

Analysis of muscle activation during reaching movement in active, active-assisted and self-assisted conditions in post-stroke patients

Análise da ativação muscular durante o movimento de alcance nas condições ativo, ativo-assistido e autoassistido em pacientes pós-AVE

Análisis de la activación muscular durante el movimiento de alcance en las condiciones activo, activo-asistido y auto-asistido en pacientes post-AVE

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ABSTRACT | A cerebrovascular accident (CVA) is a disease that often causes upper limb motor limitations and functional losses in reaching movements. The objective of this study was to analyze the muscle recruitment of the paretic upper limb during three reaching conditions: active, active-assisted and self-assisted, through electromyographic data of anterior fibers of Deltoid Muscle (DM), Biceps Brachii (BB) and Triceps Brachii (TB). Cross-sectional study that used as clinical trials the Mini-Mental State Examination, Berg balance scale, functional independence measure, the modified Ashworth scale, and the Fugl-Meyer assessment – upper limbs section. Surface electromyographic data were collected using the electromyograph and bipolar electrode configuration of the EMG System do Brasil with three channels positioned in the motor points of DM (anterior fibers), BB and TB of both upper limbs. Clinical variables showed mild motor, cognitive, and functional impairment. Electromyographic data showed that DM and TB contracted more during active-assisted than

during self-assisted exercise ($p < 0.05$). DM and TB presented significant differences during reaching movements, while the BB muscle showed no changes. Among the different reaching exercises, the active-assisted was the one that provided greater muscle activation. Clinical trials are suggested to verify the effectiveness of the training.

Keywords | Stroke; Electromyography; Rehabilitation; Physical Therapy Specialty.

RESUMO | O Acidente Vascular Encefálico (AVE) é uma patologia que frequentemente causa limitações motoras nos Membros Superiores (MMSS) gerando prejuízos funcionais nos movimentos de alcance. O objetivo do estudo foi analisar o recrutamento muscular do membro superior parético durante três condições de alcance: ativo, ativo-assistido e autoassistido, através de dados eletromiográficos das fibras anteriores do Músculo Deltoide (MD), Bíceps Braquial (BB) e Tríceps Braquial

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(TB). Estudo do tipo transversal que utilizou como testes clínicos o minixame do estado mental, escala de equilíbrio de Berg, medida de independência funcional, escala modificada de Ashworth e escala de Fugl-Meyer – seção MMSS. A coleta dos dados eletromiográficos de superfície foi realizada utilizando-se o eletromiógrafo e eletrodos de configuração bipolar da EMG System do Brasil com três canais posicionados nos pontos motores do MD (fibras anteriores), BB e TB de ambos os membros superiores. As variáveis clínicas apresentaram resultados de comprometimento motor, cognitivo e funcional leves. Os dados eletromiográficos mostraram que o MD e TB durante o alcance ativo-assistido contraíram mais que no alcance autoassistido ($p < 0.05$). Os MD e TB apresentaram diferenças significativas durante os movimentos de alcance, enquanto que o músculo BB não mostrou alterações. Entre os diversos tipos de alcance, o ativo-assistido foi o que proporcionou maior ativação muscular. Sugere-se que sejam feitos ensaios clínicos para verificar a eficácia dos treinamentos.

Descritores | Acidente Vascular Cerebral; Eletromiografia; Reabilitação; Fisioterapia.

RESUMEN | El Accidente Vascular Encefálico (AVE) es una patología que frecuentemente causa limitaciones motoras en los Miembros Superiores (MMSS) generando perjuicios funcionales en los movimientos de alcance. El objetivo del estudio fue analizar

el reclutamiento muscular del miembro superior parético durante tres condiciones de alcance: activo, activo-asistido y auto-asistido, a través de datos electromiográficos de las fibras anteriores del Músculo Deltóide (MD), Bíceps Braquial (BB) y Tríceps Braquial (TB). Estudio del tipo transversal que utilizó como pruebas clínicas el mini-examen del estado mental, escala de equilibrio de Berg, medida de independencia funcional, escala modificada de Ashworth y escala de Fugl-Meyer – sección MMSS. La recolección de los datos electromiográficos de superficie fue realizada utilizando el electromiografo y electrodos de configuración bipolar de la EMG System de Brasil con tres canales colocados en los puntos motores del MD (fibras anteriores), BB y TB de ambos miembros superiores. Las variables clínicas presentaron resultados de compromiso motor, cognitivo y funcional leves. Los datos electromiográficos mostraron que el MD y el TB durante el alcance activo-asistido contrajeron más que en el alcance auto-asistido ($p < 0.05$). Los MD y TB presentaron diferencias significativas durante los movimientos de alcance, mientras que el músculo BB no mostró alteraciones. Entre los diversos tipos de alcance, el activo asistido fue el que proporcionó mayor activación muscular. Se sugiere que se realicen ensayos clínicos para verificar la eficacia de los entrenamientos.

