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Determinants and consequences for standing balance of spontaneous weight-bearing on the paretic side among individuals with chronic stroke

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ABSTRACT

Hemiparetic stroke patients commonly bear more weight on the non-paretic side which seems intuitively linked to unilateral control deficits. However, there is evidence that some post-stroke favour weighting the paretic side, which may be problematic given altered capacity of the paretic limb to contribute to the control of upright posture. This study explores the prevalence and clinical determinants of stance asymmetry, and the relationship between stance asymmetry and postural control among chronic stroke patients. Subjects ($n = 147$; >6 months post-stroke) stood on two force plates in eyes-open and eyes-closed conditions; 59 were symmetric, 18 had paretic asymmetry (PA), and 70 had non-paretic asymmetry (NPA). Root mean square (RMS) of antero-posterior and medio-lateral centre-of-pressure under each limb and both limbs combined were compared. RMS of total medio-lateral centre-of-pressure was greater for both asymmetric groups compared with the symmetric group. PA subjects relied less on the loaded limb for control than NPA subjects and relied more on visual information for postural control than those who were symmetric. There were no differences in the characteristics of individuals between the PA and NPA groups. The loading of the paretic limb was not related to impaired postural control during stationary standing which was attributable, in part, to individuals relying on control from the non-paretic limb, in spite of lower vertical load, and a greater dependence on visual contributions. There was no evidence that greater loading on the paretic limb was related to persisting dyscontrol but may rather reflect a learned strategy.

1. Introduction

The distribution of weight between legs is an important aspect of balance control post-stroke. Favouring the non-paretic limb can reduce reliance on the more impaired limb for balance control. Typically, stroke patients have difficulty maintaining a weight shift to their paretic side [1], and there is greater postural sway when loading the paretic compared to the non-paretic leg during quiet standing [2]. The contribution of the paretic leg to balance control, in terms of the amount of corrective antero-posterior (AP) torque generated at the ankle, is less than that of the non-paretic leg even if weight distribution is symmetric [3–5]. Thus, the centre-of-mass should be shifted towards the non-paretic side when standing to minimise instability due to unilateral limb impairment [5]; indeed, many chronic hemiparetic stroke patients stand with more weight on their non-paretic side [6–9].

Despite the apparent benefits when standing still in favour of the non-paretic limb there is evidence that some post-stroke favour standing over the paretic limb [10]; this stance strategy potentially leads instability. Among healthy individuals who stand asymmetrically, the more-loaded limb contributes more to balance control than the less-loaded limb [4,11]. However, weight-bearing on the paretic limb, which likely has reduced capacity to contribute to balance control [3–5], would result in instability [2]. Such instability may be exacerbated with removal of vision. Individuals

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with stroke show greater reliance on vision for standing balance control than healthy individuals [9,12], possibly due to reduced sensory inputs from the paretic limb [13]. During asymmetric stance among healthy individuals it is speculated that unloading one limb decreases the activity of plantar cutaneous mechanoreceptors from that limb and, therefore, reduces the relevance of sensory input from that limb to balance control [14]. Loading the paretic limb, thereby influencing the reliance on sensory input from the intact non-paretic limb, potentially further increases reliance on vision for balance control. Therefore, we believe that there are important implications to understanding the prevalence, determinants and consequences of stance asymmetry post-stroke.

There are several possible explanations for standing asymmetry that favours increased loading on the paretic limb. Contraversive pushing is a perceptual disorder commonly observed in acute stroke whereby patients lean towards the affected side and actively resist any attempt to correct this posture [15,16]. While clinical measurement of pushing behaviour commonly resolves in the earlier stages of stroke recovery [15], weight bearing on the paretic side among chronic stroke patients might indicate residual pushing behaviour. Pushing has been linked to hemispatial neglect and is more common among those with right-hemisphere lesions than left-hemisphere lesions [16]. Additionally, it is possible that asymmetric stance over the paretic limb occurs among those stroke patients with less sensori-motor impairment than those who weight-bear on the non-paretic limb. Alternatively, asymmetric loading in favour of the paretic limb may reflect a strategy influenced by rehabilitation or related to the capacity to generate other balance reactions such as rapid stepping with the non-paretic limb [17].

This study aims to: 1) determine the prevalence, among chronic stroke patients, of stance strategies emphasising weight bearing over the paretic limb; 2) determine the individual characteristics that predict reliance on paretic limb during stance; and 3) determine the consequences of asymmetry for standing balance control. With respect to prevalence we predicted, on the basis of previous work [9,10], that approximately 10–30% of individuals after stroke will stand quietly favouring the paretic limb. With respect to individual determinants of stance asymmetry we predicted persisting evidence of neglect, but not degree of sensory or motor impairment, would be associated with stance towards the paretic side [15,18]. We hypothesised that stroke patients who bore more weight on their paretic limb would sway more than those who bore more weight on their non-paretic limb. Additionally, despite weight-bearing asymmetry, which should increase the contribution of the more-loaded limb to balance control [4], we hypothesised that the paretic limb would contribute less to balance control than the non-paretic limb. Finally, we expected that hemiparetic subjects weight-bearing on the paretic side may be more dependent on vision to offset any diminished sensory feedback from the impaired limb. Therefore, we predicted that removal of vision would result in a greater increase in sway for subjects bearing more weight on the paretic side than those bearing more weight on the non-paretic side.

