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ORIGINAL RESEARCH

Correlation between upper limb spasticity and hand movement after stroke

Correlação entre espasticidade do membro superior e movimentação da mão no pós-AVC

Correlación entre la espasticidad del miembro superior y el movimiento de la mano post-ACV

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ABSTRACT | Hemiparesis and spasticity are common consequences in stroke patients, hampering the movement in the affected side. Our study aimed to correlate upper limb spasticity and the ability to move the hand in these patients. This is a quantitative cross-sectional study with an ex post facto correlational design. We evaluated patients undergoing follow-up at the Neurovascular Outpatient Clinic at the Hospital de Clínicas de Porto Alegre. An evaluation form was filled out with sample data and the upper limb spasticity was evaluated using the Modified Ashworth Scale and the active hand movement using the Hand Movement Scale. Correlation of variables were verified using Kendall's rank correlation coefficient. A significance level of 5% ($p \leq 0.05$) was adopted. In total, we evaluated 47 subjects of all genders, with a mean age of 64.5 (±13) years and a mean stroke time of 2.7 (±1.8) months. The Hand movement Scale mode was 6 points, and 74.4% of patients were not spastic. Hand movement showed a significant negative correlation with the spastic muscles evaluated. There was a moderate negative correlation with the pectoral muscles ($r=-0.383$; $p=0.007$), elbow flexors ($r=-0.339$; $p=0.016$) and pronators ($r=-0.460$; $p=0.001$) and high negative correlation with wrist flexors ($r=-0.588$; $p<0.001$) and finger flexors ($r=-0.692$; $p<.001$). The greater the degree of spasticity of the upper limb, the smaller the hand movement capacity in stroke patients.

Keywords | Stroke; Stroke Spasticity Muscle; Hand Strength.

RESUMO | A hemiparesia e a espasticidade são consequências comuns em pacientes que sofreram um acidente vascular cerebral (AVC) e delas decorre a dificuldade do paciente de movimentar o hemicorpo acometido. O objetivo deste estudo foi, assim, verificar a relação da espasticidade no membro superior (MS) com a capacidade de movimentação da mão desses pacientes, a partir de um estudo transversal de delineamento ex-post facto correlacional. Foram avaliados pacientes que realizavam acompanhamento no Ambulatório Neurovascular do Hospital de Porto Alegre (HCPA). Foi preenchida uma ficha de avaliação com dados da amostra e realizada a avaliação da espasticidade do MS, por meio da escala de Ashworth modificada (MAS), e da movimentação ativa da mão, por meio da escala de movimentação da mão (EMM). Para a correlação das variáveis, foi usado o coeficiente de correlação tau de Kendall, adotando-se um nível de significação de 5% ($p \leq 0{,}05$). Foram avaliados 47 sujeitos de ambos os sexos com média de idade de 64,5 (±13) anos e média de tempo de AVC de 2,7 (±1,8) meses. A moda da EMM foi de 6 pontos e 74,4% dos pacientes não eram espásticos. O movimento da mão apresentou correlação significativa negativa com as musculaturas espásticas avaliadas. Houve uma correlação negativa moderada com as musculaturas peitoral ($r=-0{,}383$; $p=0{,}007$), os flexores de cotovelo ($r=-0{,}339$; $p=0{,}016$) e pronadores ($r=-0{,}460$; $p=0{,}001$), e correlação negativa alta com os flexores de punho ($r=-0{,}588$; $p<0{,}001$) e os flexores de dedos ($r=-0{,}692$; $p<0{,}001$). Concluiu-se que quanto maior o grau de espasticidade do membro superior, menor a capacidade de movimentação da mão dos pacientes.

Descritores | Acidente Vascular Cerebral; Espasticidade Muscular; Força da Mão.

