Clinical Correlates of Between-Limb Synchronization of Standing Balance Control and Falls During Inpatient Stroke Rehabilitation

Avril Mansfield, PhD^{1,2,3}, George Mochizuki, PhD^{1,2,3,4}, Elizabeth L. Inness, MSc^{3,4}, and William E. McIlroy, PhD^{1,2,3,5}

¹Heart and Stroke Foundation Centre for Stroke Recovery, Toronto, ON, Canada

²Sunnybrook Health Sciences Centre, Toronto, ON, Canada

³Toronto Rehabilitation Institute, Toronto, ON, Canada

⁴University of Toronto, Toronto, ON, Canada

⁵University of Waterloo, Waterloo, ON, Canada

Abstract

Background—Stroke-related sensorimotor impairment potentially contributes to impaired balance. Balance measures that reveal underlying limb-specific control problems, such as a measure of the synchronization of both lower limbs to maintain standing balance, may be uniquely informative about poststroke balance control.

Objective—This study aimed to determine the relationships between clinical measures of sensorimotor control, functional balance, and fall risk and between-limb synchronization of balance control.

Methods—The authors conducted a retrospective chart review of 100 individuals with stroke admitted to inpatient rehabilitation. Force plate–based measures were obtained while standing on 2 force plates, including postural sway (root mean square of anteroposterior and mediolateral center of pressure [COP]), stance load asymmetry (percentage of body weight borne on the less-loaded limb), and between-limb synchronization (cross-correlation of the COP recordings under each foot). Clinical measures obtained were motor impairment (Chedoke-McMaster Stroke Assessment), plantar cutaneous sensation, functional balance (Berg Balance Scale), and falls experienced in rehabilitation.

Results—Synchronization was significantly related to motor impairment and prospective falls, even when controlling for other force plate–based measures of standing balance control (ie, postural sway and stance load symmetry).

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Corresponding Author: Avril Mansfield, PhD, Mobility Research Team, Toronto Rehabilitation Institute, 11121–550 University Ave, Toronto, ON M5G 2A2, avril.mansfield@utoronto.ca.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Conclusions—Between-limb COP synchronization for standing balance appears to be a uniquely important index of balance control, independent of postural sway and load symmetry during stance.

Keywords

postural balance; stroke rehabilitation; accidental falls; center of pressure

Introduction

Individuals with stroke have impaired standing balance control compared with age-matched controls.¹ Stroke-related asymmetry of sensorimotor impairment contributes to reduced balance control.² Postural stability poststroke is often assessed by measuring the amplitude or frequency of center-of-pressure (COP) fluctuations during quiet standing on a force plate; however, investigators typically use a single force plate for this measurement.³ Examination of COP excursion under both feet combined does not allow for evaluation of the capacity for each limb to contribute to balance control. Likewise, standardized clinical assessments of functional balance used poststroke, such as the Berg Balance Scale,⁴ primarily involve evaluation of stability in bipedal stance or in postures where the patient can use the less-affected limb to compensate for deficits in the more-affected limb. Although such measures reveal some index of balance ability through adaptive compensation, they do not inform the underlying control, which is essential to track recovery and guide restorative rehabilitation strategies. To this end, recent research has begun to investigate standing balance control poststroke by examining ground reaction forces and COP excursions under each foot separately. These studies have consistently revealed weight-bearing asymmetry, with more weight borne on the less-affected side.^{2,5} Furthermore, previous research has revealed reduced contribution of the more-affected lower limb to standing balance control, with reduced amplitude of COP fluctuations under the paretic compared with the nonparetic limb^{2,6} and increased “regularity” of COP fluctuations under the nonparetic compared with the paretic limb.⁶

