Inter-observer Reliability and Concurrent Validity of Reactive Balance Strategies after Stroke

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ABSTRACT: **Background:** Falls are a common complication in persons with stroke (PwS). Reliable assessment of balance responses to unexpected loss of balance has the potential to identify risk for falls.

Objectives: To examine inter-observer reliability of balance responses to unannounced surface perturbations in PwS and to explore the concurrent validity of a balance recovery assessment protocol.

Methods: Two observers evaluated balance recovery strategies and fall threshold (a fall into a harness system) in 15 PwS and 15 healthy adults who were exposed to forward, backward, right, and left unannounced surface translations in six increasing intensities while standing.

Results: Observer agreement was 100% for the fall threshold. Kappa coefficients for step strategies were 0.960–0.988 in PwS and 0.886–0.938 in healthy adults, 0.905–0.988 for arm reactions in PwS and 0.754–0.926 in healthy adults. Significant correlations were found between fall threshold and Berg Balance Scale (r = 0.691), 6-minute walk test (r = 0.599), and fall efficacy scale-international (r = -0.581).

Conclusions: A trained examiner can reliably classify reactive balance responses to surface perturbations. The high frequency of falls observed in PwS highlights the importance of assessing reactive balance responses to different directions and intensities of surface translations.

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KEY WORDS: compensatory step, falls, fall threshold, step threshold

Falls are a leading cause of serious injury and loss of independence among persons with stroke (PwS) [1,2]. Although many factors have been linked to falls, a critical factor that determines whether a fall occurs is the ability to respond effectively to unexpected loss of balance or balance perturbations [3]. Depending on size and speed, external perturbations can elicit two distinct classes of strategies for reactive balance recovery. The fixed support strategies (e.g., ankle, hip, or arm lift) or change in support strategies induce reactive compensatory steps or grasp [3]. Studies have documented characteristics of reactive stepping performances that were associated with falls in the elderly, namely initiating compensatory stepping responses at lower levels of instability (lower step threshold) [4,5], failing to recover equilibrium [3], and taking multiple balance recovery steps rather than a single step response [6]. Multiple step response is a strong predictor for falls in older adults [7].

Recent studies have documented substantially impaired reactive balance responses in PwS [8-10]. These responses were characterized by the need for assistance, inability to initiate a step, high frequency of multiple step response, and falls into a harness system [8,11]. Most studies with PwS have focused on the control of balance responses to forward and backward perturbations. However, lateral perturbations involve different biomechanical demands than forward or backward perturbations, especially in PwS with unilateral hemiparesis. In addition, the fact that PwS tend to fall toward the paretic side [12,13] highlights the importance of studying these reactions in response to multidirectional perturbations.

Among the most commonly used clinical instruments to assess balance and fall risk in PwS are the Berg Balance Scale (BBS) [14], the Timed Up and Go [15], and the Balance Evaluation Systems Test [16]. However, these assessment instruments are limited, especially in assessing the ability to recover from unexpected loss of balance. Assessing balance recovery abilities using a movable platform provides a high level of unpredictability of perturbations, similar to unexpected loss of balance that frequently lead to falls in real life. The timing, intensity, and direction of perturbations are unexpected, making it less likely that participants could adjust their response. Using a video camera for the assessment of balance recovery responses and balance capacity in PwS may be a simple and a sensitive tool. An excellent inter-observer reliability of balance recovery responses, especially step and multiple step thresholds were previously found for older adults [17]. To the best of our knowledge, this is the first report of a fall threshold that may be a direct measure for balance capacity and fall risk in PwS. In this study, fall threshold was defined as the perturbation intensity that results in unsuccessful balance recovery such as when a subject is being unambiguously supported by the harness system [9,18]. Reliable assessment of balance responses to perturbations and fall threshold in particular, may potentially be used for clinical and research-related assessment of reactive balance capacity in PwS.

