The Relationship of Asymmetric Weight-bearing with Postural Sway and Visual Reliance in Stroke

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Abstract

Due to motor and sensory deficits in individuals with stroke, we proposed that they must compensate for these impairments during standing with greater dependence on vision. In addition, we hypothesized that asymmetric weight-bearing, which occurs following stroke, is related to increased postural sway and those with greater asymmetry will have greater reliance on vision. Twenty-eight individuals with stroke and 28 healthy older adult controls stood quietly with eyes open or closed on a force platform while postural sway was quantified by centre of pressure measures and weight-bearing asymmetry was calculated from vertical ground reaction forces. To determine the influence of vision on postural sway, a visual ratio (eyes open/eyes closed) was calculated for the sway measures. The results demonstrated that individuals with stroke had greater visual dependence for the control of postural sway velocity in the medial-lateral, but not anterior-posterior direction, compared to controls. Further, we found that greater asymmetry was moderately related to increased medial-lateral sway for the individuals with stroke. Contrary to predictions, those individuals with stroke with mild asymmetry had greater visual dependence than those with more severe asymmetry.

Keywords

postural control; cerebrovascular accident; balance

Introduction

Quiet standing postural control requires an individual to maintain their centre of mass (COM) within their limits of stability [1] and centre of pressure (COP) measures are commonly used to assess this control by measuring the amount of body sway. Postural sway has been shown to distinguish between fallers and non-fallers in community-dwelling older adults [2]. Increased postural sway has also been shown to correlate with falls in individuals

with stroke [3]. Stroke-related impairments may contribute to the disturbed postural control and underlie the large number of falls experienced by these individuals.

One such impairment is unilateral hemiparesis, which contributes to an asymmetric weight-bearing posture often observed during standing in individuals with stroke. Clinicians often target this strategy and encourage individuals to load their paretic limb to a greater extent. This technique may serve to increase the ability of these individuals to use their paretic limb and also help facilitate a more symmetric weight-bearing posture. However, whether a standing asymmetric weight-bearing posture (i.e. greater loading on non-paretic limb) results in greater postural sway is not clear.

Asymmetry has been shown to correlate with motor function and length of hospital admission [3,4]. Furthermore, asymmetric weight-bearing during a sit-to-stand task is thought to contribute to falls in individuals with stroke [5]. Thus, we propose that asymmetric weight-bearing would be related to increased postural sway in individuals with stroke. We believe it is important to understand the contribution of weight-bearing given that the majority of individuals with stroke stand with an asymmetric posture. In addition, understanding the interactions of body posture with dynamic postural control is important not just for applications in the stroke population, but also relevant to the older adult population and many musculoskeletal and neurological conditions, which also frequently exhibit weight-bearing asymmetry.

If asymmetric weight-bearing during standing contributes to increased sway and instability, it would be reasonable to conclude that individuals with stroke would need ways of adapting to this deficit to maintain normal standing balance. Proprioceptive deficits are also common in individuals with stroke [6], which substantiates the need to find ways to compensate for the altered sensory information that would result. We propose that individuals with stroke compensate for this instability with a greater utilization of vision to maintain postural control during standing compared to healthy older adults. Furthermore, if asymmetric weight-bearing relates to increased sway, those exhibiting greater asymmetry may have a greater dependence on vision. Visual control has been shown to be important in maintaining standing balance [7, 8]. The small movements produced during sway cause changes in the optical structure of texture elements over the visual field, which can provide the central nervous system (CNS) with cues as to the direction of movement relative to the environment [9]. In fact, visual cues from the environment can be used to generate visually evoked postural responses to maintain upright standing balance [10, 11]. Furthermore, sway is increased when vision is removed in healthy older adults [7].

Therefore, the purpose of this study was to determine whether individuals with stroke have greater visual dependence for the control of postural sway compared to healthy older adults. In addition, we measured the contribution of asymmetric weight-bearing on postural control in individuals with stroke. Some clinical guidance for balance training in individuals with stroke may be implied from an understanding of the interactions of asymmetry, postural sway, and vision.