A potentially useful measure of bipedal standing balance control is the correlation between COP fluctuations under both feet (Figure 1).⁷ The COP is the point of application of forces and moments under the feet and represents cumulative influence of lower-limb activity to control the center of mass and minimize postural sway.⁸ If the COP under each foot moves in the same direction at the same time, this indicates that these lower-limb activities are synchronized in time. Therefore, the strength of the correlation between COP fluctuations under both feet is thought to indicate between-limb synchronization of actions of both feet to maintain balance.^{7,9,10} Among healthy individuals with no neurological conditions, anteroposterior (AP) COP fluctuations are highly positively correlated and mediolateral (ML) fluctuations are moderately negatively correlated.^{7,9,10} Between-limb correlations in COP fluctuations are lower for individuals with stroke than for healthy controls.¹⁰ Among individuals with stroke, reduced between-limb synchronization was correlated with increased magnitude of postural sway and increased weight-bearing asymmetry.¹⁰ Despite these relationships, we propose that measures of between-limb synchronization, overall postural sway, and weight-bearing symmetry are each independently important measures of

quiet standing balance control poststroke and reveal unique control problems. We believe that between-limb synchronization may be specifically important as an index of poststroke balance control because it reflects impaired challenge of the central nervous system coupling control of 2 limbs to achieve shared control of balance.

The objectives of this study were to determine the relationships between synchronization measures and (1) different indices of force plate measures of balance control (ie, sway and symmetry) and (2) clinical and functional measures. Regarding our first objective, we hypothesized, consistent with previous work,¹⁰ that reduced synchronization would be related to increased postural sway and increased weight-bearing asymmetry as measured using the force plate. Regarding the second objective, it was hypothesized that synchronization would be related to the underlying degree of impairment and to functional measures. The balance system requires both accurate sensation of instability and the ability to execute appropriate motor responses.¹¹ Lower-limb somatosensation, particularly plantar cutaneous sensation, has been shown to be important for balance control,¹² and asymmetry of plantar cutaneous input can alter standing balance control.¹³ Recovery of motor function—or, conversely, motor impairment—poststroke is typically measured using the Chedoke-McMaster Stroke Assessment.¹⁴ Therefore, we hypothesized that reduced between-limb synchronization would be correlated with reduced plantar cutaneous sensation and reduced Chedoke-McMaster Stroke Assessment leg and foot scores. If synchronization is an important index of balance control, it should be related to functional measures; therefore, we examined the relationships between synchronization and functional balance performance (Berg Balance Scale⁴) as well as falls, hypothesizing that reduced synchronization would be related to reduced Berg Balance Scale scores and increased falls. It is also hypothesized that the relationship of synchronization and the clinical/functional measures would be independent of the relationships to postural sway and stance symmetry. The latter would highlight the unique importance of a measure of between-limb synchronization when assessing poststroke balance control.

Methods

Participants

Data for this study were obtained by retrospective chart review of individuals with stroke admitted to Toronto Rehab over a 1-year period ($n = 175$). We included in the review all patients who could stand without physical assistance for at least 30 s and had completed assessment of quiet standing balance on admission to rehabilitation, as described below ($n = 100$). The retrospective review was approved by the institution's research ethics board, and a waiver of patient consent for inclusion in the review was approved.

Measures

Assessments were performed as part of routine clinical care by a trained physiotherapist within 5 days of admission to rehabilitation. Patient data are summarized in Table 1.

Demographic and Clinical Measures

Patients' age, sex, date of stroke onset, stroke type, stroke location, side of paresis, National Institutes of Health (NIH) Stroke Scale scores,¹⁵ Berg Balance Scale scores,⁴ Chedoke-McMaster Stroke Assessment¹⁴ leg and foot scores, and plantar cutaneous sensory thresholds¹⁶ were extracted from clinical charts. The NIH Stroke Scale is an 11-item scale that provides a gross measure of the effects and severity of stroke; a higher score indicates more severe stroke symptoms. The NIH Stroke Scale has shown good intrarater (intraclass correlation coefficient [ICC] = 0.93) and interrater (ICC = 0.95) reliability.¹⁷ The Berg Balance Scale is a 14-item observational rating scale (maximum/normal score = 56) that provides a measure of functional balance and shows good internal consistency (Cronbach's α = .92–.98) and good inter-rater (ICC = 0.95–0.98), intrarater (ICC = 0.97), and test–retest (ICC = 0.98) reliability poststroke.¹⁸ The Chedoke-McMaster Stroke Assessment assigns a score between 1 and 7 according to the level of motor recovery in the foot and leg. Scores have good intrarater (ICCs = 0.94–0.98) and interrater (ICCs = 0.85–0.96) reliability.¹⁴ Scores for both limbs were obtained; if not recorded for the nonparetic limb, then a maximum score of 7 was assumed. Plantar cutaneous sensory thresholds were assessed using monofilaments. The sensory threshold was the thinnest monofilament detected by the patient in at least 2 out of 3 trials at each site on each foot; this method shows good test–retest reliability among individuals with peripheral neuropathy (ICC = 0.96).¹⁹ Two sites were tested: under the fifth metatarsophalangeal joint (5MTP) and the center of the plantar surface of the heel. If a patient could not perceive the thickest monofilament (6.65 log force), then a score of 7 was assigned to allow for inclusion in the analysis. For individuals who were bilaterally affected, the Chedoke-McMaster Stroke Assessment and plantar cutaneous sensory threshold for the worse limb (ie, lower Chedoke-McMaster Stroke Assessment score and higher sensory threshold) was considered to be the “paretic” limb. Falls experienced during inpatient rehabilitation were obtained from incident reports, clinical charts, and patient interviews at discharge from rehabilitation; by obtaining falls information from these 3 sources, we reduced the likelihood that a fall would be missed.²⁰ Individuals who experienced 1 or more falls during inpatient rehabilitation were classified as fallers.

