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INFLUENCE OF HEMISPHERIC DOMINANCE IN UPPER LIMB RECOVERY ON STROKE PATIENTS

INFLUÊNCIA DA DOMINÂNCIA HEMISFÉRICA NA RECUPERAÇÃO DO MEMBRO SUPERIOR DE PACIENTES COM ACIDENTE VASCULAR CEREBRAL

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ABSTRACT

Introduction: The upper limb is widely used in activities of daily living, mainly in bimanual actions. There are indications that after stroke, individuals with dominant upper limb involvement present better recovery, but this is an underexplored aspect of rehabilitation. **Objective**: To verify whether the manual dominance interferes in upper limb recovery of hemiparetic stroke patients **Methodology**: This is a cross-sectional study involving 48 patients declared right-handed (24 hemiparetic on the dominant side and 24 on the non-dominant side). Hand Movement Scale (HMS), grip strength (GS), Box and Blocks Test (BBT), and Modified Barthel Index (MBI) were evaluated. Unpaired *t*-test with Welch's correction was used to compare dominant hemiparesis versus non-dominant hemiparesis groups to parametric variables. The Mann-Whitney U test was used to analyze non-parametric variables. For some variables, such as grip strength and manual dexterity patients were tested bilaterally, thus, these data were analyzed using two-way ANOVA (Tukey's multiple comparisons test). **Results**: The most important aspects that differed between the groups were about manual function (HMS) and manual dexterity (BBT) for patients with right hemiparesis. And yet, we can consider a minimal clinically important difference favorable to this group for functional independence (MBI). **Conclusion**: Our results suggest that when there is the involvement of the dominant upper limb, the recovery of manual dexterity, manual function, and functional independence are favored. This better performance may be related to the natural preference of the dominant hand. These findings underscore the importance of tailoring therapy approaches based on hemispheric dominance.

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Key words: stroke; upper extremity; functional laterality; rehabilitation.

RESUMO

Introdução: O membro superior (MS) é amplamente utilizado nas atividades de vida diárias, principalmente nas tarefas bimanuais. Indícios apontam que após o AVC os indivíduos com comprometimento dominante dos membros superiores apresentam melhor recuperação, mas este é um aspecto pouco explorado da reabilitação. **Objetivo:** Verificar se a dominância manual interfere na recuperação do MS de pacientes hemiparéticos por AVC. **Metodologia:** Estudo transversal envolvendo 48 pacientes declarados destros (24 hemiparéticos no lado dominante e 24 no lado não dominante). Foram avaliados Escala de Movimentos das Mão (EMM), força de preensão (FP), Teste de Caixa e Blocos (TCB) e Índice de Barthel Modificado (IBM). O teste t independente com correção de Welch foi utilizado para comparar grupos de hemiparesia dominante versus grupos de hemiparesia não dominante para variáveis paramétricas, enquanto o teste U de Mann-Whitney serviu para análises não paramétricas. Para variáveis como FP e destreza manual, os pacientes foram testados bilateralmente, portanto, esses dados foram analisados por meio de ANOVA bidirecional (teste de comparações múltiplas de Tukey). **Resultados:** Os principais aspectos que diferiram entre os grupos foram sobre função manual (EMM) e destreza manual (TCB) para pacientes com hemiparesia direita. Ainda, podemos considerar uma diferença mínima clinicamente importante favorável a este grupo para independência funcional (IBM). **Conclusão:** Nossos resultados sugerem que quando há comprometimento do MS dominante, a recuperação da destreza manual, função manual e independência funcional são favorecidas. Este melhor desempenho pode estar relacionado com a preferência natural da mão dominante. Essas descobertas ressaltam a importância de adaptar abordagens terapêuticas baseadas na dominância hemisférica.

Palavras-chave: acidente vascular cerebral; extremidade superior; lateralidade funcional; reabilitação.

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INTRODUCTION

Stroke is responsible for high rates of morbidity and mortality and is among the main diseases that contribute to disability.[1] Epidemiological data indicate that it is the second leading cause of death worldwide, being responsible for more than 6.5 million deaths in 2019.[2]

The involvement varies according to the affected hemisphere, location, and extent of the injury. An evident symptom well highlighted in the literature is the

impairment of the contralateral hemibody, distinguished by hemiparesis.[3] Due to the large impact on functionality, special attention should be given to disorders found in the upper limbs.[4]

The upper limb is widely used in activities of daily living (ADLs), both in unilateral (*e.g.*, writing and carrying objects) and bilateral activities. In this last, the non-dominant member has the function to stabilize loads imposed by the dominant member. Bilateral activities are routinely more common than unilateral activities.[5]

Studies have shown that in healthy individuals, the dominant limb is generally superior in speed, accuracy, coordination, muscular endurance, and grip strength.[6] In this sense, an approximate 10% difference comparing the left and right sides is commonly found in healthy elderly people, and the dominant side generally has higher values than the non-dominant side.[7] In stroke, studies indicate that 50% of cases corresponded to the left side and 50% the right side. Moreover, there is evidence that patients with hemiparesis on the non-dominant side have a strong tendency to avoid using this limb, leading to disuse and consequently reducing the possibility of recovery.[8-10] Considering these aspects, manual dominance seems to play a role in upper limb functionality and recovery after a stroke, even if few studies explored this subject.