Methods

Participants

Twenty-eight individuals with hemiparesis due to a single cerebrovascular accident volunteered to participate. The inclusion criteria consisted of (1) at least 1-year post-stroke, (2) age 50 or over, and (3) able to stand independently for at least 5 minutes without an assistive device. Persons with musculoskeletal or neurological disorders in addition to stroke were excluded from the study. Individuals with stroke were also excluded if they presented with hemispatial neglect as confirmed by the line bisection test [12]. Twenty-eight healthy older adult controls of comparable age also participated. Characteristics of the study population are shown in Table 1. In order to provide a measure of functional balance, individuals with stroke were tested on the Berg Balance Scale. This scale consists of 14 tasks scored on a 5-point scale (max. 56 points) including standing with eyes closed, standing on one foot, reaching, and turning [13]. The foot and leg components of the Chedoke-McMaster Stroke Assessment scale [14] were assessed to provide information on the presence and severity of lower limb physical impairments (range: 1, no active movement; 7, can complete normal age-appropriate complex movements). In addition, the Modified Ashworth Scale assessed spasticity of the ankle, where 0 indicates no increase in muscle tone while a score of 4 reflects the affected part rigid in flexion or extension [15].

The local university and hospital review boards provided ethics approval and informed consent was received from all participants prior to their participation in the study.

Protocol

Participants stood with their own shoes with one foot on each of two force plates (Bertec Corp.) and their arms relaxed at their sides in two quiet standing conditions: eyes open (EO) and eyes closed (EC). All participants stood with feet shoulder width apart but were allowed to choose the amount of weight-bearing load on each limb (group differences in the distance between the two feet were approximately 0.5 cm). Participants were instructed to stand quietly throughout the duration of testing and look straight ahead. Two 30-second trials with EO preceded two 30-second trials with EC. Rests were given between the EO and EC conditions to minimize fatigue. A spotter beside the participant was also present to ensure safety during testing. Twelve participants wore an ankle-foot orthosis (AFO) during data collection. The AFO consisted of a posterior strut, calf support, and footplate. While it has been shown that wearing an AFO can reduce postural sway [16], participants that used an AFO were tested with it on since they normally wore the device on a daily basis and this would simulate their natural condition.

Data and statistical analyses

Force plate data was sampled at 600 Hz for 30 seconds for each trial. A software package was used to calibrate and filter the force plate data (second-order, 50 Hz low-pass Butterworth filter) and to determine the vertical force from each force plate. The root-mean-square (RMS) COP displacement and velocity (differentiated from the displacement) in both the anterior-posterior (AP) and medial-lateral (ML) directions were determined from the net COP of the two force plates and represent the deviation around the means of the COP

displacement and velocity, respectively. Test-retest reliability (over separate days) using the individuals with stroke showed moderate to high reliability (Intraclass correlation coefficients_{3,1} of 0.63 – 0.90 in all COP measures; standard error of the measurement ranged from 0.035 – 0.061 cm and 0.127 – 0.463 cm/s for the displacement and velocity measures, respectively).

An Asymmetry Index was calculated using a formula developed by Robinson et al. [17] that provides a measure of the amount of weight-bearing on each limb. The equation for the individuals with stroke was:

$$\text{Asymmetry Index (stroke)} = \frac{(Fy_{\text{paretic}} - Fy_{\text{non-paretic}})}{(0.5(Fy_{\text{paretic}} + Fy_{\text{non-paretic}}))} \times 100,$$

where Fy refers to the vertical ground reaction force. A lower (i.e. more negative) Asymmetry Index score represents greater weight-bearing on the non-paretic limb while '0' represents perfect symmetry (50% weight-bearing on each limb) during standing.

In the controls, the Asymmetry Index was based upon the amount of weight-bearing on each limb:

$$\text{Asymmetry Index (controls)} = \frac{(Fy_{\text{lesser}} - Fy_{\text{greater}})}{(0.5(Fy_{\text{greater}} + Fy_{\text{lesser}}))} \times 100,$$

where Fy_{greater} refers to the greater loaded limb and Fy_{lesser} refers to the lesser-loaded limb. The Asymmetry Indexes were calculated using the mean vertical forces from each force plate and thus, were measured during the trial.