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RESUMEN | La hemiparesia y la espasticidad en los pacientes son consecuencias frecuentes del accidente cerebrovascular (ACV), lo que resulta en la dificultad del paciente para mover el hemicuerpo afectado. El objetivo de este estudio fue verificar la relación entre la espasticidad en el miembro superior (MS) y la capacidad de mover la mano de estos pacientes a partir de un estudio transversal, con un diseño correlacional ex post facto. Se evaluaron a pacientes en seguimiento en el Ambulatorio de Neurovascular del Hospital de Clínicas de Porto Alegre (HCPA), en Brasil. El formulario de evaluación se utilizó para recoger los datos de la muestra, y para el análisis de la espasticidad del MS se aplicó la escala de Ashworth modificada (MAS), y el movimiento activo de la mano, la escala de movimiento de la mano (EMM). Para la correlación de variables se utilizó el coeficiente de correlación tau de Kendall, con un nivel de significación del 5% ($p \leq 0,05$). Se evaluaron a 47 personas de ambos sexos, con una edad media de 64,5 (±13) años y un tiempo medio del ACV de 2,7 (±1,8) meses. La moda de EMM fue de 6 puntos, y el 74,4% de los pacientes no eran espásticos. El movimiento de la mano mostró una correlación negativa significativa con las musculaturas espásticas evaluadas. Hubo una moderada correlación negativa con la musculatura pectoral ($r=-0,383$; $p=0,007$), los flexores del codo ($r=-0,339$; $p=0,016$) y pronadores ($r=-0,460$; $p=0,001$), y una alta correlación negativa con los flexores de muñeca ($r=-0,588$; $p<0,001$) y los flexores de dedos ($r=-0,692$; $p<0,001$). Se concluyó que cuanto mayor es el grado de espasticidad del miembro superior, menor será la capacidad de movimiento de las manos de los pacientes.

Palabras clave | Accidente Cerebrovascular; Espasticidad Muscular; Fuerza de la Mano.

INTRODUCTION

The recovery of the paretic upper limb is one of the main concerns after a stroke (CVA)[1] and its recovery prognosis is slow when compared to the lower limb[2]. After stroke, 80% of people show motor deficits in the affected upper limb and of these, approximately one third recover the total function of the segment[3].

Spasticity is a neuromotor dysfunction resulting from lesions in the upper motor neuron, such as stroke, and is associated with muscle weakness and decreased joint range of motion[4]. For patients who do not reacquire voluntary upper limb movement, spasticity can generate an abnormal posture, leading to contractures, especially in the flexion of fingers and elbow, which negatively affects activities of daily living (ADL)[5]. On the other hand, for patients with voluntary movement of limbs, inadequate coactivation of agonist and antagonist muscles can also impair functional movement[5].

Spasticity influences the performance of those affected by it in tests of manual dexterity of the upper limb, which, consequently, may be aggravated[6]. A greater tendency of spasticity occurs in the region from distal to proximal extremity, being the distal extremity most affected by this tonic change, affecting neuromuscular control for fine hand movements[7].

Some functions of the hand, such as grip and sensation, are fundamental for the performance of ADL, which have as their base of motor capabilities the reach-to-grasp, grip, and manipulation of objects[8]. After stroke, patients have difficulty adjusting strength to the demands of activities, which hamper fine movement control to perform specific tasks, such as manual activities[9].

The capacity of voluntary hand movement is an important parameter to be evaluated in patients after stroke, since it is related to the recovery prognosis of the upper limb as a whole[6]. Based on clinical observation of a small number of patients, Katrak et al.[10] reported that hemiparetic patients who could shrug their shoulders and had minimal synergistic flexion of the fingers soon after stroke achieved good hand movements. Thus, these authors proposed to elaborate the hand movement scale (HMS). Although the psychometric data of HMS have not yet been studied, some researchers have used HMS in their studies, such as Smania et al.[11], Soares et al.[6,12] and Woellner et al.[13], to assess the movement capacity of the hand.

Given one of the most common and limiting alterations of post-stroke – spasticity – and the importance of active hand movement for its functionality, our study aimed to verify the relation between upper limb spasticity and hand movement capacity in the affected hemibody of patients who suffered stroke. As hypothesis, we believe that the higher the degree of spasticity in the upper limb of the patients, the lower their ability to move the hand.

METHODOLOGY

This is a cross-sectional quantitative study with a correlational design and a selected sample for convenience. It was conducted with patients with stroke sequelae attended at the Neurofunctional Physiotherapy Outpatient

Clinic, associated to the Neurovascular Clinic of the Hospital de Clínicas de Porto Alegre (HCPA), after being discharged from the Stroke Hospitalization Unit. All participants signed the informed consent form (ICF).

For the sample selection, the following inclusion criteria were adopted: having suffered only one stroke; having been affected by stroke for a maximum of six months; preservation of cognitive and sensitive functions; and being over 18 years old. Exclusion criteria were the following: having other associated neurological pathologies and showing shoulder subluxation/dislocation in the hemibody affected by stroke.

Procedures for collection and data analysis

The screening began with the review of the medical records to investigate the cognitive status of the patient using the National Institutes of Health Stroke Scale (NIHSS)[14,15], conducted at the hospital admission. To be included in the study, the patient should score zero in the categories: level of consciousness (1a), coherence in response to questions (1b) and command (1c), evidencing the maintenance of cognitive function after stroke.