We explored the inter-observer reliability and validity of an assessment protocol that exposes PwS and healthy adults to unannounced surface translations while standing. In addition, we examined the feasibility and safety of a perturbation protocol paradigm. We hypothesized that the suggested protocol of reactive balance assessment would demonstrate high inter-observer reliability. Since existing clinical examinations do not examine the ability to recover from unexpected loss of balance we also hypothesized that fall threshold would demonstrate a fair to good association with existing clinical examinations for balance and mobility in PwS. In addition, we hypothesized that the protocol would be feasible and safe for PwS.

PATIENTS AND METHODS

A convenience sample of 15 PwS was recruited from the department of neurological rehabilitation at Loewenstein Rehabilitation Hospital, Raanana, Israel. Fifteen age-matched healthy adults were recruited through fliers. Participants had to be able to stand for at least 2 minutes and to walk independently or under supervision with or without a walking aid. Exclusion criteria included neurological disorders in addition to stroke, significant musculoskeletal conditions, and significant visual impairment. Participants signed a written informed consent in accordance with approved procedures by the Helsinki Ethics Committee, Loewenstein Rehabilitation Hospital (#LOE-14-0021).

STUDY PROTOCOL AND OUTCOME MEASURES

Participants stood on a computerized treadmill system with a horizontal movable platform (Balance Tutor, MediTouch, Israel), wearing a safety harness that prevented falls but did not restrict their movements. They were instructed to stand with feet placed together and to react naturally to prevent themselves from falling in response to random unannounced forward, backward, right- and left-surface translations. Surface translations were increased in six intensities from low to high for a total of 24 perturbations. In this study perturbation direction refers to the direction of the platform translation. In case of a fall into the harness, the participant did not continue to a higher intensity. Seated rest breaks were given between trials if needed. Participants performed all trials wearing their own shoes and foot orthosis in case they needed ankle support.

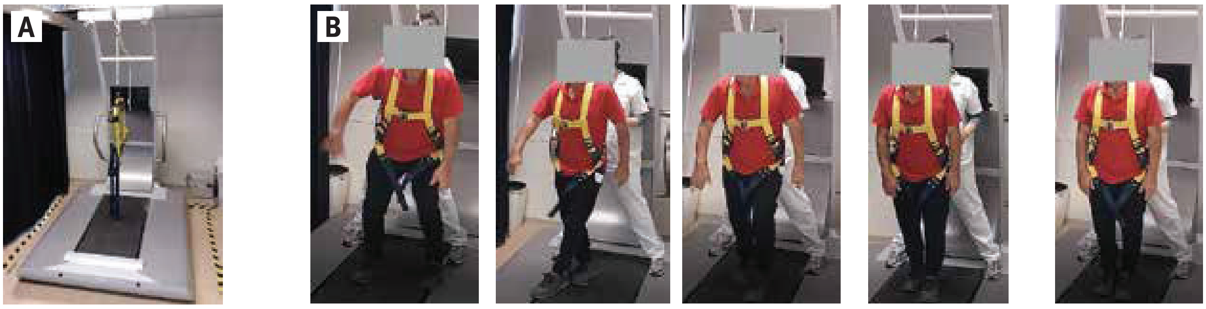
Prior to reactive balance control assessment, PwS underwent clinical assessment including the lower extremity Fugl-Meyer (LEFM), Berg Balance Scale (BBS), 6-minute walk test (6MWT) and fall efficacy scale–international (FES-I).