All measures were not normally distributed (Shapiro-Wilk test, $p < 0.05$) and thus, nonparametric statistics were employed. A non-parametric multivariate analysis of variance (MANOVA) was performed to determine the effect of Group (stroke vs. controls) on five dependent variables (AP RMS COP displacement, AP RMS COP velocity, ML RMS COP displacement, ML RMS COP velocity, and Asymmetry Index) for the EO condition. Due to the non-normality of the dependent variables, data was rank transformed before entering the MANOVAs [18]. Subsequently, Pillai's Trace value was used to calculate the L statistic, which was compared to the Chi-square critical value to determine significance as described in Thomas et al. [18]. When the MANOVA was significant, post-hoc Mann-Whitney U tests were performed to determine which measures were different between groups. To determine the contribution of vision on postural sway, visual ratios were calculated for each COP measure and the Asymmetry Index by dividing the EO by the EC condition. The ratio accounts for differences in the baseline condition (i.e. EO). A second non-parametric MANOVA was performed to determine the effect of Group (stroke vs. controls) on five visual ratio (EO/EC) measures (AP RMS COP displacement, AP RMS COP velocity, ML RMS COP displacement, ML RMS COP velocity, and Asymmetry Index) followed by post-hoc Mann-Whitney U tests.

The hypothesis that individuals with stroke who have greater asymmetric weight-bearing rely more heavily on vision than those who are more symmetric was tested by comparing the visual ratios of a subgroup of individuals. First, we averaged the Asymmetry Index values from the EO and EC conditions (note that there was no difference between the conditions, $p = 0.120$). Next, we determined the median Asymmetry Index value. Finally, we compared the visual ratios of those in which their Asymmetry Index was above the median of the group (i.e. less negative and greater symmetry) against those who were below the median (i.e. more negative and greater asymmetry) using a Mann-Whitney U test.

Spearman correlations compared the relationship between COP measures and Asymmetry Index in both individuals with stroke and controls. All statistical analyses were performed with SPSS, version 11.0 for Windows, with an alpha level of 0.05.

Results

Mann-Whitney U tests revealed no differences in COP measures between those individuals tested while wearing an AFO versus those that were not (p -value range of 0.25 – 0.96). In addition, Mann-Whitney U tests revealed no differences in COP measures between right and left hemiparetic individuals (p -value range of 0.14 – 0.93). Thus, data was combined across all stroke participants for all subsequent analyses.

Asymmetry Index and COP Measures

Results from the MANOVA and post-hoc analysis in the EO condition indicated that COP measures and degree of asymmetry were greater in individuals with stroke compared to controls (Pillai's Trace = 0.52, $p < 0.001$). AP RMS COP displacement (stroke = 0.360 ± 0.093 cm vs. controls = 0.197 ± 0.061 cm, $p < 0.001$) and ML RMS COP displacement (stroke = 0.178 ± 0.052 cm vs. controls = 0.093 ± 0.028 cm, $p < 0.001$) and velocity (stroke = 0.887 ± 0.308 cm/s vs. controls = 0.545 ± 0.149 cm/s, $p < 0.001$) for the individuals with stroke were nearly double than the values for controls (Figure 1).

Although both the individuals with stroke and controls stood with feet shoulder-width apart, the individuals with stroke chose to stand with greater weight-bearing load on their non-paretic limb. This is reflected in the Asymmetry Index, which for the individuals with stroke was $-31.5 \pm 36.8\%$ and $-36.5 \pm 35.7\%$ for the EO and EC conditions, respectively. The average RMS of the Asymmetry Index over the 30 second trials for the individuals with stroke was 4.3% and 5.2% for the EO and EC conditions, respectively. The Asymmetry Index values of the individuals with stroke were different from the controls Asymmetry Index, which were $-12.4 \pm 7.1\%$ and $-12.8 \pm 8.6\%$ for the EO ($p = 0.011$) and EC ($p = 0.001$) conditions, respectively. The average RMS of the Asymmetry Index over the 30 second trials for the controls was 3.1% and 3.2% for the EO and EC conditions, respectively. Note that a negative Asymmetry Index represents greater weight-bearing on the non-paretic limb for the individuals with stroke and the dominant limb (limb that bore the greatest load on force plate) of the controls.

