ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 12, n. 2, p. 113-20, mar./abr. 2008

Comparative study on the relationship between stroke hemisphere and functional evolution in right-handed individuals

Estudo comparativo entre a relação do hemisfério acometido no acidente vascular encefálico e a evolução funcional em indivíduos destros

Voos MC[1], Ribeiro do Valle LE[2]

Abstract

Objective: The left hemisphere is supposed to be dominant for motor control and the right hemisphere dominant for spatial orientation. This study aimed to test the hypothesis that left-side lesions cause greater impairment of voluntary movement, while right-side lesions cause loss of spatial attention loss and postural control. Individuals with left-side lesions were compared with individuals with right-side lesions, in relation to initial impairment and recovery three months after their stroke. **Methods:** Twenty-two right-handed individuals with an ischemic lesion in the area of the middle cerebral artery (11 on the left side and 11 on the right side) were assessed monthly, for the first three months after their stroke, in terms of sensitivity, tonus, posture, gait, functional independence and spatial attention. **Results:** In relation to the initial impairment, there was no difference in sensitivity, tonus, strength, posture and spatial attention between the groups. The left-side lesion group presented worse initial performance in gait and functional independence tests. In relation to the recovery rate, there were no differences in sensitivity, tonus, strength, posture, spatial attention or functional independence between the two groups. However, the gait recovery rate in the left-side lesion group was slower than in the other group. **Conclusions:** The hypothesis that left-side lesions cause greater impairment of voluntary movement (represented by gait and functional independence) than do right-side lesions was supported. However, no evidence that right-side lesions cause greater impairment of spatial attention and posture maintenance than do left-side lesions was found.

Key words: stroke; rehabilitation; functional laterality; gait.

Resumo

Objetivo: O hemisfério esquerdo é dominante para o controle motor e o direito para a orientação espacial. Este estudo visou testar as hipóteses de que a lesão à esquerda causa maior prejuízo da movimentação voluntária e a lesão à direita resulta em perda na atenção espacial e no controle postural. Indivíduos com lesão à esquerda foram comparados com indivíduos com lesão à direita, com relação ao comprometimento inicial e recuperação três meses pós-lesão. **Materiais e métodos:** Vinte e dois indivíduos destros com lesão isquêmica no território da artéria cerebral média (11 à esquerda e 11 à direita) foram avaliados mensalmente nos três primeiros meses pós-lesão em termos de sensibilidade, tônus, força, postura, marcha, independência funcional e atenção espacial. **Resultados:** Com relação ao comprometimento inicial, não houve diferença na sensibilidade, tônus, força, postura e atenção dos grupos. O grupo com lesão à esquerda apresentou pior desempenho inicial nos testes de marcha e de independência funcional. Com relação à taxa de recuperação, não houve diferenças na sensibilidade, tônus, força, postura, atenção e independência funcional dos dois grupos. Porém, a taxa de recuperação da marcha do grupo com lesão à esquerda foi inferior à do outro grupo. **Conclusões:** Foi confirmada a hipótese de que a lesão à esquerda causa maior comprometimento da movimentação voluntária, representada pela marcha e independência funcional, que a lesão à direita. Não foi obtida, no entanto, evidência de que a lesão à direita compromete de modo mais intenso a atenção espacial e a manutenção da postura que a lesão à esquerda.

Palavras-chave: acidente cerebrovascular; reabilitação; lateralidade funcional; marcha.

Received: 04/05/2007 – **Revised:** 14/09/2007 – **Accepted:** 23/11/2007

[1] Department of Physical Therapy, Fonoaudiologia e Terapia Ocupacional, Faculdade de Medicina, Universidade de São Paulo (USP) – São Paulo (SP), Brazil
[2] Physiology Department, Instituto de Ciências Biomédicas, USP
Correspondence to: Mariana Callil Vôos, Rua Cipotânea, 51, Faculdade de Fisioterapia, Cidade Universitária, CEP 05360-160, São Paulo (SP), e-mail: marivoos@usp.br

Introduction

The clinical characteristics that result from a cerebrovascular accident (CVA) have been extensively studied. It is known that CVA is highly debilitating and that after injury, many individuals depend on some kind of assistance for months or years, or even for their entire life[1,2]. Injury location and size have a strong influence on its clinical evolution[3], and the differences in the functional consequences of right and left hemispheric CVAs are of particular interest.