Palabras clave | Accidente Cerebrovascular; Electromiografía; Rehabilitación; Fisioterapia.

INTRODUCTION

Reach to grasp movements with affected upper limb in post-Accident Cerebrovascular patients (CVA) are usually deficient due to dysmetria, lack of coordination, speed reduction and decrease of elbow and wrist dislocation, as well as abnormal patterns of muscle activation due to strength deficit and/or proprioception¹. The presence of exaggerated co-contraction of antagonist muscles during the chronic stage of the disease is common in these patients².

Due to excessive activations of some muscles, the biomechanics of the reaching movement is impaired, which may, for example, generate elevation and abduction of the scapula even before starting the movement, in addition to the difficulty of extending the elbow because of this speed-dependent reflection of the biceps brachii muscle³.

The neural mechanisms underlying the spasticity include regulation deficits of inhibitory reflex pathways and hyperexcitability of a^4 motoneurons, reinforced by

damage to the upper motor neuron pathways⁵. Among the dysfunctions caused by the spasticity there are the compensations used to improve motor functions⁶ and coordination⁷.

Despite these dysfunctions caused by CVA, many patients recover their dislocation functionality; however, about 30 to 66% of them are not able to use the affected arm and less than 15% of patients undergoing rehabilitation of upper limbs get a complete motor recovery for activities of daily living. The improvement of motor function of the paretic upper limb is directly linked to the intensity of the therapeutic practice⁸, because the specific training increases cortical representation and, consequently, the functional recovery⁹.

In the physiotherapy practice, it is possible to train unimanual and bimanual reaching. Previous studies have reported that the training of unimanual reaching may promote neuroplasticity in the hemisphere affected and also bilateral cortical activation of the motor areas, suggesting that the corticospinal tract, ipsilateral to the affected hemibody, may contribute to the control of post-stroke

movements, thus improving motor learning¹⁰. As well as the unimanual trainings, bimanual exercises are also based on the bilateral activation of the cerebral hemispheres and on the aid of unaffected ipsilateral tracts. This kind of training decreases the interhemispheric transcalsal inhibition through symmetrical bilateral tasks, and it can activate both hemispheres at the same time¹¹.

Some strategies of adaptation to the reaching movement can be created by the therapist, for example, self-assisted and active-assisted movements to the manual practice of reaching. However, it is not yet clear if the aid activities in these types of movements are able to interfere on the muscle recruitment of the paretic upper limb.

The aim of this study was to analyze the muscle recruitment of the paretic upper limb during three reaching conditions: active, active-assisted and self-assisted through electromyographic data of anterior fibers of deltoid, biceps and triceps brachii muscles.

METHODOLOGY

Cross-sectional study that followed the recommendations of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement¹². The study was held in Santa Cruz, Rio Grande do Norte, in the Laboratory of Human Kinetics of Faculdade de Ciências da Saúde do Trairi (FACISA) at Universidade Federal do Rio Grande do Norte (UFRN), approved by the Ethics Committee (FACISA/UFRN) with opinion no. 851,186/2014.

The study included subjects who presented clinical diagnosis of CVA, aged ≥ 18 years, who were not bedridden, with good sitting balance (Berg > 46)¹³ and no cognitive problems, according to the Mini-Mental State Examination (MMSE)¹⁴. Those who presented subluxation of the paretic upper limb, severe rheumatic disease, amputations and orthopedic pain in upper limbs were excluded. All subjects who agreed to participate in the research signed the informed consent form. All assessments occurred in two consecutive days, one for the clinical assessment and the other for the electromyographic collection. They were performed by a trained staff, familiar with the scales and with the electromyograph.

For sociodemographic data collection, patients were interviewed to obtain information such as age, sex, injury time, number of CVAs, dominance, and affected hemibody. Then clinical trials were conducted using the MMSE¹⁴, Berg Balance Scale (BBS)¹⁵, Functional

Independence Measurement (FIM)¹⁶, Modified Ashworth Scales (MAS)¹⁷, and Fugl-Meyer Assessment – upper limbs section¹⁸.

