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Individuals with post-stroke hemiparesis are able to use additional sensory information to reduce postural sway

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ABSTRACT

The present study aimed to investigate whether stroke survivals are able to use the additional somatosensory information provided by the light touch to reduce their postural sway during the upright stance. Eight individuals, naturally right-handed pre-stroke, and eight healthy age-matched adults stood as quiet as possible on a force plate during 35 s. Participants performed two trials for each visual condition (eyes open and closed) and somatosensory condition (with and without the right or left index fingertip touching an instrumented rigid and fixed bar). When participants touched the bar, they were asked to apply less than 1 N of vertical force. The postural sway was assessed by the center of pressure (COP) displacement area, mean amplitude and velocity. In addition, the mean and standard deviation of the force vertically applied on the bar during the trials with touch were assessed. The averaged values of COP area, amplitude and velocity were greater for stroke individuals compared to healthy adults during all visual and somatosensory conditions. For both groups, the values of all variables increased when participants stood with eyes closed and reduced when they touched the bar regardless of the side of the touch. Overall, the results suggested that, as healthy individuals, persons with post-stroke hemiparesis are able to use the additional somatosensory information provided by the light touch to reduce the postural sway.

Individuals who have suffered a cerebrovascular accident (CVA) usually present balance deficits as observed by the increased postural sway during quiet stance [8,10]. These deficits may be due to motor [11,23], sensory [19,29] and/or cognitive [3] impairments exhibited after a CVA and could be associated with the limited performance of several activities of daily living [22,31] and the increased risk for falls of stroke survivals [32].

The ability to maintain body balance and orientation is achieved by the postural control system and depends on the adequate functioning of the sensory (visual, vestibular and somatosensory) and motor systems [16]. Thus, impairment in any of these systems could lead to increased postural sway as observed in stroke survivals. Indeed, sensory and motor deficits are commonly reported not only on the contralateral side of the brain lesion but also on the ipsilateral side [6,7].

Alternatively, additional somatosensory information provided by the light touch (less than 1 N) of the fingertip on an external rigid bar has been reported to be used by the postural control system to reduce postural sway [17,18,20,26]. The effect of light touch on postural sway has been observed in healthy young as well as in elderly adults [30], and other individuals with balance deficits due to anterior cruciate ligament injury [4], orthostatic tremor [2], diabetes [12], cerebellar dysfunction [28] and labyrinthine defects [21]. For stroke individuals, the influence of the touch (not a light one as the applied vertical force was more than 2 N) was investigated on the modulation of anticipatory postural adjustments when performed with more impaired hand [27] and during walking task by touching with the ipsilesional hand [5]. It was found that the contralesional touch (applied force ≈5 N) had lower effect on the adjustments in this population when compared to healthy individuals [27]. Thus, it is unclear whether the additional somatosensory information provided by the light touch (applied force <1 N) of the ipsilesional and contralesional hand affects the postural sway of individuals after a CVA similarly to healthy, aged-matched individuals during quiet standing. The use of additional somatosensory information could be an important strategy for the stroke individuals to enhance their postural stability. Therefore, the aim of the present study was to investigate the effect of light touch on postural sway of stroke survivors.

Eight chronic hemiparetic, post-stroke adults (mean ± S.D.: 57 ± 8 years old) and eight age- and gender-matched neurologically healthy volunteers (mean ± S.D.: 58 ± 6 years old) participated in the study. All participants were right hand dominant as determined by the Edinburgh handedness questionnaire [24]. They signed the

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Table 1
Characteristics of stroke participants and their healthy, matched controls.

Participant	Stroke Group								Controls					
	Gender	Age (years)	Brain lesion side	Months since stroke	Tactile sensitvity (g)[a]				Gender	Age (years)	Tactile sensitvity (g)[a]			
					Upper limb		Lower limb				Upper limb		Lower limb	
					IPL	CL	IPL	CL			IPL	CL	IPL	CL
1	F	48	LH	16	2	2	2	2	F	49	2	0.05	2	0.2
2	F	66	LH	35	0.2	0.2	2	2	F	62	0.2	0.2	2	2
3	F	67	LH	15	2	10	2	10	F	68	0.2	0.2	2	2
4	F	54	RH	62	0.05	0.2	0.2	2	F	51	0.2	0.2	0.2	0.2
5	M	60	LH	20	2	2	2	2	M	68	0.05	0.2	0.2	0.2
6	M	58	RH	47	0.05	0.05	0.2	0.2	M	50	0.05	0.05	2	2
7	M	53	RH	29	0.05	0.2	0.2	2	M	53	0.2	0.2	0.2	0.2
8	M	60	RH	26	0.2	0.2	0.2	0.2	M	58	0.05	0.2	2	2

[a] Perceived sensation to the touch of monofilaments with 0.2 is considered normal light touch to plantar feet but diminished sensation to the hand. Perceived sensation to the touch of monofilaments with 10 g is considered as having some sensation loss.

informed consent form approved by the University's Human Subjects Review Board in accordance with the Declaration of Helsinki prior to their participation. Stroke survivors were selected if they had a single unilateral CVA in the anterior arterial territory at least 6 months prior the study. Participants were selected if they could understand and follow the task instructions, did not report any concurrent medical problems such as severe sensory or visual deficits, were able to stand independently and could maintain the elbow of the paretic limb flexed to 90° for at least 1 min. The cutaneous pressure sensation of right and left hands and feet were assessed by the tactile sensitivity test using Semmes–Weinstein monofilaments. The individual characteristics of the stroke and healthy, controls are presented in Table 1.