Visual Control of Postural Sway

In the individuals with stroke, removing vision (EC condition) increased COP measures (Figure 1). When the visual ratios were compared between controls and individuals with stroke (Table 2) the MANOVA was significant (Pillai's Trace = 0.40, $p < 0.001$). However, post-hoc analysis using Mann-Whitney U tests demonstrated that only the ML RMS COP velocity visual ratio was different between controls and individuals with stroke ($p = 0.012$). The visual ratio was 20% smaller for individuals with stroke (0.68) versus controls (0.86).

As only the ML RMS COP velocity visual ratio was different between stroke and controls, we chose to compare this ratio for the individuals with stroke with a high Asymmetry Index versus those with a low Asymmetry Index relative to the median Asymmetry Index (-31.9%). The Asymmetry Index for the low Asymmetry Index group was $-5.7 \pm 22.1\%$ and for the high Asymmetry Index group was $-58.1 \pm 24.7\%$. The Mann-Whitney U test demonstrated differences for this ratio (low Asymmetry Index group = 0.62 ± 0.17 versus the high Asymmetry Index group = 0.73 ± 0.21 , $p = 0.050$). Thus, contrary to our hypothesis, individuals with mild asymmetry demonstrated lower visual ratios (indicating greater sway with their eyes closed) compared to individuals with more severe asymmetry.

Relationship between Asymmetry and Postural Sway

Table 3 demonstrates the correlations between postural sway and asymmetry. In the individuals with stroke, increasing ML RMS COP velocity was correlated with more asymmetrical weight-bearing (i.e. decreasing Asymmetry Index) in the EO condition ($r = -0.47$, $p = 0.011$). This relationship was absent in the EC condition. In controls, increasing AP RMS COP displacement was significantly correlated with more asymmetrical weight-bearing (i.e. decreasing Asymmetry Index) in the EO condition ($r = -0.39$, $p = 0.050$). Scatter plots for these two correlations are shown in Figure 2.

Discussion

Postural Sway and Asymmetry in Stroke

In a recent study using visual feedback, Dault et al. [19] showed frontal plane deficits in postural sway in acute stroke survivors. We found that ML sway was compromised in individuals with chronic stroke and was related to asymmetry. It is possible that greater weight-bearing asymmetry is accompanied by more severe stroke-related impairments (e.g., proprioceptive impairments, muscle weakness) and thus greater postural sway results from these deficits. Niam et al. [20] found impaired ankle proprioception in individuals with chronic stroke resulted in increased sway as measured by COP measures. Additionally, asymmetrical weight-bearing results in greater body mass stacked over one limb, which could lead to greater sway due to the mechanically unstable posture. This is the first study to our knowledge that quantifies the relationship of asymmetric weight-bearing to postural sway in a chronic stroke population. Since correlational studies do not infer causation, further research is needed to evaluate whether changing the symmetry during standing through treatment interventions would lead to reduced postural sway.

Visual Control of Postural Sway

Removing vision had the effect of increasing postural sway. Horizontal optical motion of objects moving in relation to one another on the retina (i.e. motion parallax) may serve to regulate sway [10, 11]. Our results suggest that individuals with stroke may use visual information more heavily, in the medial-lateral control of postural sway, than healthy older adults. Recently, Bonan et al. [21] found AP sway increased in individuals with stroke in standing conditions where visual input was absent or providing conflicting information. However, these researchers did not consider ML sway in their study. The group differences in visual ratios of the sway measures only occurred in the ML direction, which might be explained by the fact that individuals with stroke are more biomechanically compromised in this direction (i.e. unilateral hemiparesis). Increased perceived threat to stability can also induce greater sway [22,23]; however, our participants did not appear fearful or anxious during testing.