Assessment of Quiet Standing Balance Control

Two force plates (Advanced Mechanical Technology, Inc, Watertown, Massachusetts) were positioned side by side, so that they were as close together as possible without touching (ie, <1 mm apart). Patients stood with 1 foot on each force plate in a standardized position (feet oriented at 14° with 17 cm between the heels²¹), with each foot equidistant from the midline between both plates. Patients were instructed to stand as still as possible for 30 s. Ground-reaction forces and moments were sampled at 256 Hz and were low-pass filtered using a fourth-order dual-pass Butterworth filter at 10 Hz prior to processing. AP and ML COPs were calculated separately for both force plates and under both feet combined.

Stance load symmetry was defined as the mean vertical force recorded by the force plate under the less-loaded limb and was expressed as a percentage of the total mean vertical force recorded by both force plates combined (ie, body weight). The root mean square (RMS) of the AP and ML COP time series was calculated for the total COP under both feet; the RMS provides a measure of the amplitude of postural sway.²² Synchronization of COP motion

between feet was calculated as the cross-covariance of the COP time series under the left and right feet. The mean AP and ML COPs were subtracted from the time series, and the right and left COP were cross-correlated on a point-by-point basis over the entire duration of the trial.^{9,10} The correlation coefficient at time 0 was determined (ρ_0) because COP motion should be synchronized at the same point in time.⁷ Other than subtracting the mean, COP time series were not normalized. Therefore, the correlation coefficient indicates the similarity in the temporal profiles of COP time series, independent of changes in amplitude. The magnitude of ρ_0 was assumed to represent the strength of the synchronization between the 2 limbs. A large positive ρ_0 indicates that the 2 time series are in phase, and a large negative ρ_0 indicates that the 2 time series are antiphased.

Statistical Analysis

Spearman correlation was used to determine the relationship between AP and ML ρ_0 and continuous measures: RMS of ML COP, RMS of AP COP, stance load symmetry, Berg Balance Scale scores, Chedoke-McMaster Stroke Assessment foot and leg scores, and plantar cutaneous sensory thresholds. One-way analysis of variance (ANOVA) was used to determine the differences between fallers and nonfallers. For univariate analysis, α was adjusted using Holm method²³ for 6 multiple comparisons with force plate balance measures (objective 1; $\alpha = .0021$) and 20 multiple comparisons with clinical measures (objective 2; $\alpha = .0024$). Because force plate measures of quiet standing balance control could be related to both synchronization measures and clinical measures,¹⁰ we determined the relationships between AP and ML ρ_0 independent of RMS of ML COP and stance load symmetry with multiple regression; linear regression was used for continuous independent variables, and logistic regression was used for prospective falls. AP or ML ρ_0 , RMS of ML COP, and stance load symmetry were the independent variables, and those clinical measures showing a significant relationship or AP or ML ρ_0 in univariate analysis were the dependent variables. Prior to linear regression, data were rank-transformed to account for the nonnormal distribution of the clinical scales.²⁴ For multivariate analysis, α was .05.