Surface electromyographic data were collected using the electromyograph and bipolar electrode configuration of the EMG System do Brasil[®] with three channels positioned in the motor points of Deltoid Muscle (DM) (anterior fibers), Biceps Brachii (BB), Triceps Brachii (TB) of both upper limbs following the standardization of Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM)¹⁹. The electrodes were fixed after trichotomy and asepsis with hydrated alcohol at 70%.

During the entire procedure, patients remained seated, with flexion of hip and knee at 90° and trunk stabilized in the back of the chair. Before all the electromyographic collections, the Maximum Isometric Voluntary Contraction (MIVC) of the muscles assessed was measured. Everybody performed three repetitions per muscle with isometric contraction of six seconds, alternating the muscle at each contraction. For MIVC, patients remained seated and flexed the shoulder, so the data on anterior fibers of DM were measured; elbow flexion, to assess the BB muscle activation; and elbow extension, to assess the TB muscle activation. The whole procedure was done with shoulder abducted at 90° and rotated internally at 30° against manual resistance of one trained assessor.

For the specific reaching movement, the paretic arm was aligned with shoulder abduction at 30° and elbow at 90°, resting on a support. The distance from the target was the functional arm length calculated by the distance from the axillary line to the fold of the wrist by a tape measure. From the xiphoid process of the sternum, the distance obtained was measured and the target location was found. The data of the non-paretic limb were collected only after the (non-paretic) active reaching movement.

Three movements were made: active, active-assisted, and self-assisted reaching. All movements were made with a comfortable speed by the paretic upper limb. Three sets of 15 seconds were held for each type of reaching, with two-minute intervals for each set. In active reaching, the patient performed the (active paretic) movement with the paretic upper limb without help from the therapist. Self-assisted exercise was performed with help from the non-paretic upper limb, whose support was held on the fold of the wrist by the patient him/herself. For the active-assisted movement, the support was made by the

therapist in the olecranon region and fold of the wrist of the paretic limb.

EMG signals were collected with 4000Hz frequency, amplitude of -1 and 1mV, with no rectification and preprocessed, using a Butterworth filter of 4th order (20-400 Hz). The values used were obtained through the Root Mean Square (RMS).

Statistical analysis

The RMS of the MIVC was used as normality pattern (100%), being extracted the proportional percentage of electrical muscle activation from other collections.

The normality of the data was verified using the Shapiro-Wilk test. The values were expressed in median and interquartile intervals, considering the first interval (25% – 1Q) and the third interval (75% – 3Q). For the analyses between the three reaching movements and the three muscles, the Friedman test was used with post-hoc of Dunn. The values of each muscle group analyzed by MAS (elbow flexion and extension muscles and shoulder flexion muscles) were added to a single value.

RESULTS

The sample was composed of 12 people. Table 1 shows the clinical and sociodemographic data.

Table 1. Demographic and clinical variables

Variables	N	Median	1Q	3Q
Age (years)	12	63	58.5	67.5
Sex (F/M)	4/8			
Injury time (years)		7.5	3.25	9.5
Number of CVA cases				
1	11			
2	1			
Manual dominance (R/L)	10/2			
Affected Hemibody (R/L)	4/8			
MMSE		26	21.75	28.25
BBS		50.5	48	52
Motor FIM		82	79.75	86.5
Cognitive FIM		34	30.5	35
Total FIM		115.5	111	119.25
Fugl-Meyer upper limbs		40.5	29.5	59
MAS		3.0	1.0	4.0

N: Total number; F: Female; M: Male; CVA: Cerebrovascular accidents; R: Right; L: Left; MMSE: Mini-mental state examination; BBS: Berg Balance Scale; motor FIM: Motor part of the functional independence measure; Cognitive FIM: Motor part of the functional independence measure; Upper limbs: Upper limbs section; 1Q and 3Q: 1st Quartile and 3rd Quartile; MAS: Modified Ashworth Scale.

Table 2 shows the comparison between the results of active paretic, active-assisted and self-assisted movements

made by the paretic upper limb of DM, BB and TB muscles. We noted that DM showed higher activation in active-assisted movement compared with the self-assisted one (p=0.04), while the TB showed higher activation in the active-assisted movement compared with the active paretic and self-assisted ones (p=0.001).

Table 2. Analysis of biceps, deltoid and triceps muscle contractions in different reaching movements.

