg by axis did not differ significantly. However, there was significantly greater VCOP and ECOP on the AP axis than on the ML axis in both legs (VCOP: left/right, $p=0.002/p=0.016$; ECOP: left/right, $p=0.004/p=0.005$).

Figure 2 presents the stroke participant's COP trajectory for each leg alone, and for both legs together ("overall COP") during LGL at T1 and T2. A comparison of data from T1 in the healthy participants and the stroke participant as shown in Table 2, revealed the five characteristics of LGL in the stroke participant: 1) longer time required for LGL and more garment pulls; 2) greater %BW on the non-paretic leg; 3) larger COP ENV area; 4) PCOP asymmetry between the paretic and non-paretic legs on the AP axis; and 5) higher values for VCOP and ECOP on the AP axis than on the ML axis, similar to healthy participants.

Table 2 also shows that the changes in LGL from T1 to T2 in the stroke participant: 1) required less time and fewer garment pulls; 2) slight reduction in %BW on the non-paretic leg, although clear asymmetry remained; 3) a smaller COP ENV area; 4) improvement in PCOP asymmetry between the paretic and non-paretic leg on the AP axis; 5) a decrease in VCOP values on both axes, but an increase in VCOP on only the AP axis on the non-paretic side; and 6) a decrease in ECOP on the paretic leg and an increase on the non-paretic leg on the AP axis.

DISCUSSION

This study showed that during LGL by healthy participants using the left arm, %BW, PCOP, VCOP, and ECOP were similar in the left and right legs, and VCOP and ECOP were greater on the AP axis than the ML axis in both legs. These findings were thought to reflect LGL requiring bending the trunk forward and reaching for the garment, followed by moving

Table 1. Characteristics of the study participants

Characteristics	Controls (n=6)	Stroke participant	
		T1	T2
Time since stroke (days)	-	64	106
Brunnstrom stage (UE)	-	II	II
Brunnstrom stage (hand)	-	I	I
Brunnstrom stage (LE)	-	III	III
MAS score	-	0	1+
SIAS (touch) score	-	1	2
SIAS (position) score	-	2	3
FAC score	-	2	3
FIM (motor) score	-	70	77
FIM (cognitive) score	-	35	35
COP LNG of quiet standing (cm)	33.9 ± 3.4	69.1	67.5
COP ENV area of quiet standing (cm ²)	0.7 ± 0.4	4.0	7.1
%BW of the left leg during quiet standing	51.4 ± 2.4	68.5	84.2
%BW of the right leg during quiet standing	48.8 ± 2.4	31.8	15.9

Values for the controls are mean ± SD.

UE: upper extremity; LE: lower extremity; MAS: Modified Ashworth Scale; SIAS: Stroke Impairment Assessment Set; FAC: Functional Ambulation Categories; FIM: Functional Independence Measure; COP: the foot center of pressure; COP LNG: total length of COP movement; COP ENV: environmental area of the COP movement; BW: body weight; SD: standard deviation.

Table 2. Postural control indices for lower garment lifting in the study participants

Parameter	Controls (n=6)	p		Stroke participant		
		Lt vs Rt	ML vs AP	T1	T2	
The time required (sec)	6.9 ± 1.2			15.2	12.5	
The number of garment pulls	8.3 ± 2.0			14	10	
%BW	Lt (non-paretic side)	48.5 ± 2.4		74.5	72.1	
	Rt (paretic side)	51.4 ± 2.3		25.8	28.3	
COP ENV area (cm ²)	19.0 ± 10.2			30.2	19.0	
PCOP (cm)	ML axis	Lt	-10.9 ± 0.4	-10.4	-11.2	
		Rt	11.3 ± 0.5	12.2	13.3	
	AP axis	Lt	-1.6 ± 0.7	-4.5	-1.3	
		Rt	-2.1 ± 1.2	1.8	2.1	
VCOP (cm/sec)	ML axis	Lt	2.5 ± 1.1	**	1.6	1.6
		Rt	3.1 ± 1.3	*	2.9	2.2
	AP axis	Lt	6.1 ± 1.8		5.9	6.4
		Rt	5.7 ± 1.8		6.0	4.0
ECOP (cm)	ML axis	Lt	2.7 ± 0.8	**	2.1	2.0
		Rt	3.2 ± 1.2	**	3.7	4.3
	AP axis	Lt	7.0 ± 2.2		6.3	9.4
		Rt	6.4 ± 1.7		7.5	5.7

Values for the controls are mean ± SD. **p<0.01, *p<0.05.

Lt: left; Rt: right; BW: body weight; COP: the foot center of pressure; COP ENV: environmental area of the COP movement; PCOP: average COP position; VCOP: average COP fluctuation velocities; ECOP: COP excursion; ML: medio-lateral; AP: antero-posterior.

the center of gravity forward to pull up the garment while combining bending and rotation motions of the trunk⁵⁾.