Besides severe language dysfunctions, patients with left hemispheric injuries tend to demonstrate a greater frequency of apraxias[4,5]. Motor activities that require planning are more related to the left hemisphere and are therefore more affected after left hemispheric injuries[4]. As the majority of activities of daily living involve complex motor sequences, it is possible to suppose that performance of these activities will be more affected in patients with left hemispheric injuries, especially because of the alterations in motor responses observed after CVA (hemiparesis), therefore, part of the movement sequence would need to be reprogrammed for activities of daily living.

Difficulties in activities of daily living would be additionally aggravated in right-handed patients with left injuries as they would not be able to count on their dominant extremity, especially during the beginning of the recovery period, when the strength deficit is more pronounced. In healthy individuals, the dominant upper extremity is superior to the non-dominant extremity in tasks that that demand velocity, precision, coordination[6], muscle resistance[7] and prehensile strength[8]. Therefore, it is possible to suppose that impairments of the dominant upper extremity would be most detrimental for activities of daily living compared to impairments on the non-dominant side, with the result of greater performance losses in right-handed individuals with left hemispheric injuries and right-side hemiparesis.

Some studies have reported that patients with left CVA demonstrate inferior performance on daily living activities during the first month of recovery, as measured by functional independence scales (Functional Independence Measure and the Barthel Index)[9,10]. Other studies that investigated this issue, however, did not find such performance differences.

Clinical practioners frequently have the impression that the functional recovery of patients with left-side CVA is worse than the recovery of patients with right-side CVA, however, no experimental confirmation of this idea has been found. Some authors describe poorer recovery of symmetry and velocity in sit-to-stand movements in these types of patients[14], however, results are difficult to interpret because patients with sensory deficits and hemineglect were excluded from the studied samples. Other authors report a slightly inferior performance recovery, as measured by the Functional Independence Measure, two months after left hemispheric injury[10].

The functional impact of injuries to the right hemisphere is also considerable. Patients with such injuries, initially demonstrate body image deficits, neglect of the extracorporeal space opposite to the side of the injury[15,16] and visuomotor deficits[17,18]. Initially, there is greater weight-bearing on the non-affected side of the body and postural alignment is affected[19].

Hemineglect and the consequent lack of recognition of functional losses on the opposite side of the body could constitute a particularly important obstacle to functional recovery of patients with injuries in the right hemispheric. The lower demands for use of the non-dominant upper extremity in daily activities compared to the dominant upper extremity would be an additional factor to interfere with recovery. This would reduce the motivation of the patient to try to use the affected extremity, leading to its maintenance of neglect. One study reported poorer recovery of postural stability while standing[20] and two other studies reported inferior recovery of the ability to sit without support and the presence of trunk compensations for stability in these patients[21,22]. Additionally, there are some studies describing inferior recovery of functional independency, as measured by the Barthel Index, in patients with right hemispheric injuries[23,24], however, these reported differences were not observed in other studies[11,12].

The reported findings indicate some consistencies in the literature regarding the specificity of some deficits caused by injuries to the left and right hemispheres, but also point out some disagreement in regard to the specificity of other deficits. Such disagreements could result from the considerable variability of injury magnitude and location. In fact, the lack of careful control of those variables in many studies indicates the need for cautious interpretation of their results. Care is even more important in face of the lack of control of hand dominance of the studied patients[5,9,10,14,21,23,24], the exclusion of patients with dysphasia[22,24,25] and hemineglect[14]. These procedures obviously limit the conclusions that can be drawn from the referred studies. A careful characterization of functional deficits demonstrated by patients with left and right hemispheric injuries is certainly important from the clinical standpoint, since this could assist the clinician to select the most appropriate therapeutic interventions for the rehabilitation of each of the two types of patients.

The objective of the present study was to systematically investigate the similarities and differences in the functional deficits initially produced by injuries to the left and right hemispheres. In addition, the respective rates of recovery after the CVA were examined with careful control of the local and magnitude of the injuries for the dominant side of the body in a sample that included patients with both dysphasia and hemineglect. Only individuals who suffered an obstruction of the main stem of the middle cerebral artery (MCA) were

included in the study, as such an obstruction is the most common cause of CVAs. All individuals underwent assessments of sensory functions, muscle tone, muscle strength, postural control, gait, functional independence and spatial attention over the first three moths after injury.