Movements	Biceps	Deltoid	Triceps
Paretic active	73.5 (29.4-150.4)	38.8 (20.6-67.5)	82.1 (12.9-215)
Active-assisted	58 (35.3-223.9)	61.1 (37.5-91.3)	101 (45.7-236.8)
Self-assisted	33.5 (23-102)	22.6 (11.5-49.8)	39.9 (12.8-186.7)
P-value	0.12	0.04	0.001

Values expressed in percentages (extracted from RMS, normalized by MIVC) and presented in mean and interquartile range 25%-75%. Bold shows the statistical significance of differences.

Regarding active reaching by non-paretic limb, anterior fibers of DM showed significant difference in activation when compared with the active-assisted movement (in bold) (p=0.002). Also, TB showed differences in activation between active-assisted and self-assisted movements (in bold) (p=0.02). Table 3 show all data.

Table 3. Analysis of biceps, deltoid and triceps muscle contractions in different reaching movements, comparing them with non-paretic limb contraction

	Biceps	Deltoid	Triceps
Non-paretic active	41.7 (21.8-88.2)	17.3 (11.7-36.9)	82.5 (5.9-193)
Paretic active	73.5 (29.4-150.4)	38.8 (20.6-67.5)	82.1 (12.9-215)
Active-assisted	58 (35.3-223.9)	61.1 (37.5-91.3)	101 (45.7-236.8)
Self-assisted	33.5 (23-102)	22.6 (11.5-49.8)	39.9 (12.8-186.7)
P-value	0.08	0.002	0.02

Values expressed in percentages (extracted from RMS, normalized by MIVC) and presented in mean and interquartile range 25%-75%. Bold shows the statistical significance of differences.

DISCUSSION

This study analyzed the muscle recruitment of the paretic upper limb of post-stroke individuals during active, active-assisted and self-assisted reaching, through electromyographic data of anterior fibers of DM, BB and TB. All clinical variables measured showed results of mild motor, cognitive, and functional impairment. Electromyographic data showed that anterior fibers of DM and TB in active-assisted reaching contracted more than in the self-assisted one, showing that active-assisted reaching had better results (greater recruitment) among the muscles analyzed.

Spasticity and strength reduction are some of the main causes that promote synergies in the reaching movement, which can reduce functionality and incur a loss of selective activity in the various muscle groups of the upper limbs. The electromyographic results of BB muscle, which did not show statistical significance in active, active-assisted and self-assisted conditions, corroborate recent data supporting the hypothesis that the high degree of spasticity of this muscle can trigger spontaneous discharges, which are kept in rest and excited even with a slight muscle stretch²⁰. In addition, these patients have difficulty in maintaining TB muscle strength constant during voluntary contraction of paretic muscles, resulting in a wide range of EMG signs²¹.

Studies show that, unlike injuries that affect the rubrospinal tract and spinal tract (brain stem lesions), lesions in the corticospinal tract affect distal muscles. However, our results show a significant difference in the data of the proximal DM muscle, which may be related to the degree of injury²².

The RMS values of anterior fibers of DM and TB were significantly higher during active-assisted reaching performed by the paretic limb compared with the active reaching movement by the non-paretic limb. Corroborating these results, some authors indicate that changes in motor recruitment during active movements of the paretic upper limb can be attributed to the increased activity of the BB muscle, in addition, there is an ineffective modulation of motor units, which reduces the number of activations, generating a need for more motor recruitment to perform the movement²³. Our results are in agreement with that information, as we also hypothesize there may have been an excessive contraction during the active-assisted movement and/or some influence of the therapist's hand for assistance.

Regarding the action of the TB muscle during the reaching movement, we highlight the importance of maintaining the coaptation of the elbow because of its distal ulna insertion that promotes stability in the flexoextension of this articulation²⁴, so its performance as synergist in the flexoextension movement of the elbow is essential¹. This study found that post-stroke patients showed lower values of RMS of the TB muscle when they executed the self-assisted reaching movement compared with the active-assisted one. This can be justified by the great assistance given by the non-paretic limb, in an attempt to perform the movement more quickly. Corroborating this claim, some authors have noted that there is a difference in

the speed of the movement performed by both upper limbs in unimanual and bimanual tasks. Therefore, the interpretation made is that the non-paretic limb, changing its speed and strategy, can help the limitations of the paretic limb²⁵.

The limitations of this study include the small sample size, which may have turned the data into nonparametric data.

CONCLUSION

DM and TB muscles showed differences during the reaching movements (active, active-assisted and self-assisted), while the BB muscle showed no significant changes. The active-assisted exercise provided greater muscle activation, so it must be considered in the choice of treatment of post-stroke patients. We suggest that clinical trials are made to verify the effectiveness of this type of reaching on the muscles of the paretic upper limb of post-stroke patients.

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