Two video cameras were placed at an angle of 45°, 4 meters in front of the treadmill. Balance outcomes were evaluated by two experienced physical therapists (SH, FSH). The observers were blinded to each other's assessment, reviewed the videos separately and determined fall threshold and balance recovery strategies. If necessary, videos were viewed in slow motion. Strategies in response to forward-backward unannounced surface translations were classified as fixed base of support, single step response, and multiple step response (> 1 step). These groups were sub-grouped according to traditional/hopping/pivoting [9]. Upper limb strategies for forward-backward surface translations were classified as no movement, lifting one arm, and lifting both arms. Strategies for lateral surface translations were classified as fixed base of support (BOS); base-width neutral step (BNS), in which the step does not extend BOS; unloaded leg side step, which extends the BOS width in the opposite direction of the falling center of mass; loaded-leg side step where the limb passively loaded by the disturbance is utilized to extend the BOS; crossover step (COS), in which the limb passively unloaded by perturbation crosses in front of or behind the stance leg to extend the BOS; and side-step sequence (SSS), in which a short medial step with the unloaded leg is followed by a large lateral step with the contralateral leg to extend the BOS [6]. Upper limb movements for lateral surface translations were classified as no movement; perturbation direction arm lift, in which the arm in the direction of the surface translation is abducted to a greater extent than the contralateral arm [19]; and perturbation opposite direction arm lift, in which the arm in the opposite direction of the surface translation is abducted to a greater extent than the contralateral arm; and two arms lift. The experimental setup and upper and lower body strategies are shown in Figure 1. In addition, fall threshold, defined as the minimum surface translation intensity that elicits a fall into harness system, was investigated. Each of the 625 unannounced surface translation trials was evaluated for either a fall or a successful response. Each successful response was evaluated for a lower body and an upper body strategy.

STATISTICAL ANALYSIS

Statistical analyses were performed using IBM Statistical Package for the Social Sciences statistics software, version 24 (SPSS, IBM Corp, Armonk, NY, USA).The level of agreement among the two observers, namely Cohen's Kappa coefficient and a 95% confidence interval (95%CI) for Kappa were determined. Kappa values of 0.41–0.60 indicate moderate agreement, 0.61–0.80 indicated substantial agreement, and 0.81–1.0 indicated almost perfect or perfect agreement [20]. Inter-tester agreement was determined for fall threshold, as well as lower and upper limb strategies. Concurrent validity of balance recovery parameter was evaluated through the association between fall thresholds to the performance-based clinical measures, BBS, 6MWT, and FES-I using Spearman's correlation coefficients (r). Correlation strength was estimated as absent to low (r = 0.00–0.25), low (r = 0.26-0–49), moderate (0.50–0.69), high (0.70–0.89), or

Figure 1. Experimental setup for reactive balance control assessment
[A] A harness system prevented ground contact in the event of unsuccessful response. **[B]** Lower and upper body balance recovery strategies by direction of surface translations demonstrated by a person with stroke (right hemiparesis)



Perturbation direction	←	→	↑	↑	↓
Lower body strategy	LLSS	COS	Single step	Single step	FBS
Upper body strategy	PDAL	PDAL	2AL	No arm movement	No arm movement

COS = crossover step, FBS = fixed base of support, LLSS = loaded leg side step, PDAL = perturbation direction arm lift, 2AL = two arms lift

very high (0.90–1.00) [21]. Descriptive statistics were used to characterize balance recovery strategies in PwS and in healthy adults. A *P* value < 0.05 was considered statistically significant.

RESULTS

Fifteen sub-acute PwS and 15 healthy age-matched individuals participated in the study. All PwS had a unilateral stroke, 14 of them with hemisphere brain damage and 1 with damage in the posterior fossa structures above the pyramidal decussation. The demographic characteristics of the participants are summarized in Table 1.

There was no adverse event or report of any discomfort during or post trials. The healthy participants performed 359 unannounced perturbation trials while the PwS performed 266 trials due to falls into the harness system. One of the trials in the healthy participants group was not recorded due to technical issues. Classification of strategies for each trial took between 30 seconds and 2 minutes.

There was a 100% agreement between observers for fall threshold and falls were not observed in the healthy group. However, 11 PwS (73%) fell at least once in response to perturbations for a total of 14 falls. Among failed responses, 64.3% (9/14) occurred during lateral surface translations, and 5 of them occurred during surface translation toward the non-paretic side. Among the falls, 35% (5/14) occurred in response to forward or backward surface translations, mostly (4/5) in forward surface translations. Most falls were at a moderate-high intensity of surface translations and multiple step responses were taken prior to all falls.