Results

On average, AP ρ_0 was positive and ML ρ_0 was negative, and the magnitude of the correlation coefficients indicated that COP fluctuations under both feet were moderately to highly correlated (mean AP $\rho_0 = 0.77$; mean ML $\rho_0 = -0.56$). Figure 1 shows examples of COP time series with high and low synchronization.

Relationship Between Synchronization and Force Plate Measures of Balance

This study revealed a relationship between measures of synchronization and RMS of ML COP (absolute $r = 0.31$; $P < .0021$) but not RMS of AP COP (absolute $r < 0.17$; $P > .15$; Table 2). The correlations between synchronization and stance load symmetry were not significant using the adjusted α (correlation coefficient for ML $\rho_0 = -0.81$, $P = .068$; correlation coefficient for AP $\rho_0 = 0.23$, $P = .023$).

Relationship of Between-Limb Synchronization and Clinical Measures

Chedoke-McMaster Stroke Assessment foot and leg scores and Berg Balance Scale scores were significantly correlated with AP ρ_0 and ML ρ_0 (absolute $r > 0.29$; P values $< .0024$; Table 2). AP ρ_0 was also significantly different between fallers and nonfallers (fallers: 0.59 ± 0.42 ; nonfallers: 0.81 ± 0.20 ; $P = .0012$; Figure 2).

To determine the independent contribution of limb synchronization, the relationships between clinical and synchronization measures were re-evaluated when controlling for RMS of ML COP and stance load symmetry (Tables 3 and 4). This was conducted to establish if relationships between clinical measures and synchronization were independent of sway and symmetry. In multivariate analysis, both AP ρ_0 and ML ρ_0 were significantly related to Chedoke-McMaster Stroke Assessment foot and leg scores (P values $< .020$). The partial correlations indicate that between 5% and 9% of variability in synchronization measures was accounted for by the Chedoke-McMaster Stroke Assessment scores. Increased AP ρ_0 was also related to reduced probability of experiencing a fall during rehabilitation (odds ratio: 0.10 [0.12, 0.91]; $P = .041$) when controlling for RMS of ML COP and stance load symmetry. In contrast, the relationships between AP ρ_0 and ML ρ_0 and Berg Balance Scale score were no longer significant when controlling for RMS of ML COP and stance load symmetry (P values $> .13$).

Discussion

This study found that reduced between-limb correlations of COP fluctuations under the feet during quiet standing were significantly related to increased motor limb impairment and prospective risk for falls among individuals with stroke. It is important to note that this relationship was independent of other force plate-based measures such as COP sway and symmetry. The correlation between COP fluctuations under the right and left feet while maintaining quiet standing balance has been thought to represent between-limb synchronization of lower-limb motor activity to maintain standing balance.^{7,10} Individuals with stroke were previously found to have poorer between-limb synchronization of balance control than healthy individuals.^{10,25} We found that the synchronization measures were correlated with ML but not AP postural sway, which supports results in our previous work.¹⁰ In spite of these associations, the significant relationships between synchronization and motor impairment and falls persisted even when controlling for ML postural sway and stance load symmetry; therefore, it appears that synchronization is a meaningful measure of standing balance control, independent of stance load symmetry and postural sway. Measures that describe the contribution of each limb to bipedal standing balance are particularly important poststroke² because unilateral impairments may not be exposed with measures that examine performance of both limbs combined. Between-limb synchronization is potentially a useful and informative measure to add to a repertoire of force plate-based measures of standing balance control. The importance of exploring the contributions of both limbs to balance parallels the gait literature, where composite measures of walking that reflect both limbs (eg, velocity) are distinguished from measures indicating individual-limb contributions (eg, symmetry).^{26,27}