Because the left hemisphere plays a lager role in motor behavior[4, 5, 26], it was hypothesized that patients with left hemispheric injuries would demonstrate greater initial deficits and slower recovery of the motor functions of gait and functional independence after injury assessed in this study. On the other hand, because the right hemisphere plays a larger role on spatial orientation[17,19,27] and posture[21], it was hypothesized that patients with right hemispheric injuries would demonstrate greater deficits and slower recovery rates of the postural and spatial attention functions after injury.

It is important to emphasize that no studies were found that compared the rate of recovery of sensory functions, muscle strength, postural control, functional independence and spatial attention between individuals with right and left hemispheric injuries attending Brazilian rehabilitation services. The low educational level of most of the individuals using these services, as well as the socio-cultural differences regarding care were considered. For example, one must consider institutionalization in developed countries *versus* home care and attendance to outpatient services in Brazil, which could lead to different findings from those described for the populations in developed countries. Additionally, no studies that investigated the recovery of all those functions in the same group of patients were found in the literature. The Research Ethics Committee of the University Hospital of the Universidade de São Paulo approved this study.

Methods

Initial screening resulted in the selection of 68 patients diagnosed with ischemic CVA in the University Hospital of the Universidade de São Paulo for possible participation in the present study. A specialized physician with experience in the technique and who had no knowledge of the objectives of the study, analyzed computerized tomography exams of the patients. Only those cases with similar injury magnitudes which involved the areas supplied by the MCA, including the motor area, somatosensory cortex and sensoriomotor association areas were selected, along with the Broca and Wernicke areas in the left hemisphere, and the putamen, caudate, globus pallidus, internal capsule and corona radiata.

Eighteen individuals were excluded because they did not undergo computerized tomography over the first 48 to 72 hours after injury, thus impeding the adequate assessment of the magnitude of the injury. Twenty-two other individuals were excluded because the injury magnitude was either considerably smaller or greater than the mean values, or the local of the injury did not correspond to the inclusion criteria. Three other patients were excluded because they were left-handed, according to their scores on the Edinburgh Questionnaire[28]. The study sample was thus comprised of 25 right-handed individuals, of whom 22 concluded the study. Two individuals discontinued participation and one died during the study course.

Eleven of the 22 participants were male. All individuals had been diagnosed with an ischemic CVA involving the MCA area. All participants reported an absence of auditory or visual alterations or previous neurological diseases, and eleven individuals had right hemispheric injuries. Although all individuals with left hemispheric injuries demonstrated difficulties in verbal comprehension, they were all able to understand the instructions given by the examiner during the assessments.

Functional performance was assessed with the following scales: the Medical Research Council, which classifies muscular strength into grades that vary from zero to five and is frequently used in clinical practice; the Postural Assessment Stroke Scale[29], which assesses maintenance and change of postures from lying on one's side to single limb stance; the Functional Ambulation Classification[30], which classifies the amount of assistance needed for ambulation on a scale from zero to four; and the Barthel Index[31], which assesses functional independence during performance of activities of daily living. The Star Cancellation Test[32] assesses the ability to perceive visual stimuli and was also used to assess spatial attention. Tactile, pain and proprioceptive sensory functions, as well as the tonus of the affected upper extremity, trunk and affected lower extremity were clinically tested.

All participants and their caregivers received oral instructions regarding study objectives and signed a consent form. Assessment sessions started 15 to 30 days after the CVA. Assessments were performed monthly during three months, always by the same examiner. Patients underwent the usual rehabilitation program, according to their specific needs for Physical, Speech, Occupational, Medical or Psychological Therapy. Patients who did not adhere to the rehabilitation program were not included in the study in order to maintain homogeneity between studied samples.

Data regarding muscle strength, posture, gait, functional independence and spatial attention were compared with an ANOVA for repeated measures. In each case the analysis was performed with the factors "groups" (injury to the right or left hemispheres) and "sessions" (assessment 1, 2 or 3). When appropriate, *post hoc* analyses were performed with the Newman-Keuls test at a level of significance set to 0.05.

Results

The mean age was 65.1±3.6 for the group of individuals with left hemispheric injuries and 56.9±3.3 for individuals with right hemispheric injury. No significant age differences were found between groups in the ANOVA. There were no significant differences between the groups for sensory function and tonus and all individuals demonstrated dysesthesia and hypertonia in the affected side of the body.