Therefore, this study aimed to determine the influence of upper limb dominance, in terms of functional independence, grip strength, manual dexterity and manual function. These findings could be used as a prognostic factor to determine specific and appropriate treatment according to the individual's dominance.

METHODOLOGY

Study design

This is a cross-sectional study conducted in the Ambulatory of Neurological Rehabilitation from the Guilherme Guimbala College. This research had the approval of the Committee of Ethics in Research of the Lutheran Educational Institute of Santa Catarina College in Joinville, Santa Catarina, Brazil (# CAAE 68560017.6.0000.5365). All participants gave their written informed consent.

Participants

Participants who met the following inclusion criteria were selected: (i) adults of any gender; (ii) hemiparesis from a single stroke; (iii) upper limb involvement, but allowing at least reaching and holding; and (iv) right-handed. Hand dominance was determined by asking individuals about their preference or ease for performing actions, such as picking up objects or writing, before the stroke.[9] The exclusion criteria were visual, auditory, and cognitive deficits that could not allow for the understanding of the tests.

Evaluations

- **Functional independence** was assessed using the Modified Barthel Index (MBI) (in the interview form). MBI is composed of 10 items assessing daily-life and mobility activities, where the score is based on the level of assistance required to complete these activities. MBI scores a total of 100 points, where 0 indicates total dependence and 100 complete independence.

- **Grip strength** was evaluated using a manual dynamometer (Takei Scientific Instruments, Japan) in the left and right hand. This test was performed according to the recommendations of the American Society of Hand Therapists: participants sat with hips and knees at 90° flexion, adducted shoulder, elbow flexed to 90°, forearm, and wrist in a neutral position, and the examiner held the dynamometer. It was requested of the participants to grip the dynamometer as strongly as possible. An initial measure was performed to familiarize oneself with the equipment and movement. After that, 3 measurements were made on each side (paretic and non-paretic) and the mean values were calculated. The measurements were performed alternately, and 60 seconds were adopted between each measurement.

- **Manual dexterity** was assessed using the box and block test. This test is composed of a wooden box (53.7 x 25.4 x 8.5 cm), a taller dividing wall separating the box into 2 identical compartments, and 70 blocks of 2.5 cm. It was requested of participants to transport the blocks from one side to the other side of the box as fast as possible. Before the test, participants had a familiarization phase for 15 seconds. Afterwards, one minute was timed and the number of transported blocks was counted. Initially, the individuals performed the task with the non-paretic side and then with the paretic side.

- **Manual function** was assessed using the hand movement scale in both hands. This test is a simple, inexpensive, quick-applied, and predictive tool for the functional recovery of the hand. It quantifies fingers and thumb movements with a total score of 6 points. The highest score, the best, is the manual function. In this test, participants were asked to perform active flexion and extension of the fingers, an extension of the index finger, keeping the other fingers in a flexion position and opposition between the thumb and all fingers.

Procedures

The entire procedure was previously clarified, and the signature of the informed consent was requested. After participants' recruitment, they were separated into two groups: the *dominant hemiparesis* (DH) and the *non-dominant hemiparesis* (NDH). The above-mentioned tests were conducted in a dedicated room at a single time by an experienced physical therapist.

Analyses

The statistical analyses were performed with GraphPad Prism 6 software (GraphPad Software, Inc., USA). Participants were characterized using the following descriptive measures: mean and standard deviation for parametric variables; and median, interquartile range and frequency distributions for non-parametric variables. Shapiro-Wilk's and Levene's tests were conducted to check the assumptions of normality and homoscedasticity, respectively. Unpaired t-test with Welch's correction was used to compare the DH versus NDHs groups concerning parametric variables. For the comparisons between groups for grip strength and manual dexterity, as patients were assessed bilaterally, a two-way ANOVA (Tukey's multiple comparisons test) was used. In this same way, comparisons for manual function were conducted by the Mann-Whitney U and Wilcoxon tests (non-parametric tests). The level of significance was set at 5% ($p < 0.05$).