The observers agreed completely regarding the occurrence or non-occurrence of a step response in the PwS group and for 356 of the 359 responses to perturbations in the healthy control group (agreement rate 99.1%, Kappa coefficient 0.968, 95%CI 0.915–1.00, *P* < 0.001). Observers agreed on classification of step pattern to lateral surface translation in 121 of the 125 responses in PwS (Kappa coefficient 0.960, 95%CI 0.918–0.991, *P* < 0.001) and in 163 of the 179 responses observed in the healthy control group (Kappa coefficient 0.886, 95%CI 0.831–0.934, *P* = 0.001). Among the agreed balance response strategies in the PwS group, the unloaded leg side step was the most frequently observed step strategy (observed in 40% of responses) and fixed base of support (observed in 24% of responses), and the COS (observed in 14% of responses) were less frequent. Among the agreed strategies in the healthy control group the unloaded leg side step, COS and loaded-leg side step were observed in 25%, 22%, and 20% of responses, respectively. Most disagreements were for the SSS strategy mainly in controls. Regarding upper body responses to lateral surface translations the Kappa coefficient for the PwS group was 0.905, 95%CI 0.836–0.961, *P* < 0.001 and 0.754, 95%CI 0.663–0.836, *P* < 0.001 for the healthy control group. The most common upper body response observed in the PwS group was the two-arm lift response (51/125 agreed responses) and in the healthy control group was perturbation direction arm lift response, observed in 82/179 agreed responses [Table 2]. Most disagreements in controls were on the perturbation direction arm lift response.

Regarding surface translations to forward-backward directions, observers agreed on the pattern of balance response for 126/127 (Kappa coefficient 0.988, 95%CI 0.957–1.000, *P* < 0.001) in the PwS group and for 173/180 responses in the healthy control group (Kappa coefficient 0.938, 95%CI 0.884–0.982, *P* < 0.001). Of the 173 agreements in the healthy control group, single step was seen most frequently (in 75 of the agreed responses), and of the 126 agreements in the PwS

Table 1. Characteristics of stroke and healthy participants

Subject	Sex	Age (years)	Height (cm)	Weight (kg)	Time since stroke (days)	Stroke side, type	Assistive device	Orthosis	LEFM	BBS	6MWT (m)	FES-I
1	M	48	165	87	103	R, H	Quadripode	AFO	Missing	34	150	41
2	M	59	170	75	30	R, H	None	None	34	56	515	18
3	M	56	170	72	103	R, I	Walker	None	31	36	422	28
4	M	66	164	64	61	L, H	Crutches	Eight band	32	46	382	22
5	F	57	163	64	73	R, I	Walker	None	33	34	180	59
6	M	59	167	74	47	L, H	None	None	33	50	523	33
7	M	52	168	98	71	R, I	Cane	AFO	27	39	208	48
8	M	72	174	79	43	L, I	Walker	Eight band	28	40	244	21
9	M	61	160	73	40	L, I	None	None	34	56	555	18
10	M	55	164	65	63	R, I	Walker	AFO	27	38	236	28
11	F	74	160	69	58	R, I	Walker	None	34	40	262	22
12	M	62	168	71	18	L, I	Walker	None	34	55	Missing	18
13	M	65	175	81	17	R, H	Walker	None	30	46	351	17
14	M	57	168	70	46	R, I	Walker	Eight band	27	34	195	46
15	M	68	160	78	60	L, I	Walker	Eight band	16	12	90	60
Totals												
Stroke mean ± SD (range)	F = 2 M = 13	60.1 ± 6.9	172.1 ± 5.6*	78.4 ± 11.8	62 ± 21.27	L=6 I=10 R=9 H=5	Walker n=9 Crutches n=1 Quadripode n=1 Cane n=1 None n=3	AFO n=3 Eight band n=4 None n=8	31.5 (16–34)	40 (12–56)	308.1 ± 150.2*	28 (17–60)
Healthy Control (n=15) mean ± SD	F=2 M=13	60.7 ± 7.2	166.4 ± 4.7*	74.8 ± 9.1			None = 15	None = 15				