Some may argue that the visual ratio indicates a deficit of the residual somatosensory system since it plays a major role in balance [24]. However, while we agree that somatosensory deficits may contribute to increased sway and inappropriate utilization of residual sensory feedback, this may result in compensation with a greater utilization of vision. Recent results from a more complex paradigm, the Sensory Organization Test, have led Bonan et al. [21] to suggest that absent somatosensory information is not sufficient to explain abnormal balance in stroke survivors since AP sway was no different than healthy individuals when somatosensory information was altered. In contrast, using the same paradigm Marigold et al. [25] found increased AP sway in individuals with stroke versus healthy individuals when somatosensory information was altered. However, there was no correlation between cutaneous plantar foot sensation and sway. Although, ankle proprioception and/or plantar foot pressure sensation may be important for controlling sway. Thus, it is not yet clear how somatosensory deficits affect postural sway in individuals with chronic stroke. Additional information regarding sensory and visual deficits is needed to better support our findings and provide a more definitive answer. These issues should be investigated in future studies.

The visual dependence for postural sway may manifest itself from the need to compensate for widespread impairments present in stroke. Integration of sensory cues contributes to the postural body scheme formed by the CNS. In stroke, this postural body scheme may lack appropriate somatosensory information due to altered supraspinal centres. When vision is removed (and visual cues such as motion parallax are no longer available), the body scheme is further compromised (particularly in the ML direction where asymmetry is most prevalent) and increased sway results. Additionally, lower extremity muscle strength is compromised in stroke [26], which may have an interaction with the visual dependence of postural sway and the challenge of the task. For example, quadriceps strength and visual tests (e.g. contrast sensitivity) have been found to be predictors of sway during challenging conditions (standing on foam), but not on firm surfaces in older adults [8].

Although unexpected, the result that individuals with stroke with greater asymmetry relied less on vision than those with mild asymmetry may be explained in part by their standing posture. For example, greater load on a fully extended (or hyper-extended) paretic knee joint in those with severe asymmetry could potentially act as a fixed strut, which might reduce

sway. Still, it is important to note that regardless of the Asymmetry Index, individuals with stroke have greater visual dependence for the control of ML sway than healthy older adults.

A limitation of our visual ratios (EO/EC) is that they may not account for the nonlinear processing of multi-sensory information [27]. However, postural sway with or without vision can be approximately modeled by linear systems [28]. A further limitation of our study was the fact that several participants wore an AFO during testing. It is known that an AFO can reduce sway [16] and thus, there may have been an interaction between the AFO and visual dependency that we did not detect.

In conclusion, increased visual dependence in the ML direction for postural sway was found for individuals with chronic stroke. The increased visual dependence in stroke could be used potentially as a therapeutic tool as the EC task would provide a particularly increased challenge to postural control.

