Article
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The surface electromyography analysis of the non-plegic upper limb of hemiplegic subjects

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ABSTRACT

Many authors have studied physical and functional changes in individuals post-stroke, but there are few studies that assess changes in the non-plegic side of hemiplegic subjects. This study aimed to compare the electromyographic activity in the forearm muscles of spastic patients and clinically healthy individuals, to determine if there is difference between the non-plegic side of hemiplegics and the dominant member of normal individuals. 22 hemiplegic subjects and 15 clinically healthy subjects were submitted to electromyography of the flexor and extensor carpi ulnaris muscles during wrist flexion and extension. The flexor muscles activation of stroke group (average 464.6 u.n) was significantly higher than the same muscles in control group (mean: 106.3 u.n.) during the wrist flexion, what shows that the non affected side does not present activation in the standart of normality found in the control group.

Key words: muscle spasticity, surface electromyography, hemiplegia.

Análise da eletromiografia de superfície do membro superior não plégico de hemiplégicos

RESUMO

Muitos autores estudaram as modificações funcionais e físicas em indivíduos pós-acidente vascular cerebral; porém, poucos estudos avaliam alterações no hemicorpo não plégico de indivíduos hemiplégicos. O objetivo deste estudo foi comparar a atividade eletromiográfica nos músculos do antebraço de pacientes espásticos e indivíduos clinicamente saudáveis, para averiguar se há diferença entre o lado não plégico de indivíduos hemiplégicos e o lado dominante de indivíduos clinicamente saudáveis. 22 indivíduos hemiplégicos e 15 clinicamente saudáveis foram submetidos à eletromiografia dos músculos flexor e extensor ulnar do carpo durante a flexão e extensão do punho. A ativação dos músculos flexores dos hemiplégicos (média: 464,6 u.n), foi significantemente maior que nos indivíduos do grupo controle (média: 106,3 u.n) durante o movimento de flexão do punho, o que demonstra que o hemicorpo não acometido dos pacientes estudados não apresenta o comportamento padrão de normalidade encontrado no grupo controle.

Palavras-chave: espasticidade muscular, eletromiografia de superfície, hemiplegia.

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After a stroke, a lot of hemiplegic patients are able to walk during early rehabilitation, but most of them are unable to use their upper extremities in their activities of daily living (ADL), after months of standard occupational therapy and physiotherapy. It was estimated that 55% of stroke survivors have a non-functional upper extremity after initial therapy and that 30% of hemiplegics had some partial recovery of upper extremity function in terms of range of motion and strength, but are still unable to perform the daily activities with the affected limbs. It occurs because the motor

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recovery of upper limb of hemiplegics is known to occur mainly in the proximal upper limb (shoulder and elbow), but is always limited in the distal (wrist)[1,2]. These facts indicate the need for more studies in order to understand changes found in the upper limbs of hemiplegics, as well as therapeutic approach aimed at them[3].

It is known that the lesion in the motor cortex or corticospinal tract, as occurs in a stroke, can result in loss of movement on the contralateral side of the body, ranging from a transient weakness, decreased accuracy and strength or a complete and lasting paralysis, depending on the kind and extent of the injury. However, there is a growing trend that these losses are not only contralateral but also ipsilateral[4]. Perhaps these losses are related to the mode of division and crossing of the cortico-spinal fibers that are responsible for motor control. Passing by pyramidal decussation, some of the fibers continues ventrally, forming the corticospinal tract anterior or medial, and the remaining crosses to form the corticospinal tract side[5]. There is not a consensus in the literature about what percentage of fibers that does not cross, it is cited about 10 to 20%, and some authors suggest that part of that percentage does not cross at the pyramidal decussation, but crosses to reach the segment end. Thus, unlike the majority of studies have reported the involvement of a neurological injury is not exclusively in the contralateral side of lesion; the hemiplegia is installed contralateral to the brain damage, but the ipsilateral side to the lesion is also, in less proportion, affected[6-8].

Sunnerhagen et al.[9] relates in his study that more sensitive tests for hemiplegic patients are needed to detect changes in muscle function in the half-body without motor symptoms and the unaffected side should not be considered normal. The lower performance observed in the experiment on the side ipsilateral to the lesion could be the result of both lack of training on the unaffected hemisphere, or the fact that approximately 10% of descending motor pathways do not cross to the other side[9]. This explanation is supported by the results of Sinkjaer and Magnusson who found that the stiffness of the ankle reflex on the unaffected side was different from healthy subjects. In the clinical rehabilitation, the reduced performance of the unaffected limb should be considered to train functional procedures involving both extremities[10].

