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Static and dynamic impairment following stroke reflecting hemispheric asymmetry for postural control

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ABSTRACT. This paper evaluates whether there is a relationship between postural control and hemispheric asymmetry following a stroke. Twenty right or left brain-damage patients and ten healthy control subjects were included in this study. The static (weight symmetry) and dynamic posture (velocity, maximal excursion and the directional control of the center of mass) were analyzed by quantitative posturography. Factors such as clinical neurological assessment, postural skills, muscle strength, spasticity, sensitivity and hemineglect were also collected. Results showed that in static posture, right-brain-damaged patients had worse performance. In the dynamic tests, left-brain-damaged patients were selectively impaired on maximal excursion and the directional control of the center of mass, while right-brain-damaged patients were more impaired on movement velocity. The results show specific mechanisms for modulating posture depending on the damaged side. These findings support the idea that each hemisphere contributes differently to static and dynamic postural control.

Keywords: posture, functional laterality, stroke.

Influência da assimetria hemisférica pós AVC no controle postural estático e dinâmica

RESUMO. O objetivo deste trabalho foi avaliar se existe relação entre o controle postural e a assimetria hemisférica após acidente vascular cerebral (AVC). No total, vinte pacientes com danos cerebrais à direita ou à esquerda e dez controles saudáveis foram incluídos neste estudo. A postura estática (simetria e peso) e dinâmica (velocidade e excursão máxima de controle direcional do centro de massa) foram analisadas por posturografia quantitativa. Fatores como avaliação clínica, neurológica, habilidades posturais, força muscular, espasticidade, sensibilidade e heminegligência também foram analisados. Os resultados mostraram que, na postura estática, os pacientes com AVC direito tiveram pior desempenho. Nos testes dinâmicos, observou-se que os pacientes com AVC à esquerda foram prejudicados seletivamente na excursão máxima e no controle direcional do centro de massa, enquanto os pacientes com lesão à direita tiveram pior desempenho na velocidade de movimento. Os resultados mostraram mecanismos específicos para a modulação da postura, dependendo do hemisfério afetado. Estes dados suportam a ideia de que cada hemisfério contribui diferencialmente para o controle postural estático e dinâmico.

Palavras-chave: postura, lateralidade funcional, acidente vascular cerebral.

Introduction

Postural disorders represent a common impairment after a stroke, with a substantial impact on the functional capacities and on the independence of daily tasks of survivors (KISSELA et al., 2009). Because of acquired deficits, there is an asymmetric weight bearing over the affected or unaffected lower limbs (MARTINS et al., 2011; ROUGIER; GENTHON, 2009).

Studies that investigate the relationship between postural control and hemispheric specialization present conflicting results. Some studies demonstrate that patients have better recovery whenthe lesion occurs to the left of the balance and postural control (ROUGIER; GENTHON, 2009). Other studies indicate that the right hemisphere is more specialized in controlling the mechanisms linked to posture, such as trunk movement and weight-bearing over the lower limbs (SPINAZZOLA et al., 2003), and still other studies have not found a relationship between the lesion side and the adopted posture after a stroke (YAVUZER et al., 2001). Furthermore, most investigations assess this relation only in regards to the static posture, and only a few studies mention the dynamic posture analysis (BENAIM et al., 1999; TEIXEIRA-SALMELA et al., 2000). Some studies involving lower limbs state that the planning and motor control employ bihemispheric nets through projection from the corpus callosum. During the chronic stage in stroke however, these cortico-cortical connections can be reduced with greater functional connectivity in the intact hemisphere (GENTHON et al., 2008; SCHAEFER et al., 2007). Considering this motor lateralization model, our hypothesis is that there must be a similar pattern in the lower limbs with a functional differentiation between the right and left hemispheres in the static and dynamic postural control.

Thus, the aim of the present study was to analyze each hemisphere contribution related to the postural control and to verify whether there were differences in the participant's performance during the adopted postural pattern (static or dynamic).

Material and methods

Design

A prospective observational study was conducted, ex post facto, with individuals aged 40 to 65 years old, selected by accessibility. The groups were split into patients who suffered stroke in the right hemisphere (RH), and left hemisphere (LH), compared to healthy control individuals (CG), and all of them were paired by sex and age. The Institutional Ethics Committee approved this study. All participants gave written informed consent before data collection began.