Muscular Strength

In general, performance was worse for the upper extremity than for the lower extremity in all patients. No significant differences were found between groups for the upper extremity [$F_{1.20}$= 2.70; p= 0.115] and lower extremity strength [$F_{1.20}$= 3.14; p= 0.091]. A significant difference between sessions was found for the upper extremity [$F_{2.40}$= 17.20; p< 0.001] and lower extremity strength [$F_{2.40}$= 28.84; p< 0.001]. Performance was better on the second assessment compared to the first for upper extremity (p< 0.001) and lower extremity strength (p< 0.001), and better on the third assessment compared to the second for upper extremity (p= 0.045) and lower extremity strength (p< 0.001). No interactions were found between groups and sessions for the upper [$F_{2.40}$= 0.10; p= 0.905] and lower extremity strength [$F_{2.40}$= 0.05; p= 0.956]. These result indicated that the two groups demonstrated the same rate of recovery of muscular strength.

Posture

No differences were found between groups for postural alignment tests [$F_{1.20}$=2.83; p= 0.107]. Significant differences were found between sessions [$F_{2.40}$=71.15; p< 0.001]. Performance was better on the second assessment compared to the first (p< 0.001) and better on the third assessment compared to the second (p< 0.001). There was no interactions between groups and sessions [$F_{2.40}$= 1.40; p= 0.257]. These results indicated that the two groups demonstrated the same rates of recovery for postural control.

Gait

The group with left hemispheric injury demonstrated lower gait performance [$F_{1.20}$= 8.88; p= 0.007]. A significant difference was found between sessions [$F_{2.40}$= 25.23; p< 0.001]. Performance was better for the second assessment compared to the first (p= 0.003) and better on the third assessment compared to the second (p< 0.001). An interaction was found between groups and sessions [$F_{2.40}$= 5.09; p= 0.011] which indicates that the group with left hemispheric injuries demonstrated a slower recovery of gait compared to the group with injuries to the right hemisphere (Figure 1).

Functional Independence

The score of the Barthel Index was significantly different between groups [$F_{1.20}$= 15.48; p< 0.001] and sessions [$F_{2.40}$= 79.17; p< 0.001]. The group with left hemispheric injuries demonstrated lower scores, indicating less independence in daily activities. Performance was better on the second assessment compared to the first (p< 0.001) and better on the third assessment compared to the second (p< 0.001). There was no interaction between groups and sessions [$F_{2.40}$= 1.36; p= 0.267], which indicates that the two groups demonstrated the same rate of recovery of functional independence (Figure 2).

Spatial Attention

Performance on the star cancellation test did not differ between groups [$F_{1.20}$=0.08; p= 0.776], but a significant difference was found between sessions [$F_{2.40}$=19.22; p< 0.001]. Performance was better for the second session compared to the first (p< 0.001) and better on the third assessment compared to the second (p=0.019). There were no interactions between groups and sessions [$F_{2,40}$=1.90; p= 0.161] which indicates that the two groups demonstrated the same rate of recovery for spatial attention.

Discussion

In the present study, a longitudinal assessment was performed of sensory functions, muscle tonus, muscle strength, posture, gait, functional independence and attention in individuals who had suffered an ischemic injury to the brain area supplied by the right or left MCA with the magnitude of the injury being carefully controlled. No other similarly comprehensive studies were found in the literature in regards to these assessed variables and the characterizations of the injured areas.

All assessed individuals demonstrated alterations in sensory functions, muscle tonus, posture, gait, functional independence, and spatial attention. These findings corroborated reports from other authors on the occurrence of hemiparesis, dysesthesia, postural instability, gait deficiencies, functional dependence and inattention[1-3, 19, 33] after CVA. The considerable degree of initial impairment in all assessed parameters was