The significant relationship between motor impairment and synchronization is not surprising. Despite synchronization in COP fluctuations among healthy young adults, there is little evidence of synchronization in the motor command to each limb⁹; therefore, each lower limb acts independently, in an apparently synchronized manner, to maintain standing balance. Individuals with stroke who have a Chedoke-McMaster Stroke Assessment foot score of 3 or lower have limited active plantarflexion, dorsiflexion, inversion, and eversion. However, these movements are responsible for COP fluctuations under each limb.⁷ Those with Chedoke-McMaster Stroke Assessment foot scores ≤ 3 may not have the capacity in the more-affected limb to generate the necessary forces around the ankle and at the foot to control standing balance, resulting in less-synchronous COP fluctuations. The relationship between motor impairment and asymmetry of lower-limb control of standing balance has been observed previously. Genthon et al found that motor weakness was related to increased weight-bearing asymmetry during quiet standing.² Similarly, Roerdink et al found that COP fluctuations were more “regular” under the nonparetic than the paretic leg but only for those individuals with marked lower-limb motor impairment,⁶ indicating that the nonparetic limb is more actively involved in balance control than the paretic limb.

Synchronization measures were not related to plantar cutaneous sensation. Previous studies among nonstroke clinical populations have found that reduced plantar cutaneous sensation is related to impaired standing balance control.¹² However, among individuals with stroke, there is no correlation between postural sway and plantar cutaneous sensation.²⁸ Despite this previous finding, we expected that asymmetry of sensory impairment might contribute to reduced ability of the lower limbs to work together in a synchronized manner to maintain balance because asymmetrical somatosensory input can alter standing balance control.¹³ Although we did not analyze differences in sensation between the paretic and nonparetic lower limbs, sensory thresholds for the 2 limbs were similar (Table 1). The absence of association is likely linked to the lack of somatosensory impairment among this sample; mean sensory thresholds were actually below those for healthy older adults (65 years old).²⁹ Among a more impaired group, sensation might play a greater role in balance control. Difficulties in administering the plantar cutaneous threshold test to those individuals with cognitive and/or communication impairments limited the analysis of relationships between sensation and synchronization to 72 of the 100 individuals, which might have also contributed to the negative findings. Finally, one might argue that a more comprehensive assessment of sensory function, including measures of ankle proprioception may show a link between synchronization and somatosensation³⁰; these measures were not available in this retrospective review.

Synchronization measures were related to the Berg Balance Scale in univariate analysis but not when controlling for RMS of ML COP and stance load symmetry. This potentially indicates that participants can compensate for unilateral lower-limb motor impairment in order to perform the Berg Balance Scale tasks. The Berg Balance Scale is an index of overall ability rather than a measure of limb-specific dyscontrol because several of the tasks are performed with the non-paretic limb; for example, the unilateral stance item is the “best” score, which is often achieved by standing on the non-paretic limb. The fact that the Berg Balance Scale does not expose the capacity of each limb to contribute to balance control

certainly limits its utility to guide treatment decisions and track recovery among clinical populations who commonly present with unilateral motor deficits, such as stroke.

As has been reported previously,^{7,10} absolute values of the correlation coefficients were greater for AP than ML COP. Changes in AP COP are mostly a result of the actions of ankle plantarflexors and dorsiflexors, whereas ML COP fluctuations under each limb are controlled by invertors and evertors. However, because the invertors and evertors are also involved in plantarflexion and dorsiflexion, there is likely some overlap between AP and ML COP synchronization⁸; the overlap in AP and ML COP changes is also affected by foot orientation.³¹ Additionally, inversion and eversion have little influence on overall ML COP fluctuations, which are controlled primarily by loading and unloading of the limbs.⁷ Therefore, AP ρ_0 may be a more meaningful measure of synchronization than ML ρ_0 . Indeed, we found that AP ρ_0 was related to an increased falls risk but not ML ρ_0 .

This study involved retrospective review of data collected for clinical purposes, and multiple assessors scored patients on the clinical measures such as the Berg Balance Scale and the Chedoke-McMaster Stroke Assessment. Individual scoring biases potentially limited the reliability of the scores of the clinical scales. However, all assessors were trained physiotherapists, with at least 10 years of clinical experience in neurorehabilitation. Furthermore, the Berg Balance Scale¹⁸ and Chedoke-McMaster Stroke Assessment¹⁴ have high interrater reliability when administered to individuals with stroke.

To conclude, this study demonstrated that reduced between-limb correlations in COP fluctuations in quiet standing were significantly correlated with increased motor impairment and increased falls. Between-limb COP correlations appear to be clinically meaningful measures of the degree to which the lower limbs act in a synchronized manner to maintain quiet standing balance.