Participants

Upon admission, all patients were submitted to a clinical neuropsychological assessment and to a standard neurological exam. Neurological assessment was based on the National Institute of Health Stroke Scale (NIHSS) (BROTT et al., 1989). For the Control Group, a Cumulative Illness Research Scale (CIRS) was applied to guarantee the participation of healthy individuals in this group (FORTIN et al., 2011).

For diagnostic criteria, ICD-10 (International Statistical Classification of Diseases and Related Health Problems*)* was used and data was obtained from medical records and Functional Magnetic Resonance Imaging (fMRI). All patients were recruited from the Public Health System for treatment of hemiparesis or hemiplegia after a stroke in the acute stage. The following brain regions were examined: frontal, parietal, temporal, corona radiata and internal capsule.

Exclusion criteria were hemorrhagic stroke, recurring, extensive cerebral lesion, incapability of completing the interview and assessment due to serious aphasia, psychiatric dysfunctions, orthopedic diseases, unable to give informed consent, unconsciousness or use of drugs that modulate activity of the central nervous system. To be included in this study, participants in both groups had to have a minimum tolerance of 30 minutes in the standing position and be able to sit in a chair of standard height (45 to 50 cm) without assistance.

Outcome measures

The postural abilities were assessed using the Postural Assessment Scale for Strokes (BENAIN et al., 1999), with scores ranging from 0 to 36 (good postural control). The muscular strength of lower limbs was assessed by the Medical Research Council (MRC) scale (O'BRIEN, 1989), which ranged from 0 (no contraction) to 5 (normal strength). The spasticity was assessed through the Ashworth scale, a 6-point scale in which the spasticity is assessed from no increase in the muscular tonus (0 points) to a rigid state (5 points) (ASHWORTH, 1964). Sensibility was assessed by Semmes-Weinstein monofilament (BELL-KROTOSKI; TOMANCIK, 1987). Hemineglect was assessed through the Bell Cancellation test (GAUTHIER et al., 1989). The symmetry measures were estimated through the Balance Master System (BMS), version 8.0.393, which allows for assessing multiple dimensions of balance through some static and dynamic tests. The tests applied in this study were Weight Bearing Squat and the Limits of Stability (LOS).

The Weight Bearing Squat test was used to assess the weight symmetry in orthostatic position, quantified by the corporal weight distribution supported by each lower limb with the knees completely extended (0° of extension measured by a goniometer). Values over 100 indicate that the right leg bears more weight, thus values under 100 indicate that it is the left leg which bears more.

Regarding the LOS test, the parameters used in this study were Movement Speed (MS), Maximum Excursion (ME), Directional Control (DC), and Corporal Mass (CMC) in right and left directions. The peripheral targets are positioned in the 100% difficulty level of LOS, calculated by the equipment based on the participant's height.

Every individual went through a maximum 5-minute period to become familiar with the movements in order to guarantee registering their balance ability in a consistent and representative manner. Regarding the dynamic tests, the participants were able to reach each of the eight targets presented in a random sequence during the familiarization period.

Data analysis

The individual dependent measures were analyzed using Split-Plot ANOVA, with side (left or right) and group (healthy control or hemisphere-damaged) with between-subject factors and task (static or dynamic) as the within-subject factor. Post-hoc analyses were performed using the Bonferroni test. Finally, effect sizes were calculated using Cohen's d, with correction of Hedge's g. Student's t-test was used for paired comparisons.

Results and dicussion

Flow of participants through the study

Only cases that met the inclusion criteria were selected. Therefore, 20 patients who had suffered a stroke (10 in each hemisphere, RH and LH), and 10 healthy control individuals (CG) participated in this study. Among the eligible subjects, the socio-demographic characteristics did not significantly differ, as demonstrated in Table 1.

Table 1. Personal data of the participants.

Characteristics	CG	LH	RH
Age (yr), mean (SD)	49.4 (5.3)	48.3 (2.1)	49.5 (5.1)
Gender, n males (%)	5 (50)	5 (50)	6 (60)
Height (m), mean (SD)	1.70 (0.06)	1.70 (0.10)	1.68 (0.13)
Weight (Kg), mean (SD)	69.1 (2.4)	68.7 (1.3)	68.1 (1.7)

CG: Control Group; LH = left-brain-damaged patients; RH = right-brain-damaged patients. No significant differences were found between groups.