LGL by the stroke participant in T1 required a long time to perform the task, many garment pulls, a large COP ENV area, and a greater %BW on the non-paretic leg. These results are consistent with those of Iwata et al.¹³⁾. The stroke participant displayed PCOP asymmetry on the AP axis whereby the PCOP was displaced further behind the center of the foot on the non-paretic leg and further in front of the center of the foot on the paretic leg. These results are consistent with those of de Haart et al.¹¹⁾, in that stroke patients with ankle clonus exhibit marked PCOP asymmetry during quiet standing. LGL skills of the stroke participant improved in speed and number of garment pulls (efficacy)²¹⁾, with both decreasing from T1 to T2. The results of stroke participant (recovered LGL skill, walking and ADL independence, but stable predominant weight-bearing on the non-paretic leg) were consistent with Laufer et al.'s results¹²⁾. This suggests that different mechanisms were involved in altering function of the paretic leg and improving LGL skill.

Geurts et al.¹⁰⁾ suggested that more effective muscular compensation by the non-paretic leg might improve ADL recovery. Considering changes in each COP index of the non-paretic leg from T1 to T2 in the stroke participant, PCOP asymmetry between the paretic and non-paretic legs on the AP axis improved due to the PCOP on the AP axis of the non-paretic leg being displaced forward (from -4.5 cm to -1.3 cm). Increased VCOP and ECOP of the non-paretic leg were seen, particularly along the AP axis. Latash et al.²²⁾ reported postural control in post-stroke hemiplegic patients as not abnormal, but results from central nervous system adaptations to optimize postural maintenance. Greater weight-bearing on the non-paretic leg, narrowing of the COP ENV area, forward displacement of the PCOP, and increased VCOP and ECOP on the AP axis of the non-paretic leg may be necessary for efficient LGL. This suggests enhanced selective COP mobility on the non-paretic leg AP axis, could promote LGL toileting independence.

There are some limitations to this study. First, the healthy participants and the stroke participant had a difference in height and weight, it may be necessary to conduct future studies that control for height and weight. Second, the stroke participant data were taken from a right hemiplegic patient with moderate paralysis about 2–3 months post-stroke. Patients with different paralysis levels might show different characteristics in comparison. The results of this study might have changed further if this study had followed this stroke participant for a longer time period. A larger patient cohort followed for a longer duration is needed. Third, the toilet environment of this study was wider than the toilet in ordinary households. In the future, it is necessary to study in a general household-sized toilet.

This is the first report of postural control characteristics during LGL in healthy individuals and a stroke patient during toilet activity in an actual toilet environment. The stroke participant had postural instability and weight-bearing asymmetry in

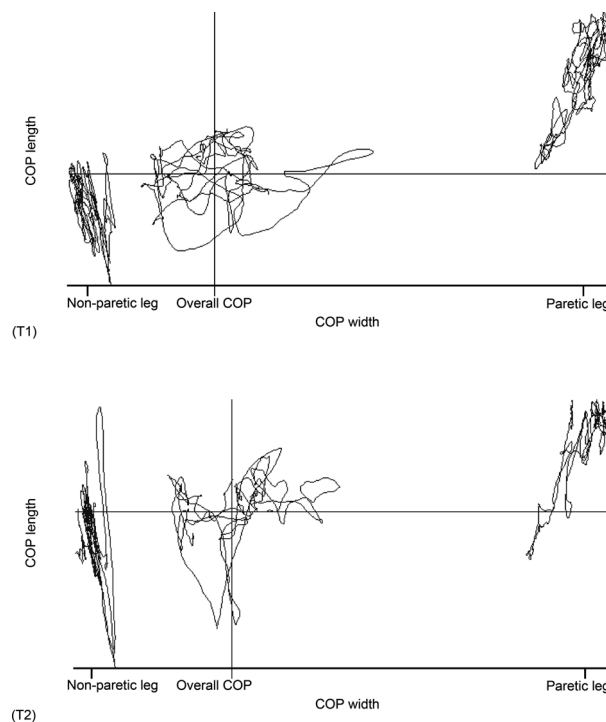


Fig. 2. COP trajectory for each leg alone and for both legs together (“overall COP”) during LGL at T1 and T2 (stroke participant).

(T1) Weight-bearing asymmetry is reflected in the lateral axis of the overall COP trajectory towards non-paretic leg. PCOP asymmetry is shown between the paretic and non-paretic legs on the AP axis. (T2: Approximately 1.5 months after T1) Weight-bearing asymmetry remained in T2, but PCOP asymmetry between the paretic and non-paretic leg on the AP axis improved. The ECOP on the non-paretic leg increased along the AP axis.

toilet activities. He did not show obvious changes in asymmetry, but improvements after rehabilitation appeared to be most prominent in the AP axis of the non-paretic leg. This suggests that selective COP mobility on the AP axis of the non-paretic leg during LGL could be helpful for stroke patients. Due to the wide range of impairments in stroke patients, this study analyzed one patient's data to show realistic characteristics as first step. It is necessary to accumulate individual patient data in the future.

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Conflict of interest

None.

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