Participants were asked to stand, barefoot and with their heels separated by a distance about of 16 cm, on a force plate (OR6-7, AMTI, Watertown, USA) for 35 s. The forces and moments were recorded from the force plate at a sampling frequency of 100 Hz and used to compute the center of pressure (COP) displacement in the anterior–posterior (AP) and medial–lateral (ML) directions. The participant's foot position at the first trial was marked on the force plate and was reproduced in each trial.

Two trials of each somatosensory and visual condition were performed by each participant under the instruction to maintain their body position as quietly as possible. Three somatosensory conditions (no light touch, right or left light touch) and two visual conditions (eyes open or closed) were manipulated in the experimental trials. In the no touch condition, both arms hang by the side while in the light touch condition, participants were asked to touch (applied vertical force <1 N) with their right (left) index fingertip a small bar while the left (right) arm hung passively at the side of the body. The height of the touch bar (Touch-Synch, EMG System) was adjusted in such way that the participants could keep their elbow flexed to 90°. Participants received prior practice related to the amount of force to be applied on the touch bar. During the experiment, the amount of force was checked by the experimenter and if it was greater than 1 N, participants were verbally informed to reduce it. In the eyes open condition, participants were instructed to look at a target (black, 2.5-cm diameter circle) displayed on a computer monitor placed on 1 m ahead at eye level. Three blocks of four trials were performed by the participants. Each block was defined by a somatosensory condition with two trials for each visual condition. The visual conditions were alternate within each somatosensory condition. The order of the blocks was randomized for all participants. Individuals could rest any time between trials or blocks and fatigue was never reported.

The data processing was run in Labview 2009 software. The COP time-series was low-pass filtered at 10 Hz with a Butterworth filter. The first and last 2.5 s of the trial were removed from the analysis after filtering. For the remaining 30 s of the COP data, the area of the COP sway and the mean sway amplitude and velocity of the COP trajectory results for each direction were computed. The area was estimated by fitting an ellipse that encompasses 85% of the COP data in both directions using the method given in Duarte and Zatsiorsky [13]. The mean and standard deviation (variability) of the applied force during the touch trials were also evaluated.

For statistical analyses the variables data were organized based on the brain side lesion of stroke group. That is, data of the touch condition performed by the index fingertip ipsilateral to the brain lesion were defined by the left (right) hand side if individuals had a CVA on the left (right) side of the brain. For the control group, data from the touch condition performed with the left index fingertip of four individuals were considered as ipsilateral side while the right touch condition was the contralateral side to match the hand side of the stroke individuals. Analyses of variance (ANOVA) were used to verify the effects of group (stroke and control groups), somatosensory (no touch, NT; ipsilateral touch, IPT; or, contralateral touch, CLT) and visual (open or closed eyes, respectively, OE or CE) conditions, with the last two factors as repeated measures, on the COP area. Mixed design MANOVA was used to examine the effects of group, somatosensory and visual conditions on the other variables (AP and ML directions of the postural sway measures and mean and variability for applied force were used as dependent variables). The level of significance was set at $p < 0.05$. Statistical analyses were performed in SPSS 16.0 (SPSS Inc., Chicago, USA).

Fig. 1 illustrates the typical COP trajectory in each somatosensory (NT, IPT and CLT) and visual condition of one representative participant from stroke and control group. Increased COP displacements in the AP and ML directions were observed for the stroke participant. Additionally, both representative individuals reduced the area of COP trajectories with the light touch, regardless of the side of the touch, and increased the area of COP trajectories without vision and no touch (NT).

ANOVA revealed statistically significant effect of group [$F(1,14) = 9.35$; $p = 0.009$], with the COP area being significantly greater for the stroke participants than for control individuals. There was also somatosensory and visual condition effects on the COP area [$F(2,28) = 18.37$; $p < 0.001$ and $F(1,14) = 13.65$; $p = 0.002$, respectively]. However, none significant double (group by visual condition, group by somatosensory condition, and visual by somatosensory condition) and triple (group by visual by somatosensory condition) interaction was revealed ($p > 0.087$). For both groups, the COP area increased with eyes closed and reduced with the touch, regardless of the side of the touch (Fig. 2A).

To investigate whether such effects differed between AP and ML directions, the mean sway amplitude and velocity of COP time-series for each direction were also analyzed. MANOVA indicated