Hand sensitivity was evaluated via Fugl-Meyer scale, using sensitivity domains that are divided into exteroceptive and proprioceptive[16]. In the evaluation of exteroceptive sensitivity, after bilateral touch in the tested regions – anterior and posterior region of the thumb and index finger – the patient was asked if he felt a difference between the sides. The answer was then classified as: anesthesia (0); difference between the two limbs — hypo or hypersensitivity — (1); normal sensitivity, equal between the two members (2). The patient should score two for the four regions tested, thus evidencing the maintenance of exteroceptive sensitivity. In the evaluation of proprioceptive sensitivity, after each movement tested in the affected hand – abduction, adduction, opposition, and thumb extension, colloquially denominated as opening, closing, going forward and going backwards, respectively – the patient was asked what movement was performed and, at the end, his/her answer was measured in: absence (1), that is, all the wrong answers; at least 75% of the correct answers (2); all the correct answers (3). To be included in the study, the patient should score two or three in this test. Moreover, these evaluations were already part of the routine of the Neurofunctional Physiotherapy Outpatient Clinic.

After signing the ICF, the patients were evaluated in relation to spasticity using the modified Ashworth scale[17], in which the patient was placed in supine position and the evaluator passively performed the total movement of abduction with horizontal extension of the shoulder, extension of the elbow, supination of the radioulnar joint, extension of the wrist and fingers, as well as the passive thumb extension movement of the affected upper limb. Neuromuscular response was measured once in each joint and measured in: eutonia (0); increased tone at the beginning or end of the arc of motion (1); increase in tone in less than half of the arc of motion, manifested by abrupt tension and followed by minimal resistance (1+); increase in tone in more than half of the arc of motion (2); bending or extension parts and moved with difficulty (3); rigid parts in flexion or extension (4). After the evaluation, spasticity was classified as follows: discrete to grades 1 and 1+, moderate to grades 2 and 3; and severe to grade 4. The intra-examiner reliability of the scale was considered adequate to excellent (kw=0.77–0.84), depending on the joint evaluated when used in the upper limb in stroke patients[18].

The hand movement capacity was evaluated using the hand movement scale[10]. For its application, the evaluator asked the patient to perform a sequence of movements with the fingers of the affected hand, after demonstrating the movements with his/her own hand, according to the scale protocol. The capacity for voluntary hand movement was then classified into the following grades: grade 1, ie, no active movement of the fingers; grade 2, which indicated active flexion of all fingers in synergy; grade 3, ie, active flexion and extension of all fingers in synergy; grade 4, representing the ability to extend the index finger, keeping the other fingers in flexion; grade 5, that is, the ability to make the opposition of the thumb with the index finger; grade 6, which denotes the ability to perform the opposition of the thumb with the other fingers. Screening and complete evaluation of each patient were performed in a single meeting and by only one previously trained evaluator.

After collecting this information, the patients received guidance for home exercises, recommended according to their physical deficits, which were evaluated in the data collection, and according to the follow-up routine of the Neurofunctional Physiotherapy Outpatient Clinic at the HCPA, where the patient was invited to participate in the study. Moreover, participants were provided a feedback on the evaluation and, when necessary, an indication and/or referral for physiotherapy care.

Statistical analysis

A sample measurement was performed in the G*Power 1.1.7 software, using exact tests — correlation test, normal bivariate model — and assuming a correlation of 0.5, an alpha of 0.05 and a power of 95%. In total, 46 patients were needed, but predicting a sample loss of one patient (2.1%), the sample consisted of 47 patients.

The description of the continuous quantitative variables was executed by mean and standard deviation — age and time of stroke. In the quantification of gender and type of stroke, the simple frequency was used. Kendall's rank correlation coefficient was used to correlate the variables, considering a significance level of 5% ($p \leq 0.05$).