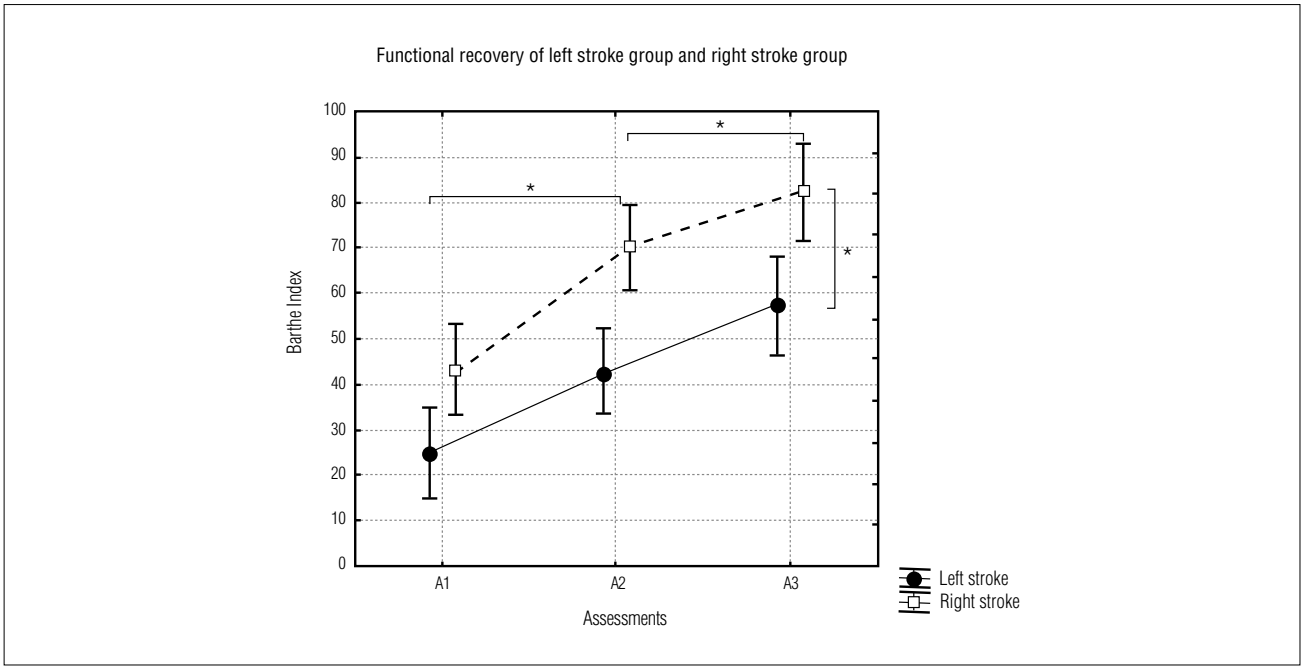

Figure 1. Comparisons between left-side (continuous line) and right-side (dotted line) stroke groups. Bars indicate 95% confidence intervals. The *Barthel* Index[31] was used in this comparison. Patients were assessed monthly. Left stroke group showed lower scores than right stroke group [$F_{1.20}$= 15.48; p< 0.001]. There were significant differences between assessments [$F_{2.40}$= 79.17; p< 0.001]. Assessment 2 showed better performance than assessment 1 (p< 0.001). Assessment 3 showed better performance than assessment 2 (p< 0.001). No interactions between groups and assessment were found [$F_{2.40}$= 1.36; p= 0.267], indicating that both groups had the same recovery levels.