RESULTS

Table 1 presents the characteristics of forty-eight participants who met all inclusion/exclusion criteria. They were divided equally into both DH and NDH groups. Each group was composed of 14 men and 10 women. They realized all the tests without difficulty. There were no significant differences between the groups in terms of age and stroke time (p=0.159 and p=0.831, respectively), indicating group homogeneity. In both groups, most patients were in the chronic phase (67%).

Table 1 – Summary of demographic and clinical features.

Variables	DH (n 24)	NDH (n 24)	p-value
Age (years)	61.1 (10.3)	57.1 (9.0)	0.159
Stroke time (months)	21.2 (18.8)	22.7 (27.5)	0.831
Sex			
Male (nb / %)	14 / 58	14 / 58	- - - -
Female (nb / %)	10 / 42	10 / 42	- - - -
Phase of the stroke			
Acute (nb / %)	5 / 21	4 / 17	- - - -
Subacute (nb / %)	3 / 12	5 / 21	- - - -
Chronic (nb / %)	16 / 67	15 / 62	- - - -

Abbreviations: DH, dominant hemiparesis group; NDH, non-dominant hemiparesis group; nb, number.

Table 2 shows group comparisons in terms of functional independence, grip strength, manual dexterity, and manual function. Although statistically significant differences were not observed, DH tended to be a better functional independence than the NDH group (mean [SD]: DH= 95 [19] vs. NDH= 85 [23]; U= 203; z= -1.775; p=

0.053). For grip strength, significant differences were not observed between DH and NDH groups for both paretic (p= 0.239) and non-paretic sides (p= 0.775). For the manual dexterity, differences in the box and blocks test between DH and NDH were observed only in the paretic upper limb (t= 3.214; p= 0.002). For the hand function, differences in the Hand Movement Scale between DH and NDH were observed only at the paretic upper limb (U= 196.0; p= 0.045).

To finish, and as expected, differences between paretic and non-paretic upper limbs for both DH and NDH groups were found for all the variables studied (p< 0.001).

Table 2 – Group comparisons in terms of functional independence, grip strength, manual dexterity, and manual function.

Variables	Hemibody	DH (n 24)	NDH (n 24)	*p-value* DH *vs.* NDH
Modified Barthel index (0-100)	NA	95.0 (19.0)	85.0 (23.0)	0.053
Grip strength (kgf)	Paretic	16.8 (7.6)	13.5 (11.2)	0.239
	Non-paretic	28.5 (8.5)	29.2 (9.8)	0.775
	p-value **Paretic *vs.* Non-paretic**	< 0.001	< 0.001	
Box and blocks test (blocks/min)	Paretic	29.8 (13.4)	17.4 (13.2)	0.002
	Non-paretic	46.5 (11.6)	40.2 (13.5)	0.061
	p-value **Paretic *vs.* Non-paretic**	< 0.001	< 0.001	
Hand movement scale (1 to 6)	Paretic	5.00 (1.00)	5.00 (3.00)	0.045
	Non-paretic	6.00 (0.00)	6.00 (0.00)	0.317
	p-value **Paretic *vs.* Non-paretic**	< 0.001	< 0.001	

Abbreviations: NA, not applicable; DH, dominant hemiparesis group; NDH, non-dominant hemiparesis group.

DISCUSSION

The current work aimed to verify whether dominance affects individuals' independence, grip strength, dexterity, and manual function. Previous findings suggest that, even after stroke, dominance still impacts upper-limb functionality, and on the paretic side, individuals with a NDH may have a lower upper-limb function than individuals with a DH. This was, in general, verified in our study.

First, for the MBI, although there was no significant difference (p= 0.053) between the DH and NDH groups, the MBI was 10 points lower in the NDH group than in the DH group. Considering the minimum clinically important difference (MCID) for MBI found in a previous study[11] (i.e., 1.85 points), the difference between NDH and DH represents 5 times lower than the MCID cutoff in disfavor of the NDH group.

Greater independence in daily activities is associated with the use of both upper limbs, which is the most common pattern in healthy individuals.[7,12] These results indicate that the dominant hand may facilitate greater efficiency in performing bimanual tasks, which are critical for activities of daily living as evaluated by the MBI. Probably must be an effort to use the dominant limb, which was naturally the main task-maker.[13,14]

We did not find significant differences in grip strength between DH and NDH groups, neither for the paretic side (mean difference: 3.3 kg) nor for the non-paretic side (mean difference: 0.7 kg). Our results contrast with the results of a previous study based on 93 persons with chronic stroke, which found a lower grip strength for NDH than DH.[9] However, the difference found in this previous study is still relatively small (mean difference: 3.7 kg; $p = 0.04$). In both studies, differences are lower than the MCID found for an equivalent population (i.e., 5kg).[15] These results suggest that after a stroke, the dominance effect, which is naturally observed in healthy people, tends to disappear. The observed phenomena can be attributed to ipsilateral deficits, which in healthy people may diminish the typical disparities. Notably, individuals with a paretic right hand often exhibit a more pronounced recovery in the left hand, further contributing to the reduction of these ipsilateral deficits.[16] Additionally, it is noteworthy that injuries to the left hemisphere tend to manifest deficits in both contralateral and ipsilateral movements. In contrast, injuries to the right hemisphere primarily result in contralateral deficits. This underscores the importance of considering hemispheric distinctions in understanding motor deficits.[17]