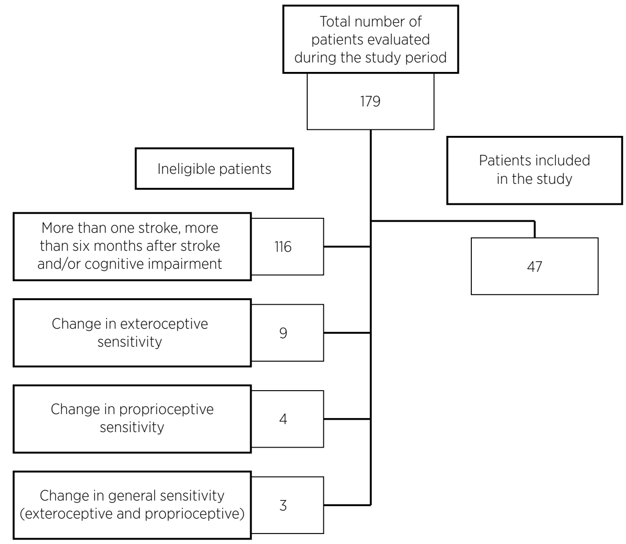


Figure 1. Flowchart of patients evaluated during the study period

RESULTS

During the study period, a total of 179 patients were evaluated at the Neurofunctional Physiotherapy Outpatient Clinic. Figure 1 shows the flowchart of patients evaluated during the study period and the reasons for inegibility.

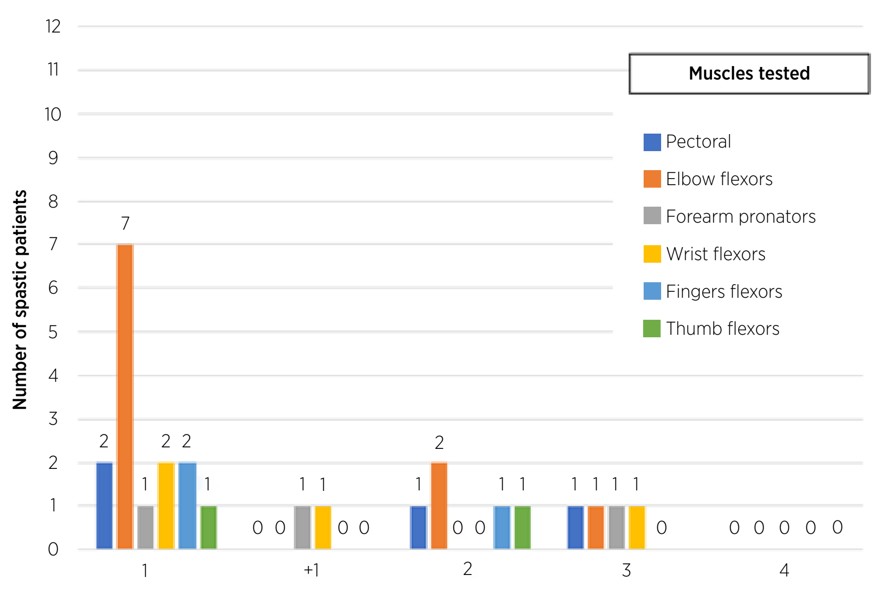
A total of 47 students participated in the study. Table 1 shows the characteristics of the sample.

Of the 47 patients evaluated, 35 (74.4%) showed no spasticity in any muscles evaluated in the upper limb, while 12 (25.5%) showed spasticity in some musculature. Graph 1 shows the distribution of patients by degree of spasticity in each muscle tested.

Table 1. Sample characteristics

	n (%)
Gender (men/women)	27 (57.4%)/20 (42.5%)
Age in years (mean±SD)	64.5±13
Stroke (ischemic/hemorrhagic)	43 (91.4%)/4 (8.5%)
Stroke time in months (mean±SD)	2.7±1.8
Thrombolysis	9 (20.9%)
Affected hemibody (left/right)	21 (44.6%)/26 (55.3%)
Dominance (left/right)	3 (6.3%)/44 (93.6%)
Affected on the dominant side	24 (51%)

n: number of patients; SD: standard deviation.



Graph 1. Distribution of patients by degree of spasticity in each muscle tested.

1 and 1+: discrete spasticity; 2 and 3: moderate spasticity; 4: severe spasticity.

Most patients — 41 (87.2%) — showed a score of six in the HMS (HMS mode=6). Table 2 shows the hand movement capacity of the evaluated patients.

Table 2. Values of hand movement scale obtained in patients

HMS (scores)	n
1	2 (4.2%)
2	2 (4.2%)
3	1 (2.1%)
4	0
5	1 (2.1%)
6	41 (87.2%)
Total	47 (100%)

HMS: hand movement scale; n: number of patients.

As for the correlation between the degree of spasticity of the upper limb and the ability to actively move the hand, the latter showed a significant negative correlation with spasticity for all muscle groups evaluated (Table 3), i.e., a low correlation with thumb flexors, moderate with pectoral musculature, elbow flexors and forearm pronators, and high with wrist flexors and finger flexors.