This study aimed to analyze the non-plegic side of hemiplegic individuals by surface electromyography, compared to the same movement in the dominant limb of normal subjects, in order to verify functional changes in the non-affected member.

METHOD

The focus of this study was the electromyographic analysis (EMG) of flexor and extensor carpi ulnaris for determining the degree of muscle activation during active movements of wrist flexion and extension. In both movements were evaluated both the agonist and the antagonist, to allow the calculation of the agonist-antagonist relationship.

Subjects

It was evaluated 37 individuals, divided into two groups: [i] hemiplegic group: 22 post-stroke hemiplegic patients - referred by physicians with a diagnosis of unilateral ischemic stroke with no other associated diseases - with 11.6±9 years of injury in mean, age of 64.2±11.7 years old, 16 males and 6 females individuals, 15 with right hemiplegia and 7 left; in this group the assessment was done in the non-plegic side and only individuals with spasticity degrees 0 to 2 in the Ashworth scale were evaluated, because the individuals with 3 and 4 degrees do not present range of movement; [ii] control group: 15 clinically healthy individuals, with no history of neurological disease, mean age (60.1±9.5 years old) similar to that of hemiplegic and able to obey simple commands, 8 males and 7 females, all with right-side dominant, which was evaluated. The individuals assessed prior have signed an informed consent form after receiving information about their participation in the study and the ethical implications involving the procedures proposed were approved by the Committee of Ethics in Research of FCT/UNESP (061/2005).

Instrumentation

For this experiment execution a support of PVC with wooden base was confectioned to locate the forearm in neutral position of prono-supination, in order to prevent interference with the instruments of measurement used and to allow that the wrist movements of flexion and extension occurred freely. And an electrogoniometer constituted by a linear potentiometer of precision of 10 KW that registers the angular position of the wrist articulation was developed and confectioned.

Signals were captured using 2 pairs of surface Ag/AgCl electrodes (Meditrace model of 3M), 10 mm in diameter. The electrodes had been located in parallel, separated between themselves for 20 mm. In the handle of the electrode is present a preamplifier circuit with gain of 20 times, CMRR (Common Mode Rejection Ratio) bigger than 80 dB and impedance of 1012 W.

All the signals had been caught in a conditioning signals module of Lynx, model EMG 1000. In this module a canal is configured to receive the signals from electrogoniometer and others two to receive the signals from EMG, presenting a digital filter type Butterworth, low-pass with frequency of 500 Hz and a high-pass with cut frequency of 20 Hz and final gain of 1000 times. All the

canals present frequency of sampling of 2000 Hz. The acquisition and storage of the signals in archives of data had been made by software Bioinspector 1.8 (Lynx®).

As it doesn't have in literature standardization of the positioning of the electrodes in forearm, the position was determined by the localization of motor points in the flexor and extensor carpi ulnaris muscles using an electro stimulator and an electrode type "pen". After the localization the electrodes had been located approximately 4 cm below of the point, prioritizing the region of the muscular womb.

Protocol

With the forearm in neutral position of prono-supination, the individual executed the movement of wrist extension and after that, the wrist flexion, with the non-plegic limb; and the individuals of the control group with the dominant side. Each movement was repeated ten times, in order to get an adequate amostral number.

Data processing and analysis

Extracted EMG signals of each cycle had been submitted to a digital filter band- pass type Butterworth, with order 4 and cut frequency of 20 and 500 Hz. After the filtering, it was gotten the linear wrap of the signal. The wraps gotten in the 10 cycles of extension and flexion had been normalized in the time and the amplitude. For the normalization in the amplitude the value of the average of the signal was used; and in the time, the interpolation of data by cubical splines. After the normalization it was gotten an average tracing of EMG signal of each muscle, for the 10 cycles of each movement. The IEMG (integral of electromyography signal) was tabulated and expressed in u.n. (normalized unit).

Initially, an exploratory analysis of the data through the application of descriptive statisticians was achieved to verify the profiles of the groups in study. After this, statistical tests were applied in order to verify differences between the groups (p-value<0.05). For comparisons that the distributions of the groups were normal, the t-student for unpaired samples was applied, however for those populations that the distribution was not Gaussian (determined by the normality test of Kolmogorov-Smirnov), Mann-Whitney Rank Sum Test was used.