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References

- Shumway-Cook, A., Woollacott, MH. Motor control: theory and practical applications. 2. Philadelphia: Lippincott Williams & Wilkins; 2000.
- Maki BE, Holliday PJ, Topper AK. A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. *J Gerontol A Biol Sci Med Sci*. 1994; 49:M72–M84.
- Sackley CM. Falls, sway, and symmetry of weight-bearing after stroke. *Int Disabil Stud*. 1991; 13:1–4. [PubMed: 1917796]
- Sackley CM. The relationship between weight-bearing asymmetry after stroke, motor function and activities of daily living. *Physio Theory Prac*. 1990; 6:179–185.
- Cheng P-T, Liaw M-Y, Wong M-K, Tang F-T, Lee M-Y, Lin P-S. The sit-to-stand movement in stroke patients and its correlation with falling. *Arch Phys Med Rehabil*. 1998; 79:1043–1046. [PubMed: 9749681]
- Carey LM, Matyas TA, Oke LE. Sensory loss in stroke patients: effective training of tactile and proprioceptive discrimination. *Arch Phys Med Rehabil*. 1993; 74:602–611. [PubMed: 8503750]
- Brooke-Wavell K, Perret LK, Howarth PA, Haslam RA. Influence of the visual environment on the postural stability in healthy older women. *Gerontology*. 2002; 48:293–297. [PubMed: 12169794]
- Lord SR, Menz HB. Visual contributions to postural stability in older adults. *Gerontology*. 2000; 46:306–310. [PubMed: 11044784]
- Turano K, Rubin GS, Herdman SJ, Chee E, Fried LP. Visual stabilization of posture in the elderly: fallers vs. nonfallers *Optom Vis Sci*. 1994; 71:761–769. [PubMed: 7898883]
- Bronstein AM, Buckwell D. Automatic control of postural sway by visual motion parallax. *Exp Brain Res*. 1997; 113:243–248. [PubMed: 9063710]
- Guerraz M, Sakellari V, Burchill P, Bronstein AM. Influence of motion parallax in the control of spontaneous body sway. *Exp Brain Res*. 2000; 131:244–252. [PubMed: 10766276]
- Schenkenberg T, Bradford DC, Ajax ET. Line bisection and unilateral visual neglect in patients with neurologic impairment. *Neurology*. 1980; 30:509–517. [PubMed: 7189256]
- Berg K, Wood-Dauphinee S, William JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can*. 1989; 41:304–311.

14. Gowland C, Stratford P, Ward M, et al. Measuring physical impairment and disability with the Chedoke-McMaster Stroke Assessment. *Stroke*. 1993; 24:58–63. [PubMed: 8418551]
15. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther*. 1987; 67:206–207. [PubMed: 3809245]
16. Mojica JAP, Nakamura R, Kobayahsi T, Handa T, Morohashi I, Watanabe S. Effect of ankle-foot orthosis (AFO) on body sway and walking capacity of hemiparetic stroke patients. *Tohoku J Exp Med*. 1988; 156:395–401. [PubMed: 3245041]
17. Robinson RO, Herzog W, Nigg BM. Use of force platform variables to quantify the effects of chiropractic manipulation on gait symmetry. *J Manipulative Physiol Ther*. 1987; 4:172–176.
18. Thomas JR, Nelson JK, Thomas KT. A generalized rank-order method for nonparametric analysis of data from exercise science: a tutorial. *Res Q Exerc Sport*. 1999; 70:11–23. [PubMed: 10100331]
19. Dault MC, de Haart M, Geurts ACH, Arts IMP, Nienhuis B. Effects of visual center of pressure feedback on postural control in young and elderly healthy adults and in stroke patients. *Hum Mov Sci*. 2003; 22:221–236. [PubMed: 12967755]
20. Niam S, Cheung W, Sullivan PE, Kent S, Gu X. Balance and physical impairment after stroke. *Arch Phys Med Rehabil*. 1999; 80:1227–1233. [PubMed: 10527078]
21. Bonan IV, Colle FM, Guichard JP, Vicaud E, Eisenfisz M, Huy TB, Yelnik AP. Reliance on visual information after stroke. Part I: Balance on dynamic posturography. *Arch Phys Med Rehabil*. 2004; 85:268–273. [PubMed: 14966712]
22. Maki BE, Holliday PJ, Topper AK. Fear of falling and postural performance in the elderly. *J Gerontol*. 1991; 46:M123–31. [PubMed: 2071833]
23. Maki BE, McIlroy WE. Influence of arousal and attention on the control of postural sway. *J Vestib Res*. 1996; 6:53–59. [PubMed: 8719510]
24. Nashner, LM. Computerized dynamic posturography. In: Jacobson, GP, Newman, CW., Kartush, JM., editors. *Handbook of balance function testing*. San Diego: Singular Publishing Group, Inc; 1997. p. 280-307.
25. Marigold DS, Eng JJ, Tokuno CD, Donnelly CA. Contribution of muscle strength and integration of afferent input to postural instability in persons with stroke. *Neurorehabil Neural Repair*. 2004; 18:222–229. [PubMed: 15537993]
26. Eng JJ, Kim CM, MacIntyre DL. Reliability of lower extremity strength measures in persons with chronic stroke. *Arch Phys Med Rehabil*. 2002; 83:322–328. [PubMed: 11887111]
27. Oie KS, Kiemelb Y, Jeka JJ. Human multisensory fusion of vision and touch: detecting non-linearity with small changes in the sensory environment. *Neuroscience Letters*. 2001; 315:113–116. [PubMed: 11716976]
28. Kiemel T, Oie KS, Jeka JJ. Multisensory fusion and the stochastic structure of postural sway. *Biol Cybern*. 2002; 87:262–77. [PubMed: 12386742]