Regarding the clinical assessment, significant differences were found among the participants in the following scores: NIHSS, $F (1, 27) = 19.15$, $p = 0.01$; posture, $F (1, 27) = 8.78$, $p = 0.02$; and spasticity $F (1, 27) = 13.16$, $p = 0.02$, as demonstrated in Table 2. Such differences are in reference to the neurological and functional impairment, typical after a vascular lesion.

Table 2. Results obtained at the neurological assessment by the participants.

Test score	CG mean (SD)	LH mean (SD)	RH mean (SD)
NIHSS (0 - 75)	0.27 (0.09)	6.41 (0.44)*	6.34 (0.56)*
CIRS (0 - 4)	0.1 (0.01)	N/A	N/A
Posture (0 - 36)	34.8 (0.76)	24.3 (3.78)*	26.4 (2.61)*
Strength (0 - 5)	4.8 (0.05)	3.5 (0.95)	3.3 (1.23)
Spasticity (0 - 5)	0.0	2.1 (1.48)*	2.3 (1.90)*
Hypoesthesia (1.65 - 6.65 mg)	6.3 (0.02)	5.1 (1.85)	5.3 (1.29)
Hemineglect (0 - 35 omissions)	1.7 (0.04)	2.9 (0.60)	2.6 (0.23)

NIHSS = National Institute of Health Stroke Scale; CIRS = Cumulative Illness Rating Scale; CG = control group; LH= left-brain-damaged patients; RH = right-brain-damaged patients; N/A= Not Applicable; *$p < 0.05$.

Weight symmetry – Static Control

The weight symmetry averages were practically the same for the right and left sides in the CG [100.2 (0.7)] and in LH patients [103.7 (0.4)], while the greater deviations were found in RH patients [65.4 (2.5)].

Therefore, a noteworthy interaction between the direction of movement (to the left and right), and group (healthy individuals or with hemispheric lesion) was verified, $F (1,27) = 25.17$, $p = 0.03$, $\eta^2 = 0.38$. Post-hoc comparisons revealed that patients with damage in the right hemisphere had a greater tendency to shift their weight to the contralateral side (to the right), $t (8) = 9.21$, $p = 0.02$, $d = 1.11$. In contrast, LH patients presented similar symmetry indices for the weight between the right and left limbs, $t (8) = 0.42$, $p = 3.10$, $d = 0.11$. Thus, damage in the right hemisphere but not in the left may produce specific deficits in weight symmetry when compared to the performance of healthy individuals.

Limits of stability – Dynamic Control

In all the dynamic tests, the profile of participants from control group was equivalent, not considering whether the tests were performed to the right or to the left. LH patients had worse performance in the speed test, and RH patients in the further tasks (excursion and directional control) as can be verified in Table 3.

Table 3. Limits of stability tests in terms of velocity, excursion and directional control.

Variables	CG mean (SD)	LH mean (SD)	RH mean (SD)
Velocity			
Left	3.4 (1.4)	1.8 (1.1)*	0.7 (0.4)*
Right	3.1 (0.8)	1.6 (0.9)*	0.9 (0.2)*
Excursion			
Left	84.7 (4.9)	21.9 (2.4)*	40.1 (0.2)*
Right	91.2 (6.1)	18.8 (0.7)*	59.7 (3.5)*
Directional Control			
Left	75.4 (3.2)	19.8 (1.6)*	44.3 (3.6)*
Right	90.1 (2.7)	15.6 (1.9)*	54.1 (0.8)*

CG = control group; LH= left brain-damaged patients; RH = right brain-damaged patients; *$p < 0.05$.

Concerning the speed test, a group effect was observed, $F (1, 27) = 41.15$, $p = 0.02$, but no directional effect, $F (1, 27) = 7.08$, $p = 0.52$. The interaction effect between Group x Direction was statistically significant, $F (1, 27) = 27.19$, $p = 0.03$, $\eta^2 = 0.37$. Later analysis demonstrated that LH patients presented higher average speed in relation to the others groups, concerning the left side, $t (8) = 11.29$, $p = 0.01$, $d = 1.03$, and the right side, $t (8) = 8.76$, $p = 0.01$, $d = 0.97$.