*$P < 0.05$

AFO = ankle foot orthosis, BBS = Berg balance scale, F = female, FES-I = fall efficacy scale-international, H = hemorrhagic, I = ischemic, L = left, LEFM = lower extremity Fugl-Meyer, M = male, R = right, 6MWT = 6-minute walk test

Table 2. Level of agreement, Kappa coefficient and 95% confidence interval of reactive balance strategies to lateral surface perturbations in healthy adults (n=15) and in persons with stroke (n=15)

Pattern		Healthy			Stroke		
		Observer 1	Observer 2	Agreement	Observer 1	Observer 2	Agreement
Lower body response	Fixed base of support	21	22	21	31	30	30
	BNS	2	5	2	1	0	0
	Unloaded leg side step	48	54	46	51	54	51
	Loaded leg side step	41	41	37	16	16	15
	COS	44	40	40	18	18	18
	Side-step sequence	23	17	17	8	7	7
Kappa coefficient (95%CI)		0.886 (0.831–0.934)			0.960 (0.918–0.991)		
Upper body response	No arm movement	30	28	27	27	26	26
	2 arm lift	43	63	41	53	57	51
	Perturbation direction arm lift	104	85	82	40	36	34
	Opposite perturbation direction arm lift	2	3	2	5	6	5
Kappa coefficient (95%CI)		0.754 (0.663–0.836)			0.905 (0.836–0.961)		

BNS = base-width neutral step, 95%CI = 95% confidence interval, COS = crossover step

Table 3. Level of agreement, Kappa coefficient and 95% confidence interval of reactive balance strategies to forward and backward surface perturbations in healthy adults (n=15) and in persons with stroke (n=15)

Pattern		Healthy			Stroke		
		Observer 1	Observer 2	Agreement	Observer 1	Observer 2	Agreement
Lower body response	Fixed base of support	32	33	32	27	27	27
	Single step	79	78	75	35	34	34
	Multiple step (traditional)	69	69	66	64	65	64
	Multiple step (hopping)	0	0	-	1	1	1
Kappa coefficient (95%CI)		0.938 (0.884–0.982)			0.988 (0.957–1.000)		
Upper body response	No arm movement	47	44	43	47	46	46
	2 arm lift	124	126	122	64	65	64
	1 arm lift	9	10	9	16	16	16
Kappa coefficient (95%CI)		0.926 (0.859–0.9777)			0.988 (0.956–1.000)		

95%CI = 95% confidence interval

group, multiple step strategy was observed in most cases (in 65 agreed responses). For upper body responses to forward-backward surface translations the Kappa coefficient was 0.988, 95%CI 0.956–1.000, $P < 0.001$ and 0.926, 95%CI 0.859–0.977, $P < 0.001$ for PwS and the healthy control groups respectively. The most common upper body response observed in both groups was the two arm response (70% in the healthy control group and 50% in the PwS group) [Table 3].

CONCURRENT VALIDITY

Significant positive correlations were found between fall threshold to the BBS and 6MWT ($r = 0.691$, $P < 0.01$ and $r = 0.599$, $P < 0.05$, respectively). Significant negative correlation was found between fall threshold and FES-I ($r = -0.581$, $P < 0.05$).

DISCUSSION

The results of this study demonstrate the feasibility and safety of exposing PwS to increased intensities of surface perturbations to forward, backward and lateral directions. We showed that experienced physical therapists can reliably classify reactive balance responses to unannounced surface translations.