Acknowledgments

The authors acknowledge Boyd Badiuk, Justues Chang, Tahira Devji, Aimee Dubeau, Lou Biasin, Karen Brunton, Julia Fraser, Shelley Makepeace, and Kira Pattison for their assistance with data collection and analysis.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by the Heart and Stroke Foundation Centre for Stroke Recovery, the Heart and Stroke Foundation of Canada, the Canadian Institutes of Health Research, and the Canadian Stroke Network. We also acknowledge the support of Toronto Rehabilitation Institute, which receives funding under the Provincial Rehabilitation Research Program from the Ministry of Health and Long-Term Care in Ontario. The views contained in this publication are those of the grantees and do not necessarily reflect those of the funding agencies.

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Figure 1.

Sample center of pressure (COP) time series: panels A and B show trials with high synchronization (anteroposterior [AP] $\rho_0 = 0.99$; mediolateral [ML] $\rho_0 = -0.94$), and panels C and D show trials with low synchronization (AP $\rho_0 = -0.02$; ML $\rho_0 = -0.01$). Stance load symmetry is similar for all trials (35%–40% body weight on the right leg).

Figure 2.

Comparison of synchronization measures between fallers and nonfallers: values illustrated are means with standard deviation error bars. The P value is for the 1-way ANOVA comparing groups within each variable. The comparison marked with an asterisk was investigated further in multivariate analyses (adjusted $\alpha = .0024$; Table 4). Abbreviations: ML, mediolateral; AP, anteroposterior.

Table 1

Demographic and Stroke Information, and Results of Sensorimotor and Balance Tests for Individuals Included in the Review^a

	Mean/Number	Standard Deviation	Minimum	Maximum
Age, y	66.9	14.9	26	94
Gender, n				
Female	39			
Male	61			
Time poststroke, d	22.9	23.5	4	122
Stroke type, n				
Ischemic	73			
Hemorrhagic	20			
Transforming to hemorrhagic	6			
Unknown	1			
Affected hemisphere, n				
Right	26			
Left	49			
Both	25			
Affected side of body, n				
Right	54			
Left	31			
Both	13			
No paresis	2			
NIH Stroke Scale, score ¹⁵	3.5	3.0	0	14
Berg Balance Scale, score ⁴	36.9	14.6	8	56
Chedoke–McMaster Stroke Assessment, score ¹⁴				
Leg score, paretic ^b	4.8	1.3	2	7
Foot score, paretic ^b	4.5	1.4	1	7
Leg score, nonparetic ^b	6.7	0.8	3	7
Foot score, nonparetic ^b	6.6	1.0	3	7
Plantar cutaneous sensory threshold, log force ^c				
5MTP, paretic ^b	4.39	0.82	3.22	7
Heel, paretic ^b	4.71	0.90	3.61	7
5MTP, nonparetic ^b	4.28	0.70	3.22	7
Heel, nonparetic ^b	4.72	0.92	3.61	7
Fallers, n				
No	80			
Yes	20			
Quiet standing balance				
ML ρ_0 , correlation coefficient	−0.56	0.35	−0.95	0.61

	Mean/Number	Standard Deviation	Minimum	Maximum
AP ρ_0 , correlation coefficient	0.77	0.27	-0.55	0.99
RMS of ML COP, mm	4.6	3.5	0.86	25.3
RMS of AP COP, mm	6.7	2.8	2.3	17.2
Stance load symmetry, percentage body weight	43.5	5.8	20.0	49.9

Abbreviations: 5MTP, fifth metatarsophalangeal joint; AP, anteroposterior; COP, center of pressure; ML, mediolateral; NIH, National Institutes of Health; RMS, root mean square.

^aMean, standard deviation, minimum, and maximum are presented for continuous data. The number of individuals in each category is presented for count variables.

^bFor individuals who were bilaterally affected, the “paretic” side was the side with worse motor recovery (ie, lower Chedoke–McMaster Stroke Assessment scores) or with reduced plantar sensation (ie, increased sensory threshold).

^cBecause of difficulties in administering this test to individuals with cognitive and/or communication impairments, data are only available for 72 individuals.