RESULTS

Data were compared in two moments: flexion and extension. For it movement it was calculated the difference between the muscles and the agonist-antagonist relationship. The Table shows all the results and the statistical differences. For the comparisons with significantly difference, the graphs were plotted and are illustrated in Fig 1 and 2.

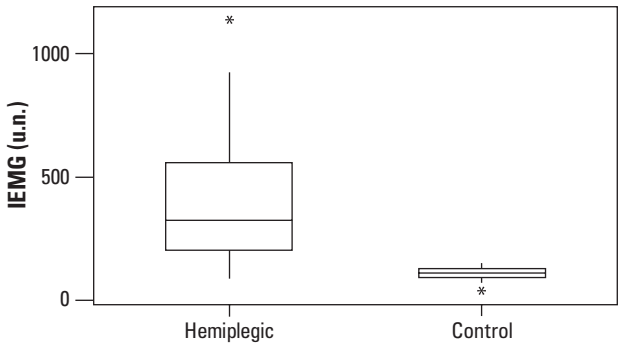

Fig 1. Comparison between flexor muscles (agonists) of hemiplegic and normal individuals during the wrist flexion.

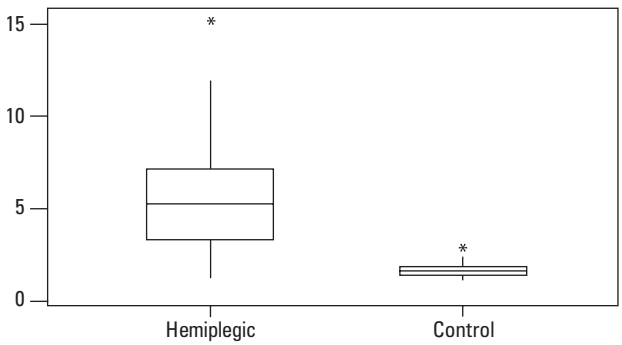

Fig 2. Comparison between agonist-antagonists relationship of hemiplegic and normal individuals during the wrist flexion.

Table. Values of mean and standard deviation (mean±SD, in u.n.) of evaluated muscles and agonist-antagonist relationships in the wrist flexion and extension movements separated into the groups (hemiplegic: non-plegic side evaluated; and control: dominant side evaluated).

Movement	Muscle	Hemiplegic	Control	p-value
Flexion	Flexor	418.6±290.7*	106.3±26.8*	< 0.0001
	Extensor	71.6±22.1	64.2±14.9	0.26
	Agonist-antagonist relationship	5.8±3.5*	1.6±0.4*	< 0.0001
Extension	Flexor	77.3±21.7	85.8±22.7	0.25
	Extensor	106.1±19.1	110.6±19.4	0.45
	Agonist-antagonist relationship	1.4±0.4	1.3±0.2	0.45

*Refers to statistical significantly differences

Flexion

The comparisons between the muscles revealed that the agonists (flexor) are much more activated in the hemiplegic patients (418.6±290.7 u.n.) when compared to clinically healthy individuals (106.3±26.8), the statistic test applied in this case was Mann-Whitney that showed significance between the groups ($p<0.0001$). This comparison is illustrated in the Fig 1. When the compared muscles were the antagonists (extensor), the difference were not significantly ($p=0.26$) by the t-student test; the hemiplegic group achieved 71.6±22.1 u.n. and the control group 64.2±14.9. Consequently, when applied Mann-Whitney test, the agonist-antagonist relationship was significantly different too ($p<0.0001$), the relation was 5.8±3.5 for hemiplegics and 1.6±0.4 for control group (Fig 2).

Extension

In this movement, the difference was not significantly for any comparison. In relation to the agonists muscles, the extensor of hemiplegic groups demonstrated an activation of 106.1±19.1 u.n. and for the control group the activation was 110.6±19.4 ($p=0.45$). The antagonists (flexor) showed an activation of 77.3±21.7 in the hemiplegic and 85.8±22.7 in the control ($p=0.25$). For these two comparisons it was used t-student test. For agonist-antagonist relationship, it was used the Mann-Whitney test and the difference was not significantly too ($p=0.45$), the relation was 1.4±0.4 for hemiplegic and 1.3±0.2 for control.

DISCUSSION

During the wrist flexion, it was observed an important difference of the non-plegic side of hemiplegics in relation to the clinically healthy individuals; while the individuals of control group presented a mean activation of 106.3 u.n. in the flexor ulnaris, the hemiplegic individuals presented, in their normal side, a mean of 464.6 u.n. during the same movement, resulting in a p-value<0.0001. In the antagonist muscles (extensor carpi ulnaris), it was not observed a significant difference. So, the agonist-antagonist relationship during the wrist flexion have presented significant difference between the groups; while in hemiplegic the mean relationship was 6.7, in control group it was 1.7 (p-value<0.0001). During the extension movement, there was no statistic difference between the evaluated groups.