We found 100% agreement on fall threshold between observers. Falls were not observed in healthy adults but were observed in 73% of stroke participants. Similar results were reported by Inness et al. [11] who observed failed response or multiple step (≥ 3 steps) responses seen in 71% (99/139) of PwS ready to discharge from rehabilitation settings, and by Salot et al. [10] who showed that 71.4% (10/14) of chronic PwS experienced a fall in response to large magnitude slip like perturbation. However, these studies did not examine fall threshold and focused only on one direction of perturbation. In our study, 64% of falls were in response to lateral perturbations. These findings are in accordance with previous studies showing an increase in mediolateral postural sway in PwS during quiet stance and reduced lateral stability when assessing limits of stability compared to age-matched controls [22,23]. Falls in response to forward and backward perturbations were more frequently observed in response to forward perturbations in accordance with a previous study in PwS [24]. Frequencies of falls among PwS were reported in a different study as a response to backward surface translations, although the perturbation intensities in that research were much higher than ours [9]. Participants in both studies were more than one year after stroke.

We found almost perfect agreement on stepping strategies in perturbations to all four directions. Inter-observer reliability in all measures was higher for PwS than healthy participants. This finding may be a result of PwS exhibiting similar responses to different perturbation intensities in most cases, so it was easy to detect. The unloaded leg side step strategy was most commonly observed in both groups in response to lateral perturbations. There is conflicting evidence regarding the frequency of using COS strategy vs. SSS strategy in response to lateral perturbations in older adults compared with young adults [6,25] In our study, most PwS fell at perturbation magnitudes where COS strategy and SSS strategy were usually observed in healthy controls. However, the fact that all falls in response to lateral direction involved either COS or SSS strategy with multiple steps indicates difficulty in controlling mediolateral balance with these strategies as perturbation intensity increases.

We also found almost perfect agreement for arm reaction classification to forward and backward surface translations for both groups and to lateral translations in PwS. Only substantial agreement was found in the healthy adult group in response to lateral perturbations. The main disagreement was on perturbation direction arm lift response. This response is characterized by lifting the arm in the direction of surface translation. It was often observed with a smaller response in the opposite arm which might be classified as a two arm lift response.

The higher correlation between fall threshold to BBS (r = 0.691) than between fall threshold to 6MWT (r = 0.599) suggests that fall threshold has a better potential to assess balance tasks requiring balance control (defined as a task specific multi-joint skill that includes the interaction of several physiological systems), than assessing long distance walking performance (6MWT), which is related to endurance (defined as the capacity to walk long distance). Not surprisingly FES-I was negatively correlated with the fall threshold (r = - 0.581). A greater fear of falls in PwS was associated with a low fall threshold, which is a lower ability to recover from unexpected loss of balance without falling. This finding suggests that PwS are capable of accurately perceiving their balance recovery abilities and are afraid of losing balance and falling.

CONCLUSIONS

The high inter-observer reliability indicates that experienced physical therapists can reliably classify fall threshold as well as step and arm strategies in response to surface translations in PwS and in healthy adults. Analyzing strategies using video clips could be a simple and inexpensive assessment to detect severity of balance recovery impairments in PwS. This assessment could be used with other populations at increased risk for falls such as Parkinson's disease, traumatic brain injury, and multiple sclerosis patients. These findings provide insight into the complexity of balancing during unpredicted loss of balance. Of particular importance is the fall threshold that could be used as a more direct measure for balance capacity and to measure a change of the balance capacity as a result of intervention. Moreover, it can be used for identifying the intensity and direction of perturbation that challenges the patient when planning perturbation-based balance training.