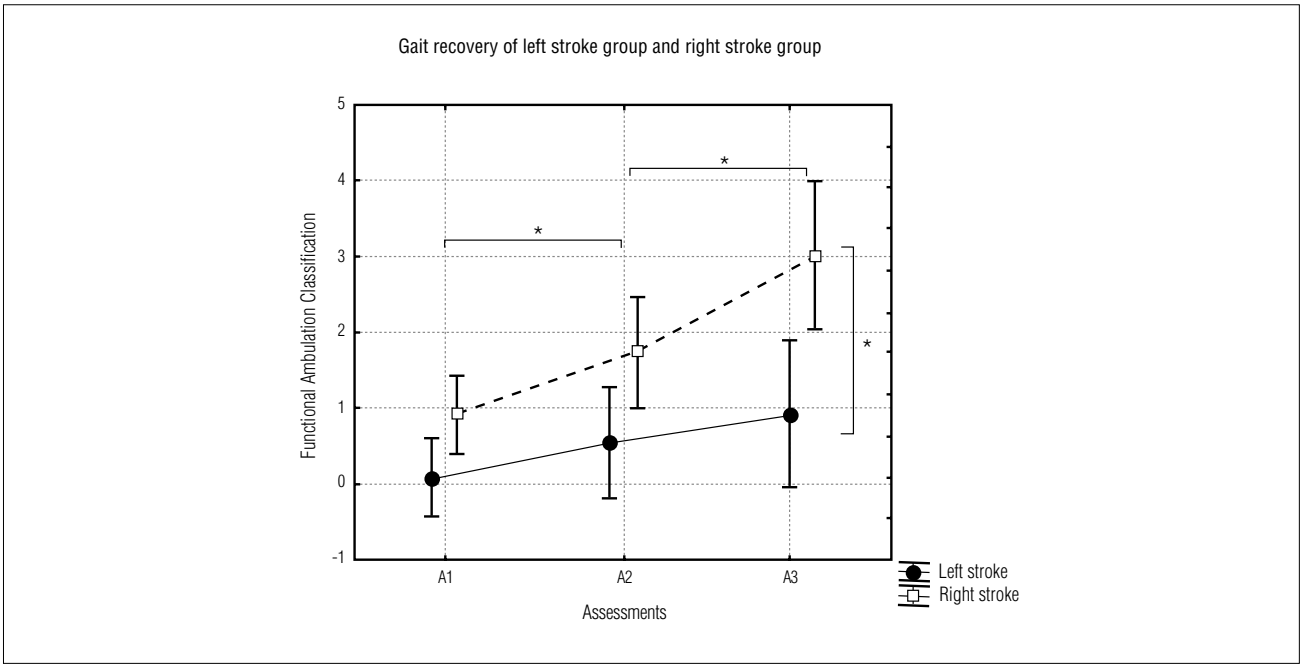

Figure 2. Comparisons between left-side (continuous line) and right-side (dotted line) stroke groups. Bars indicate 95% confidence intervals. Functional Ambulation Classification (FAC)[30] was used in this comparison. Patients were assessed monthly. The left-side stroke group showed lower scores than right stroke group [$F_{1.20}$= 8.88; p= 0.007]. There were significant differences between assessments [$F_{2.40}$= 25.23; p< 0.001]. Assessment 2 showed better performance than assessment 1 (p< 0.003). Assessment 3 showed better performance than assessment 2 (p< 0.001). There were significant interactions between group and assessment [$F_{2.40}$= 5.09; p< 0.011], indicating that both groups had the same recovery levels.

probably related to the relatively large injury areas demonstrated by individuals included in the study sample. Similar results have been reported for patients with large fronto-parietal injuries[2, 3].

As expected, all assessed variables demonstrated improvements from the first to the third month after the CVA. This observed functional recovery was related to the reversal of edema and biochemical alterations in the interstitial area of the injury[34], as well as to the neural reorganization resulting from the demands of daily life and rehabilitation training[1, 3, 9, 24, 33].

The initial severe deficits in upper extremity muscle strength and the subsequent poor recovery observed over time may be a consequence of injuries involving the corona radiata or the posterior limb of the internal capsule[1], as well of the fact that movement control of the upper limb is predominantly unilateral. The less significant involvement and the fairly satisfactory recovery observed for the muscles of the lower extremities were probably related to the bilateral control of these muscles.

Initial performance and rate of recovery of the sensory functions, muscle tonus, muscular strength, posture and spatial attention were not significantly different between groups with right and left CVAs. Initial gait performance was more affected and rate of recovery was slower in the group with left CVA compared to the group with right CVA. Initial functional independence was more affected in the group with left hemispheric injuries compared to the group with those of the right, but the recovery rate did not differ between the two groups.

The greater gait impairments observed initially for individuals with left hemispheric injuries contrast with observations of two other authors[19, 21]. They observed that the proportion of patients with right hemispheric injuries capable of walking on the parallel bars was smaller than the proportion of patients with left hemispheric injuries. In these studies, however, individuals were recruited in outpatient clinics, and as these patients generally demonstrate less severe sensory and motor deficits, the discrepancy in results may be attributed to the greater severity of deficits demonstrated by patients in the present study. The lower rate of recovery of gait in the group with left CVA also contrasts with reports of lower rates for individuals with right CVA compared to individuals with left CVA[23-25]. Since the magnitude of the injury was not controlled in other reported studies, it is possible that deficits in additional areas may be related to the differences in their results to the present study.

Regarding functional independence, other studies reported lower initial performance in individuals with left CVA[9, 10]. Granger et al.[10] related this finding to the dysphasia demonstrated by the majority of individuals. It is interesting to remark that all individuals with left CVA in the present study demonstrated difficulties in verbal expression. The absence of any differences in the degree of independence between individuals with left and right CVA, reported in other studies[11, 12, 19, 21, 23], would possibly be related to the exclusion of individuals with language alterations, and presumably, more minor CVA.