Table 2Correlations Between Synchronization and Clinical and Standing Balance Measures^a

	ML ρ_0	P Value	AP ρ_0	P Value
Force plate balance measures				
Quiet standing balance				
RMS of ML COP	0.31	.0020*	-0.31	.0016*
RMS of AP COP	-0.051	.61	0.16	.12
Stance load symmetry	-0.18	.068	0.23	.023
Clinical measures				
Berg Balance Scale	-0.30	.0023*	0.36	.0003*
Chedoke-McMaster Stroke Assessment				
Leg score, paretic	-0.38	.0001*	0.41	<.0001*
Foot score, paretic	-0.40	<.0001*	0.43	<.0001*
Leg score, nonparetic	0.13	.21	-0.038	.71
Foot score, nonparetic	0.14	.18	-0.067	.51
Plantar cutaneous sensory threshold				
5MTP, paretic	0.014	.91	0.049	.68
Heel, paretic	0.036	.76	0.090	.45
5MTP, nonparetic	-0.11	.38	0.049	.68
Heel, nonparetic	-0.038	.75	0.037	.76

Abbreviations: 5MTP, fifth metatarsophalangeal joint; AP, anteroposterior; COP, center of pressure; ML, mediolateral; RMS, root mean square.

^aValues presented are Spearman correlation coefficients with associated *P* values. Comparisons marked with an asterisk were investigated further in multivariate analyses (force plate balance measures, $\alpha = .0021$; clinical measures, adjusted $\alpha = .0024$; see Table 3).

Table 3**Results of Multiple Linear Regression^a**

	Direction of the Relationship	Partial R^2	P Value
Berg Balance Scale			
Intercept	+		.62
ML ρ_0	–	0.024	.13
RMS of ML COP, mm	–	0.14	.0002
Stance load symmetry, percentage body weight	+	0.057	.018
Berg Balance Scale			
Intercept	+		.77
AP ρ_0	+	0.022	.15
RMS of ML COP, mm	–	0.094	.0022
Stance load symmetry, percentage body weight	+	0.049	.028
Chedoke-McMaster Stroke Assessment, leg score, paretic			
Intercept	+		.49
ML ρ_0	–	0.079	.0051*
RMS of ML COP, mm	–	0.10	.0026
Stance load symmetry, percentage body weight	+	0.034	.067
Chedoke-McMaster Stroke Assessment, leg score, paretic			
Intercept	+		.68
AP ρ_0	+	0.056	.019*
RMS of ML COP, mm	–	0.056	.020
Stance load symmetry, percentage body weight	+	0.025	.12
Chedoke-McMaster Stroke Assessment, foot score, paretic			
Intercept	+		.68
ML ρ_0	–	0.064	.012*
RMS of ML COP, mm	–	0.087	.0032
Stance load symmetry, percentage body weight	+	0.046	.033
Chedoke-McMaster Stroke Assessment, foot score, paretic			
Intercept	–		.90
AP ρ_0	+	0.090	.0027*
RMS of ML COP, mm	–	0.034	.071
Stance load symmetry, percentage body weight	+	0.033	.072

Abbreviations: ML, mediolateral; RMS, root mean square; COP, center of pressure; AP, anteroposterior.

^aRMS of ML COP and stance load symmetry were included in the models to investigate the relationships between each clinical measure and synchronization measures independent of magnitude of postural sway and asymmetry. Significant relationships are marked with an asterisk ($\alpha = .05$).

Table 4**Results of Multiple Logistic Regression^a**

	Estimate	Odds Ratio	P Value
Intercept	−5.8		.035
AP ρ_0	−2.3	0.10 [0.012, 0.91]	.041 *
RMS of ML COP, mm	0.26	1.3 [1.0, 1.6]	.019
Stance load symmetry, percentage body weight	0.11	1.1 [1.0, 1.3]	.060

Abbreviations: AP, anteroposterior; ML, mediolateral; RMS, root mean square; COP, center of pressure.

^aRMS of ML COP and stance load symmetry were included in the model to investigate the relationships between falls and synchronization independent of magnitude of postural sway and stance load symmetry. Significant relationships are marked with an asterisk ($\alpha = .05$).