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References

1. Masud T, Morris RO. Epidemiology of falls. *Age and aging* 2001; 30 (4): 3-7.
2. Tsur A, Segal Z. Falls in stroke patients: risk factors and risk management. *IMAJ* 2010; 12: 216-9.
3. Maki BE and McIlroy WE. Postural control in the older adult. *Clin Geriatr Med* 1996; 12 (4): 635–58.
4. Wolfson LI, Whipple R, Amerman P, Kleinberg A. Stressing the postural response: a quantitative method for testing balance. *J Am Geriatr Soc* 1986; 34 (12): 845-50.
5. Mille ML, Rogers MW, Martinez K, et al. Thresholds for inducing protective stepping responses to external perturbations of human standing. *J Neurophysiol* 2003; 90 (2): 666–74.
6. Maki BE, Edmondstone MA, McIlroy WE. Age-related differences in laterally directed compensatory stepping behavior. *J Gerontol* 2000; 55 (5): M270–7.
7. Hilliard MJ, Martinez KM, Janssen I, et al. Lateral balance factors predict future falls in community-living older adults. *Arch Phys Med Rehabil* 2008; 89: 1708-13.
8. de Kam D, Roelofs JMB, Bruijnes AKBD, Geurts ACH, Weerdesteyn V. The next step in understanding impaired reactive balance control in people with stroke: the role of defective early automatic postural responses. *Neurorehabil Neural Repair* 2017; 31 (8): 708-716.
9. Honeycutt C, Nevisipour M, Grabiner MD. Characteristics and adaptive strategies linked with falls in stroke survivors from analysis of laboratory-induced falls. *J of biomechanics* 2016; 49 (14): 3313-9.
10. Salot P, Patel P, Bhatt T. Reactive balance in individuals with chronic stroke: biomechanical factors related to perturbation-induced backward falling. *Phys Ther* 2016; 96 (3): 338-47.
11. Inness EL, Mansfield A, Lakhani B, Bayley M, McIlroy WE. Impaired reactive stepping among patients ready for discharge from inpatient stroke rehabilitation. *Phys Ther* 2014; 94 (12): 1755-64.
12. Mackintosh SFH, Goldie P, Hill K. Falls incidence and factors associated with falling in older, community-dwelling, chronic stroke survivors (>1 year after stroke) and matched controls. *Aging Clin Exp Res* 2005; 17: 74-81.
13. Hyndman D, Ashburn A, Stack E. Fall events among people with stroke living in the community: circumstances of falls and characteristics of fallers. *Arch Phys Med Rehabil* 2002; 83: 165–70.
14. Maeda N, Kato J, Shimada T. Predicting the probability for fall incidence in stroke patients using the Berg Balance Scale. *J Int Med Res* 2009; 37 (3): 697-704.
15. Flansbjer UB, Holmback AM, Downham D, Patten C, Lexell J. Reliability of gait performance tests in men and women with hemiparesis after stroke. *J Rehabil Med* 2005; 37 (2): 75-82.
16. Chinsongkram B, Chaikeeree N, Saengsirisuwan V, Horak FB, Boonsinsukh R. Responsiveness of the balance evaluation system test (BESTest) in people with subacute stroke. *Phys Ther* 2016; 96 (10): 1638-47.
17. Batcir S, Sharon H, Shani G, et al. The inter-observer reliability and agreement of lateral balance recovery responses in older and younger adults. *J Electromyogr Kinesiol* 2018; 40: 39-47.
18. Marigold DS and Eng JJ. Altered timing of postural reflexes contributes to falling in persons with chronic stroke. *Exp Brain Res* 2006; 171 (4): 459-68.
19. Hurt CP, Rosenblatt NJ, Garbiner MD. Form of the compensatory stepping response to repeated laterally directed postural disturbances. *Exp Brain Res* 2011; 214 (4): 557-66.
20. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977; 33 (1): 159-74.
21. Domholdt E. Rehabilitation Research Principles and Applications. 3rd edn. St. Louis: Saunders, 2005.
22. Marigold DS, Eng JJ. The relationship of asymmetric weight-bearing with postural sway and visual reliance in stroke. *Gait & Posture* 2006; 23 (2): 249-55.
23. Nichols DS. Balance retraining after stroke using force platform biofeedback. *Phys Ther* 1997; 77 (5): 553-8.
24. Marigold DS, Eng JJ, Inglis TJ. Modulation of ankle muscle postural reflexes in stroke: influence of weight-bearing load. *Clin Neurophysiol* 2004; 115 (12): 2789-97.
25. Mille ML, Johnson ME, Martinez KM, Rogers MW. Age-dependent differences in lateral balance recovery through protective stepping. *Clin Biomech* 2005; 20 (6): 607–16.

"Understanding is a two-way street"

Eleanor Roosevelt (1884–1962), American political figure, diplomat, and activist, served as first lady of the United States during her husband's four terms as president