The greater impact on gait and functional independence observed in the group with left CVA would not be related to the alterations of tonus, sensory functions and muscle strength, since these variables did not differ between groups. This finding may be attributed to an asymmetry between hemispheres[33], as this is in accordance with the idea that the left hemisphere exerts a dominant role in motor planning and the control of actions involving complex motor sequences in right-handed individuals[4-6, 8, 22, 26]. Gait and the majority of activities of daily life depend on elaborate motor planning and sequencing. The fact that the left hemisphere controls the right upper limb, which is more used in activities of daily living by right-handed individuals, would further influence the performance of those individuals, as assessed by the Barthel Index.

The hypothesis that individuals with CVA affecting the area of the right MCA would demonstrate poorer performance in tests of postural control and spatial attention was not confirmed. Although some studies have evidenced greater postural control impairments after injuries to the right hemisphere[19-21], there is also evidence of better functional recovery of the posture of the trunk[14] after such injuries. Results of the present study demonstrated that both cerebral hemispheres are of great and comparable importance to postural control. Additionally, these results suggested that posture is strongly influenced by spatial attention, and was similarly affected in the two groups.

The absence of asymmetry in the orientation of spatial attention in the present study is of particular importance. Reports of hemineglect in patients with right cerebral injuries are very frequent[16-18], although reports of hemineglect after left injuries can also be found[15, 32]. A possible explanation to this finding would be the fact that individuals with dysphasia were included in the group of patients with left injuries. Most studies in the literature exclude these individuals because the test battery for hemineglect requires verbal responses. The star cancellation test was used because it is very sensitive to this kind of deficit, it is the only test that can be applied to patients with left injuries who are unable to give verbal responses[33, 36] and it does not depend on intact motor control of the dominant hand, since the stars can also be cancelled with the non-dominant hand.

The results of the present study demonstrated that injuries in the MCA area can cause severe alterations of sensory functions, muscle tonus, muscular strength, postural alignment, gait, functional independence and attention. Injuries in the left MCA area result in greater impairments of gait and daily life activities compared to similar right-side injuries, but the rate of recovery of gait is inferior in left-side injuries. These differences in deficits caused by left- and right-side CVAs must be taken into account in various physical therapy approaches. The possibility that individuals with left-side CVA may need different rehabilitative training compared individuals with right-side injuries must be considered.