Our research found a lower ability to move fingers actively and synergistically in the NDH group compared to the DH group. For the tasks for which dexterity is necessary, the non-dominant hand is not the spontaneous hand used by individuals.[18] In healthy adults, speed, precision, and coordination were improved in the dominant hand.[19] Furthermore, there are differences in cortical activation between the dominant and non-dominant sides, observed by the need for higher thresholds on the non-dominant side.[20] 20This may explain why the value was lower in the NDH group, as these patients can continue to use their dominant non-paretic side for this type of activity. This spontaneous underutilization of the non-dominant upper limb, associated with hemiparesis, may increase the negative impact on dexterity. However, it is important to have in mind that the non-dominant upper limb is crucial in bilateral daily activities.[7,21]

Collectively, our results point out the importance of encouraging the use of the paretic upper limb and thus, reducing the tendency to disuse. Moreover, several daily tasks require both upper limbs (bimanual or alternation between upper limbs). This encouragement seems even more true when it is the non-dominant side that is affected.[8] As dominance still plays a role in upper limb function, different therapies should be explored.

Some studies highlight better recovery when interventions were oriented through a bimanual activity,[18,22] and a clear advantage has already been demonstrated in the Fugl-Meyer upper extremity test, isometric strength, and range of motion active and passive, after 6 weeks of bilateral training with upper limbs for patients with left and right-handed injuries.[10]

In a systematic review and meta-analysis involving 21 randomized clinical trials with 842 stroke patients, it was found that bilateral upper limb training yielded major improvements in motor function when compared to unilateral training.[23] Thus, bilateral upper limb training can be considered more effective than unilateral upper limb training after stroke. This type of exercise can activate the ipsilesional primary motor area (M1), supplementary motor area (SMA), and primary sensory cortex (S1), favoring the improvement of intra-hemispheric and inter-hemispheric connectivity within the sensorimotor network.[24]

The corpus callosum is important for the control of movement, being related to post-stroke motor function.[25] In this sense, there is evidence that even isolated training of the non-paretic limb can have an impact on improvements in muscle strength and muscle activation in the paretic limb of chronic stroke patients. These findings are justified by the important transcortical flow of information existing through the corpus callosum.[26]

Mani et al.[8] report that although individuals with DH use the contralateral limb more frequently compared to individuals with NDH, their research identified that the arrangement of objects in space plays a significant role in choosing to use the contralesional arm to achieve reach, and this factor should also be explored in therapy.

Sainburg and Duff [18] suggest the use of techniques with involvement in supervised activities that require dominant functions for the non-dominant ipsilesional member, facilitating more efficient coordination in chronic patients with the affected dominant upper limb, since the contralesional upper limb of patients with moderate commitment is unlikely to return to being used as the main controller in tasks.

After a stroke, neural changes lead to a learning process in which there is a progressive suppression of the use of the affected extremity. This phenomenon is referred to as learned non-use.[27] In addition to damage to motor pathways, there is a depression of neural excitability near the lesion. Thus, the decrease in the activity of the upper limb leads to a further reduction in excitability and, as such, starts a vicious circle of decreasing excitability and decreasing activity.[28]

To overcome this potential disuse, constraint-induced movement therapy (CIMT), a technique used to promote the use of the more affected hand via constraint of the less affected hand, has been used and showed improvement of the more affected hand without decrements to the less affected constrained hand.[29] To achieve its goals, the CIMT proposes to restrict the movement of the patient's least affected upper limb for approximately 90% of the patient's waking hours, physically forcing the use of the most affected limb during the performance of ADLs.[27]

Comparing the effectiveness of bilateral and unilateral training on upper limb function and ADLs after stroke, a meta-analysis including 8 RCTs and 445 patients, concluded that unilateral exercises using CIMT were more effective than bilateral training regarding increased upper limb motor function. However, bilateral training may be more appropriate for improving ADL, as CIMT has disadvantages such as fatigue and the need for a specific profile of the patients.[30]

Therefore, although most studies indicate superiority of the effects obtained with bilateral training in motor recovery of the upper limb after stroke, when compared to unilateral training, it is believed that the combination of these different forms of treatment is the best choice, as it enhances the achievement of different goals, including improving the performance of ADLs. In any case, encouraging the use of the paretic upper limb is essential after stroke.

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