Figure 1. Postural sway during eyes open (EO) and closed (EC) conditions for individuals with stroke (N=28) and healthy older adult controls (N=28). **A:** RMS COP displacement in the AP and ML direction. **B:** RMS COP velocity in the AP and ML direction.

Figure 2.

Scatter plots for the correlation analysis. **A:** correlation between ML RMS COP Velocity and the Asymmetry Index during the eyes open condition for the individuals with stroke ($r = -0.47$, $p = 0.011$). **B:** correlation between AP RMS COP and the Asymmetry Index during the eyes open condition for the healthy older adult controls ($r = -0.39$, $p = 0.050$). Line of best fit has been added to each scatter plot. Note that a negative Asymmetry Index value represents greater weight-bearing on the non-paretic limb for the individuals with stroke.

Table 1

Participant characteristics.

	Stroke (n = 28)	Controls (n = 28)
Gender, M/F	20/8	20/8
Age, yrs	62.1 (8.6)	62.5 (8.4)
Height, cm	166.9 (11.3)	170.1 (9.4)
Mass, kg	76.7 (16.5)	72.8 (14.1)
Time Since Stroke, yrs	4.1 (2.7)	N/A
Hemiparetic Side, R/L	12/16	N/A
Berg Balance Scale, max. 56	46.2 (42.4 – 48.6)	N/A
Chedoke-McMaster Scale		
Foot, max. 7	5 (4 – 6)	N/A
Leg, max. 7	4 (3 – 5)	N/A
Modified Ashworth Scale		
Ankle, max. 4	1 (1 – 1)	N/A

Note:

Values are mean (standard deviation) for age, height, mass, and time since stroke, number for gender and hemiparetic side; and median (IQR) for the Berg Balance, Chedoke-McMaster, and Modified Ashworth scales.

Abbreviations: M = male; F = female; R = right; L = left; N/A = not applicable; IQR = interquartile range.

Table 2

Mean (SD) of the visual ratios (eyes open/eyes closed).

Visual Ratio	Stroke (N = 28)	Controls (N = 28)	P - value
AP RMS COP	0.745 (0.181)	0.723 (0.186)	0.577
ML RMS COP	0.795 (0.254)	0.909 (0.411)	0.394
AP RMS COP Velocity	0.615 (0.154)	0.657 (0.199)	0.614
ML RMS COP Velocity	0.678 (0.193)	0.859 (0.284)	0.012
Asymmetry Index	0.795 (1.376)	1.273 (1.103)	0.294

Note: decreased visual ratio suggests increased dependence on vision

Spearman correlations of quiet standing COP measures versus Asymmetry Index in individuals with stroke (N = 28) and controls (N = 28).

Table 3

Group	Eyes Open	M/L COP	M/L COP Velocity	A/P COP	A/P COP Velocity
Stroke	Asymmetry Index	-0.21	-0.47 ^a	-0.07	-0.10
Control	Asymmetry Index	-0.33	-0.36	-0.39 ^b	-0.34

Group	Eyes Closed	M/L COP	M/L COP Velocity	A/P COP	A/P COP Velocity
Stroke	Asymmetry Index	-0.16	-0.23	0.09	-0.08
Control	Asymmetry Index	-0.18	-0.23	-0.3	-0.26

^a p = 0.011
^b p = 0.050