References

1. Shelton FN, Reding MJ. Effect of lesion location on upper limb motor recovery after stroke. Stroke. 2001;32:107-12.
2. Sturm J, Donnan G, Dewey H, Macdonell R, Gilligan A, Thrift A. Determinants of handicap after stroke: the North East Melbourne Stroke Incidence Study (NEMESIS). Stroke. 2004;35:715-20.
3. Schiemanck SK, Kwakkel G, Post MW, Kappelle LJ, Prevo AJ. Predicting long-term independency in activities of daily living after middle cerebral artery stroke: does information from MRI have added predictive value compared with clinical information? Stroke. 2006;37;1050-4.
4. Haaland KY, Prestopnik JL, Knight RT, Lee RR. Hemispheric asymmetries for kinematic and positional aspects of reaching. Brain. 2004;127:1145-58.
5. Hermsdörfer J, Blankenfeld H, Goldenberg G. The dependence of ipsilesional aiming déficits on task demands, lesioned hemisphere and apraxia. Neuropsychologia. 2003;41:1628-43.
6. Bestelmeyer PEG, Carey D. Processing bias towards the preferred hand: valid and invalid cueing of left-versus right-hand movements. Neuropsychologia. 2004;42:1162-7.
7. Farina D, Kallenberg LAC, Merletti R, Hermens H. Effect of side dominance on myoelectric manifestations of muscle fatigue in the human upper trapezius muscle. Eur J Appl Physiol. 2003;90:480-8.
8. Incel NA, Ceceli E, Durukan PB, Erdem HR, Yorgancioglu ZR. Grip strength: effect of hand dominance. Singapore Med J. 2002;43:234-7.
9. Yavuzer G, Küçükdeveci A, Arasil T, Elhan A. Rehabilitation of stroke patients. Am J Phys Med Rehabil. 2001;80(4):250-5.
10. Granger CV, Hamilton BB, Fiedler RC. Discharge outcome after stroke rehabilitation. Stroke. 1992;23:978-82.
11. Wade DT, Hewer RL, Wood VA. Stroke: influence of patient's sex and side of weakness on outcome. Arch Phys Med Rehabil. 1984;65:513-6.
12. Cifu DX, Lorish TR. Stroke rehabilitation. 5. Stroke outcome. Arch Phys Med Rehabil. 1994;75:S56-S60.
13. Mills VM, DiGenio M. Functional differences in patients with left or right cerebrovascular accidents. Phys Ther. 1982;63(4):481-8.
14. Hesse S, Schauer M, Petersen M, Jahnke M. Sit-to-stand manouevre in hemiparetic patients before and after a 4-week rehabilitation programme. Scand J Rehabil Med. 1998;30:81-6.
15. Kerkhoff G. Spatial hemineglect in humans. Progress in Neurobiology, 2001;63:1-27.
16. Raz A, Buhle J. Typologies of attentional networks. Nature Reviews, Neuroscience. 2006;7(5):367-79.
17. Farne A, Roy AC, Paulignan Y, Rode G, Rossetti Y, Boisson D, et al. Visuo-motor control of the ipsilateral hand: evidence from right brain-damaged patients. Neuropsychology. 2003;41:739-57.
18. Mattingley JB, Berberovic N, Corben L, Slavin M, Nicholls MER, Bradshaw JL. The greyscales task: a perceptual measure of attentional bias following unilateral hemispheric damage. Neuropsychology. 2004;42:387-94.
19. Laufer Y, Sivan D, Schwarzmann R, Sprecher E. Standing balance and functional recovery of patients with right and left hemiparesis in the early stages of rehabilitation. Neurorehabil Neural Repair. 2003;17(4):207-13.
20. Rode G, Tiliket C, Boisson D. Predominance of postural imbalance in left hemiparetic patients. Scandinavian Journal of Rehabilitation Medicine. 1997;29:11-6.
21. Bohannon RW, Smith MB, Larkin PA. Relationship between independent sitting balance and side of hemiparesis. Phys Ther. 1986;66(6):944-5.
22. Spinazzola L, Cubelli R, Della Sala S. Impairments of trunk movements following left or right hemisphere lesions: dissociation between apraxic errors and postural instability. Brain. 2003;126:2656-66.
23. Macciocchi SN, Diamond PT, Alves WM, Mertz T. Ischemic stroke: relation of age, lesion location, and initial neurologic deficit to functional outcome. Arch Phys Med Rehab. 1998;79(10):1255-7.
24. Alexander MP. Stroke rehabilitation outcome. A potential use of predictive variables to establish levels of care. Stroke. 1994;25:128-34.
25. Titianova EB, Tarkka IM. Asymmetry in walking performance and postural sway in patients with chronic unilateral cerebral infarction. J Rehabil Res Dev. 1995;32(3):236-44.
26. Sabaté M, Gonzalez B, Rodriguez M. Brain lateralization of motor imagery: motor planning asymmetry as a cause of movement lateralization. Neuropsychology. 2004;42:1041-49.
27. Bailey MJ, Riddoch MJ, Crome P. Treatment of visual neglect in elderly patients with stroke: a single-subject series using either a scanning and cueing strategy or a left-limb activation strategy. Phys Ther. 2002;82(8):782-97.
28. Oldfield R. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia. 1971;9:97-113.

29. Benaim C, Pérennou DA, Villy J, Rousseaux M, Pelissier J. Validation of a standardized assessment of postural control in stroke patients. Stroke. 1999;30:1862-8.

30. Stevenson TJ. Detecting changes in patients with stroke using the Berg Balance Scale. Australian Journal of Physical Therapy. 2001;47:29-38.

31. Barthel DW, Mahoney FI. Functional evaluation: the Barthel index. Md State Med J. 1965;14:56-61.

32. Kleinman JT, Newhart M, Davis C, Heidler-Gary J, Gottesman RF, Hillis AE. Right hemispatial neglect: frequency and characterization following acute left hemisphere stroke. Brain Cogn. 2007;64(1):50-9.

33. Voos MC, Piemonte MEP, Ribeiro do Valle LE. Assimetrias funcionais em pacientes com hemiparesia: uma revisão de literatura. Fisioter e Pesqui. 2007;14(1):79-87.

34. Kidwell CS, Liebeskind DS, Starkman S, Saver JL. Trends in acute ischemic stroke trials through the 20th century. Stroke. 2001;32(6):1349-59.

35. Sparrow WA, Bradshaw EJ, Lamoureux E, Tirosh O. Aging effects on attention demands of walking. Hum Mov Sci. 2002;21:961-72.

36. Ferber S, Karnath HO. How to assess spatial neglect: line bisection or cancellation tasks? J Clin Exp Neuropsychol. 2001;23(5):599-607.