Regarding the excursion test, the healthy volunteers achieved a higher percentage than the patients group, again demonstrating a group effect, $F (1, 27) = 37.95$, $p = 0.03$, however, no direction effect, $F (1, 27) = 2.14$, $p = 0.63$. There was an interaction between these two factors, $F (1, 27) = 36.20$, $p = 0.01$, $\eta^2 = 0.41$. The analysis of simple effects showed that RH patients had worse indices in the movements towards the left side, $t (8) = 12.03$, $p = 0.01$, $d = 1.93$, and the right side, $t (8) = 10.25$, $p = 0.01$, $d = 1.05$.

Lastly for the directional control, the analysis revealed a group effect, $F (1, 27) = 59.80$, $p = 0.03$, but no directional effect, $F (1, 27) = 2.23$, $p = 1.70$, with the interaction representing 47% of total variance, $F (1, 27) = 23.18$, $p = 0.02$, $\eta^2 = 0.47$. Again, in this item the RH patients presented a worse performance in the control executed to the left, $t (8) = 21.41$, $p = 0.02$, $d = 3.39$, and to the right, $t (8) = 18.63$, $p = 0.03$, $d = 2.46$.

Discussion

The study confirms the hypothesis that static and dynamic postural control after a stroke varies according to the affected hemisphere. It was verified that patients with a lesion in the right hemisphere present more impairments in most static and dynamic activities. These flaws could be related to these patients' abilities to modulate specific mechanisms responsible for postural control.

Therefore, these findings support the idea that asymmetric deficits due to stroke could be attributed to different contributions from the left and right hemispheres in postural control. This is congruent to previous studies that have emphasized that right-brain-damaged patients are more impaired and less capable of recovering an independent gait, an independent position, or a seated posture (PÉRENNOU et al., 2000; TITIANOVA; TARKKA, 1995).

Regarding the static posture, data show that lesions in the right hemisphere produce greater impairment; therefore, these patients have the tendency to shift the body weight to the contralateral hemiparesis, as verified by other research (LAUFER et al., 2003). Nevertheless, it should be observed that weight asymmetry does not explain the postural deficit by itself, as the difference between both feet is not only related to weight control, but also to the trajectories of the center of pressure (IKAI et al., 2003).

According to Spinazzola et al. (2003), there could be a specific system to code the postural representation. Such a system could refer to unconscious devices, coding the environment in terms of left and right spaces, interacting with a spatial exploration mechanism, and/or being more lateralized in the right side of the brain. Thus, the deficits in static postural responses after a lesion in the right hemisphere would be present due to possible damage in this postural representation system.

In reference to dynamic posture, right-brain-damaged patients achieved lower averages during excursion and control for both the right and left side when compared to those with a lesion to the left and the volunteers in the control group. This presentation could be related to the perceptive control made through sensorial feedback, in which the right hemisphere would primarily make the modulation. In fact, previous studies have attributed spatial errors in these patients to perceptive deficits (BOHANNON et al., 1986; GURFINKEL et al., 1988).

According to Michel et al. (2003), sensory information processing has been attributed to the right parietal cortex. More specifically, the temporoparietal area has been pointed to as being responsible for contributing to the composition of intern models, resolution of sensory ambiguity, and combining afferent and efferent information.

In opposition to most studies which indicate that patients with right-side hemiparesis presented a faster recovery from the functional and ambulatory abilities (KALRA et al., 1993; SAEKI et al., 1994), in the present study the patients with left-side damage presented greater speed during movements, both to the right and to the left. Based on these data, it is assumed that the combination of minor stabilization at the end of the movement (with little directional control as a consequence) and more facility to move the center of body weight would diminish the level of complexity over the intentional movements for these patients. As an alternative, the central nervous system could try to take advantage of the high speeds during voluntary disturbance to allow for the approach of stability limits, thereby affecting performance less.

Conclusion

The study presents some methodological limitations. First, the number of participants was relatively small, which can limit the statistical control of the results. Furthermore, the lack of a long-term control measure does not enable for determining whether the deficits observed are maintained in the other stages of stroke, in sub-acute and chronic patients.

Nonetheless, the great contribution of this study should be highlighted. The obtained data reveal systematic difference in the static and dynamic postural control after a stroke. Such difference is related to the damage in the right and left hemispheres, and it reflects a specialization for the control of characteristics aside from the movement. More research is necessary to determine how these deficits can affect functional activities and the ipsilesional limb, in addition to which therapeutic strategies could be used to improve patient recovery. Therefore, considering these factors together with the development of specific treatment protocols may have a positive effect throughout these patients' recoveries.

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