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Repeatability and minimum detectable change of margin of stability for post-stroke patients

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Background, Motivation and Objective. The risk of falls is larger among post-stroke individuals in comparison to healthy ones at the same age (10.1053/apmr.2002.28030). A possible way to evaluate the risk associated with different gait patterns is applying the dynamic stability analysis (10.1098/rsif.2012.0999). In fact, it has been shown that the margin of stability (MoS) is a good indicator of the risk of falls among post-stroke individuals (10.1016/j.clinbiomech.2013.10.010; 10.1016/j.gaitpost.2014.05.014), particularly in the anterior-posterior direction (0.2340/16501977-2234). The MoS is defined by the distance between the extrapolated center of mass (XCoM) and the limits of the base of support. The XCoM is a concept based on the inverted pendulum model, which takes into account the position and velocity of the center of mass (CoM) (10.1016/j.jbiomech.2004.03.025). Therefore, the MoS is a potentially useful clinical measure that could be employed to evaluate the effect of therapeutic interventions on the risk of falls in. To do so, it is necessary to know the repeatability and minimal detectable change of this measure, which, our knowledge, has not been determined for post stroke patients. Thus, the aim of this study was to determine the repeatability and the MDC of MoS during gait in post-stroke individuals.

Methods. Five hemiparetic patients (age 51.2±4.3 years; 4 men; right side hemiparesis; with time after stroke of 6.4±4.3 months) participated in two gait assessment sessions within an interval of 2 to 7 days. They were instructed to walk barefoot at a self-selected speed, along a walkway for 6 trials. Six infrared cameras (Motion Analysis Corporation, Santa Rosa, CA) at 60 Hz were used to capture the landmarks coordinates (Helen Hayes Marker Set). The data were low-pass filtered with a cut-off frequency of 6 Hz using a fourth-order Butterworth filter. Subsequently, CoM position was calculated (10.1016/0021-9290(95)00178-6). The MoS in anterior-posterior direction (MoSap) was calculated by the distance between the XCOM position and the front toe marker, at the foot initial contact. The XCoM position was calculated according to Hof (10.1016/j.jbiomech.2004.03.025), considering the pendulum length as the maximum CoM height during quite standing (10.1016/j.gaitpost.2014.05.014). Within-session repeatability was obtained from the intraclass correlation coefficient (ICC) among the trials 2, 3 and 4 (average of 3 values) of each session. The Friedman test was applied to identify differences among the trials within one session. Between-session repeatability was estimated by the ICC from the average of that nine values of each session. MDC was calculated from the equation: $1{,}96*\sqrt{2}*(SD*\sqrt{(1-ICC)})$. The paretic lower limb (PLL) and non-paretic lower limb (NPLL) were considered for analysis. Matlab (R2013) was used for data processing, and the IBM SPSS (v.21.0) for statistical analysis.

Results. The variance analysis showed no significant differences between the mean values of MoSap calculated for trials 2, 3 and 4 in none of the sessions, for PLL and NPLL ($p > 0.05$). The

mean results and the within-session ICC of MoSap for PLL and NPLL are shown in Table 1. The between-sessions ICC and MDC are 0.934; 6.4cm and 0.952; 3.6cm for PLL and NPLL, respectively.

Discussion and Conclusions. This is the first study to determine the repeatability and MDC of a dynamic stability parameter during gait of post-stroke hemiparetic individuals. In general, the reliability was moderate (between 0.40-0.74) and excellent (above 0.75) (10.1002/bimj.4710300308). The 3 MoSap average have satisfactory repeatability. In fact, gait assessments with up to 5 trials are considered sufficient to achieve good reproducibility (10.3233/NRE-172195). MoS is directly influenced by gait velocity and foot placement (10.1016/j.jbiomech.2004.03.025), which are parameters that show high variability in post-stroke individuals due to the typical kinematic pattern of this population. When comparing the limbs, the within-session reliability of the PLL was greater than that of the NPLL, what is in accordance with the literature which shows that the NPLL may assume more flexible behaviors that make it possible to correct and compensate PLL actions (10.3233/NRE-172195). Other studies also showed kinematic differences in the two hemibodies (10.1589/jpts.28.2634; 10.1016/j.gaitpost.2016.07.149). MoSap presented excellent inter-session reliability for both limbs. These results are relevant for sample characterization as well as outcome measures and indicate that MoSap is a parameter that may be used to determine changes in response to intervention programs designed to improve gait and reduce the fall risk in post-stroke hemiparetic individuals. In addition, this preliminary result is encouraging and the study will be conducted to identify whether such findings remain for a greater number of subjects.

Table 1. MoSap (cm) values obtained from the two assessment sessions and within-session ICC.

		Subjects											
												Within-session ICC	
	Trials	A		B		C		D		E			
		PLL	NPLL	PLL	NPLL	PLL	NPLL	PLL	NPLL	PLL	NPLL	PLL	NPLL
Session 1	2	-5.8	-15.0	-23.1	-10.7	7.1	6.9	-16.2	0.8	-8.6	-2.0		
	3	-4.0	-5.4	-16.1	0.2	13.7	13.6	-20.1	-7.2	-8.9	-6.5	0.914	0.703
	4	-8.3	-12.3	-19.7	-10.3	-3.1	1.8	-18.3	-1.4	0.9	10.0		
	Mos_9	-6.0	-10.9	-19.6	-6.9	5.9	7.5	-18.2	-2.6	-5.6	0.5		
Session 2	2	-7.3	-10.7	-8.1	-0.6	4.2	4.1	-13.6	0.3	2.9	10.7		
	3	1.4	1.9	-1.5	1.1	12.9	8.1	-19.6	2.9	-10.0	-2.3	0.845	0.627
	4	-4.2	-8.4	-15.4	-8.5	-0.4	5.9	-17.8	-4.2	6.9	3.1		
	Mos_9	-3.4	-5.7	-8.4	-2.6	5.5	6.0	-17.0	-0.4	-4.7	3.8		

Note: PLL: paretic lower limb; NPLL: non-paretic lower limb; MoS_9: mean of 9 values.

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Keywords. Reproducibility; Stroke; Dynamic stability; Gait; Fall risk.