Table 3. Correlation between active hand movement and spasticity in the muscles of the upper limb

	HMS	
Musculature evaluated	r	p
Pectoral	−0.383	0.007
Elbow flexors	−0.339	0.016
Forearm pronators	−0.460	0.001
Wrist flexors	−0.588	<0.001
Fingers flexors	−0.692	<0.001
Thumb flexors	−0.261	0.069

HMS: hand movement scale; r: Kendall's rank correlation coefficient (0.1: low correlation; 0.3: mean correlation; 0.5: high correlation); p: significance level.

From the correlations shown in Table 3, we can observe that the lower the spasticity in the muscles of the affected upper limb, the greater the voluntary movement of the hand in the acute phase after stroke in the group of patients studied.

DISCUSSION

The motor signs of stroke patients can be divided into signs of pyramidal release — spastic hypertonia, hyperreflexia, clonus, and changes in skin reflexes — and deficient signs — alteration in voluntary and selective control of movements and muscle weakness[19]. In the early stages of recovery after stroke, deficit signs predominate, while spasticity develops in intermediate stages[20].

Spasticity was investigated in this study with the modified Ashworth scale, while hand movement capacity was measured by HMS. We observed that most patients evaluated showed no spasticity, thus being classified as eutonic in the upper limb. Additionally, most patients in the study showed voluntary ability to move the preserved hand, being able to perform all the movements requested by HMS.

Considering that the size of the cortical representation area is proportional to the use of the limb, Escarcel, Müller and Rabuske[21] state that physical therapy, when initiated in the acute phase, provides faster functional improvement. In our study, all patients were treated by physiotherapy in the acute phase at the HCPA Stroke Unit, which constitutes the gold standard in acute stroke rehabilitation. Thus, we can infer that patients tended to better recover deficits, since they received adequate treatment.

Kwakkel, Kollen and Twisk[22] studied the impact of time on the recovery of 101 hemiparetic stroke patients and observed that 16% of initial recovery is spontaneous – six to 10 weeks – and that the greatest recovery occurs in the first three months. In our study, the time after the involvement was, on average, 2.7 months, characterizing the initial phase of stroke – from one day to three months[23] – and, therefore, falling within the spontaneous recovery window mentioned.

Besides these factors, we must consider the stroke severity, as it relates to the area and extent of the brain injury and the consequent deficits. A slight severity indicates a smaller affected brain area, causing smaller deficits[14,15]. This could explain why most patients in this study did not show any tonic alterations in the upper limb, but demonstrated total ability to move the hand. However, our study has limitations, since it did not verify the information regarding severity, which can be measured by the NIHSS scale, performed at the time of discharge from the hospital unit.

As observed, most of the sample did not show spasticity and showed total hand movement capacity. This profile can be explained by a possible severity, although discrete, in the group of patients studied, by the adequate care performed in the acute phase and by the spontaneous recovery that occurs after the stroke itself.

The participation of patients who mostly did not have spasticity in the upper limb was a limitation of this study.

The evaluated patients did not present different degrees of spasticity, which, from a methodological point of view, would be ideal to characterize a more heterogeneous sample composed of patients with stroke sequelae with mild, moderate, and severe degrees of spasticity.

Regarding the correlation between the spasticity of each musculature and the ability to move the hand, we observed that patients who showed spasticity in the upper limb also showed poor active hand movement. There was a moderate negative correlation with the pectoral musculature and the elbow flexors and pronators and a high negative correlation with the wrist and finger flexors.

Decades ago, Twitchell[20] established a sensorimotor recovery gradient in the proximo-distal direction for hemiparetic patients after a stroke. This distally higher involvement profile was also observed by Paz, Marães, and Borges[7].

Correia et al.[24] observed that patients who had their joints released from the static limitations caused by spasticity tended to have a greater ability to move them, in accordance with our results, since we suggest that when there is spasticity, there is difficulty in moving the segments, especially in the distal extremity of the upper limb.

We can explain post-stroke muscle weakness by the loss of motor unit activation, changes in recruitment order and firing frequency[25]. Because of impaired motor function, changes occur in the coordination of movements, as well as spasticity, abnormal synergistic movements, and decreased mobility[26]. The slow increase in muscle tone after stroke suggests a set of plastic changes and is currently attributed more to changes in the biomechanical properties of tissues due to disuse than to neurophysiological changes[7].