2. Methods

Data for this study were gathered as part of the [Heart and Stroke Foundation Centre for Stroke Recovery Longitudinal Database]. Individuals with stroke receiving treatment at one of four participating hospitals (one acute care and three rehabilitation hospitals) were recruited for this database. The purpose of the database is to characterise sensori-motor and cognitive recovery post-stroke. Participants were included in the current analysis if they completed assessment of quiet standing balance (as described below) 6 months post-stroke or later. Participants were excluded if their stroke(s) affected both hemispheres and/or if they had bilateral sensorimotor impairment of both limbs; 147 individuals met the inclusion and exclusion criteria and were included in the analysis. This study was approved by the Research Ethics Board at each participating institution and subjects provided written informed consent to participate.

Participant characteristics are presented in Table 1. Demographic information and information regarding time of stroke, stroke location and affected side was obtained from review of subjects' hospital charts. Stroke severity was determined using the National Institutes of Health Stroke Scale [19] (NIH-SS). The existence of sensory impairment was determined using the sensory item on the NIH-SS. The existence of perceptual problems was determined using the extinction item on the NIH-SS, and the line bisection test [20]. For the line bisection test, subjects were asked to place a mark in the centre of a 20 cm-long line on a piece of paper. This test was repeated three times and an average deviation from the centre was calculated. Subjects who deviated by 2.8% or more of the length of the line to the right of centre or 3.6% or more of the length of the line to the left of centre were determined to have neglect [21]. To determine if asymmetry was related to prior history of 'pushing', the Scale for Contraversive Pushing (SCP) [22] score was obtained from assessments completed upon admission to in-patient rehabilitation (i.e. sub-acute phase). Lower-limb motor impairment was determined using the leg and foot scores of the Chedoke–McMaster Stroke Assessment [23] (CMSA-leg and CMSA-foot).

Postural sway was measured by root mean square (RMS) of the COP displacement [9,24] of subjects standing on two force plates with eyes open and eyes closed (one trial in each condition). The force plates were positioned side-by-side so that they were as close together as possible without touching (i.e. <1 mm apart). Subjects stood in a standardised position (feet oriented at 14° with 0.17 m between the heels [25]) with each foot equidistant from the gap between the force plates. Participants were instructed to stand as still as possible for 30 s, looking straight ahead at a mark on the wall at eye level. Balance testing was conducted in a quiet room with no distractions. Ground reaction forces and moments were sampled at 200 Hz and were low-pass filtered using a fourth order dual-pass Butterworth filter at 10 Hz prior to processing. AP and ML COP were calculated separately for both force plates and total COP under both feet combined was also calculated.

Table 1
Characteristics of entire subject cohort. Values presented are means with standard deviations in parentheses or proportions. The *p*-value is for the comparison between the three sub-groups from a one-way ANOVA (ordinal or continuous data) or chi-square (count data). Note that 18 subjects in the non-paretic asymmetry group with high absolute asymmetry magnitude (>13.5%) were excluded from the analysis to allow for better comparison with the paretic asymmetry group. (see text for further details).

	Entire sample	Asymmetric		Symmetric	*p*-Value
		Paretic	Non-paretic		
Number of participants	147	18	52	59	
Proportion of women	60/147	8/18	21/52	26/59	*0.91*
Age (years)	67.4 (12.6)	71.8 (9.9)	67.9 (13.1)	67.5 (13.4)	*0.45*
Time since stroke (months)	12.9 (15.6)	16.8 (19.9)	10.8 (5.3)	15.2 (21.2)	*0.26*
Right-hemisphere affected	74/147	11/18	24/52	23/59	*0.28*
NIH-SS[a]	2.6 (2.6)	2.3 (2.5)	3.3 (2.9)	1.5 (1.8)	*0.0007*
Sensory impairment	42/147	4/18	15/52	11/59	*0.44*
Extinction	16/147	1/18	8/52	2/59	0.070
History of pushing ($N=101$)	13/101	1/8	6/36	2/44	*0.20*
Neglect ($N=109$)	22/109	3/11	6/39	9/43	*0.64*
CMSA-foot[b] ($N=119$)	4.7 (1.5)	4.6 (1.7)	4.6 (1.4)	5.5 (1.2)	*0.0066*
CMSA-leg[c] ($N=117$)	5.2 (1.2)	5.0 (1.0)	5.0 (1.2)	5.8 (1.0)	*0.0018*

[a] National Institute of Health Stroke Scale; score ranges from 0 to 42, with higher values indicating a more severe stroke.
[b] Chedoke–McMaster Stroke Assessment foot score; score ranges from 1 to 7, with lower values indicating greater impairment.
[c] Chedoke–McMaster Stroke Assessment leg score; score ranges from 1 to 7, with lower values indicating greater impairment.