Spasticity is related to peripheral changes in skeletal muscle and associated connective tissue, increasing muscle fiber stiffness and, consequently, generating shortenings, muscle contractures, joint stiffness, and bone deformities that further limit normal motor function[27]. Immobility, caused by negative factors of upper neuron injury, generates increased muscle tonicity in shortened muscles[28].

Paz, Marães and Borges[7] exemplify the influence of spasticity on the movement of segments, stating that spasticity in elbow flexor muscles would make it impossible to coordinate the movements of elbow extensor muscles during reach activities. Thus, we can infer that the presence of spasticity in the antagonist muscles would hinder the onset of the active movement of the agonist musculature, as it would increase the stretching resistance of the spastic muscle, interfering the voluntary motor control of the hand as a whole.

Changes in strength, coordination and muscle tone — added to the adaptive characteristics of stroke due to disuse of the segment, such as shortenings, contractures and deformities in the upper limb — difficult a person to perform functional activities[25].

Thus, it is understood that spasticity itself influences the inability to move the hand because it hinders the coordination of the agonist and antagonist muscles for functional activities, but also that, as spasticity is established, other musculoskeletal changes resulting from immobility begin to emerge, further impairing motor control.

Soares et al.[6] also observed that spastic patients show little hand movement. However, in their study, they measured the spasticity of the flexor muscles of the elbow, wrists and fingers, and made an average spasticity of the limb as a whole in 43 patients with an average stroke time of 22 months, that is, patients in the chronic phase. On the other hand, our study, whose patients had an average stroke time of 2.7 months, characterizing the sample still in the initial phase of stroke, correlated the spasticity of each musculature separately with the ability to move the hand, indicating that there is a greater correlation with the dislocated muscles of the upper limb.

The capacity of voluntary hand movement is an important parameter to be evaluated in patients after stroke, since it is related to the prognosis of recovery of the upper limb as a whole[6]. Although the psychometric data of HMS have not yet been studied, we choose to use it due to other studies has already used this scale to evaluate hand movement after stroke.

Soares et al.[6] also indicate that HMS has a good correlation with manual dexterity tests, such as the nine-hole peg test and the box and blocks test, which allow estimating the functionality of the upper limb. Subsequently, these authors conducted a study to analyze the predictive value of handgrip dynamometry for the recovery of the paretic upper limb by stroke, using HMS to evaluate the ability of active hand movement. The results showed that manual dynamometry has a good correlation with HMS[12].

HMS was also used as a measure of hand motricity to evaluate the effects of task- specific training of reaching and grasping the hemiparetic upper limb[13]. To evaluate whether four of the upper limb recovery rates — performed at the bedside in a simple way — could predict the levels of autonomy in activities of daily living, Smania et al.[11] also choose to use HMS.

Given the importance of the upper limb in functional independence and the physical barriers that stroke sequelae impose to return to function, our study aimed to investigate the influence of upper limb spasticity on voluntary hand movement capacity and we were able to observe that occurs, in fact, an intrinsic relationship between the two variables.

The contribution of our study was to analyze separately the correlation between the spasticity of each musculature and the ability to move the hand, indicating that there is a greater correlation in the dislocated muscles of the upper limb. Moreover, we used HMS, an accessible instrument which can be used without extensive training and is of rapid application for the physiotherapist's care routine at any level of activity. As the scale has a good correlation with other manual dexterity tests[6] and with manual dynamometry[12], it is suggested the use of HMS as an instrument to predict the recovery of the paretic upper limb by stroke, as well as to perform further studies to verify the psychometric data of HMS, which still lack in the literature.

From the correlation between the appearance of upper limb extremity spasticity with active hand movement, we believed that it is possible to establish a recovery prognosis still in the initial phase of rehabilitation of patients who have suffered stroke. We proposed to use approaches in physiotherapy that stimulate the voluntary movement of the hand of patients in the post-stroke period from the initial phase to avoid the emergence of spasticity and musculoskeletal complications resulting from immobility, which can interfere in the acquisition of voluntary movement of the upper limb affected by stroke.

CONCLUSION

Our study demonstrates that patients who show no spasticity in the upper limb affected by stroke — or show it to a lesser extent — have a greater ability to move the hand. We concluded that the greater the spasticity in the upper limb affected by stroke, the lower the capacity of voluntary movement in the hand.

Our data show how spasticity and hand movement capacity correlate, as well as demonstrate the need to evaluate these variables in the initial phase of stroke and the importance of establishing conducts for their treatment in the rehabilitation process of patients.

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