These founds suggest that there is alteration in coordination and muscular compensation in the limb not affected by the stroke, showing that the non-plegic side of the hemiplegic individuals evaluated neither present the normal pattern found in the control group. It suggests that the central control of the motor units perhaps may be impaired, what contradicts a premise of some authors, that the motor units of the non-plegic limbs of subjects with hemiplegia were essentially normals[11].

Mirbagueri et al.[12] when studied the mechanical properties of upper and lower extremities of hemiplegic have observed changes similar to these. The hemiplegic individuals had intrinsic and reflex stiffness in the extremities less affected by stroke, larger than the control subjects. One possible explanation comes from the hyperexcitability of stretch reflexes in the non-paretic members and to the fact that the paths of the monoaminergic system are distributed bilaterally, and its activity may be increased due to stroke. Soon the corticospinal fibers that do not cross may have an increase in activity by altering the excitability of ipsilateral motoneurons. This physiological explanation may be the key for understand the altered patterns of activation found in our study.

Yarosh, Hoffman and Stric[13] in their study of surface electromyography of the extensor and flexor carpi during movement of the wrist found results similar to ours. Patients with upper limb hemiparesis resultant of a unilateral stroke had deficits in the ability to move the ipsilateral wrist. The deficits were of dominant and non-dominant hemispheres injured: the ipsilateral wrist movements were less uncoordinated than the contralateral, but presented deficit in coordination to reach a target, were weaker and slower than the healthy control subjects studied.

In a previous study conducted by our group, when compared plegic and non-plegic sides of hemiplegic individuals, it was showed that during wrist flexion there is a significantly lower activation of flexors in the plegic side. And for the extensor muscles there were no difference in relation to the control group, both for flexion and the extension[14]. It is known that in the stroke there is a preference of the spasticity for the flexor muscles in the upper limbs and extensor in the lower limbs[15-17], what may explain why, apparently by the results, the stroke did not affect the pattern of neuro-motor activation of the extensor carpi ulnaris.

Ponten et al.[18] in a study about morphologyc properties of carpi flexor and extensor muscles in children with cerebral palsy, questioned why the flexor muscles are more strong as a group, suggested that may be possible that the hyperactivity of the nervous system simply activates both flexors and extensors. The flexors overlap the extensors, causing the wrist flexion, because the moment arm of the flexor is larger than the extensor moment arm wrist in flexion, the flexor muscles have the appearance of being stronger.

Barela and Almeida[19] compared the non-plegic side of individuals with hemiplegic spastic cerebral palsy with the dominant side of normal subjects in flexion of the shoulder and elbow. The results showed that the non-plegic side cannot be considered normal or intact, since the movements in the more distal were managed differently from the proximal portions, which did not occur with normal subjects.

In other study, it was compared parameters related to torque in four isometric exercises with hemiplegia. It

reported that the apparent weakness of the less affected limb by the stroke might be due to: lower percentage of the descending cortical tract fibers that are originated in the injured local and remains ipsilateral; or more generally, due to a sedentary lifestyle of hemiplegics, which may not be able to maintain the same force exerted by a non-dominant arm of a healthy person[20].

Our results are added to a crescent group in literature that demonstrates the ipsilateral limb "non-affected" does not work normally after a unilateral stroke of brain motor areas[21-23]. Even with these studies pointing to the differences inconsistencies are showed when we visualize the techniques used in the rehabilitation clinic of upper limbs of hemiplegics patients. One is the training of bilateral movements. This applies neurological postulates of motor coordination inter-members to activate motor synergies between members. Specifically, voluntary movements of the intact limb can facilitate voluntary movements in the paretic member. This activates the primary motor cortex and supplementary motor area for the member intact to increase the probability of voluntary muscle contraction (i.e. motor synergies) in the affected limb when symmetrical movements are executed[24].

The possible neural mechanisms underlying the bilateral movements are numerous. A basic assumption of the use of bilateral movement is that the therapy of bilateral symmetrical movements activate similar neural networks in both hemispheres when homologous muscle groups are activated simultaneously. Bilateral symmetrical movements, therefore, may allow the activation of the uninjured hemisphere to increase the activation of the injured hemisphere and facilitate control of plegic limb movements promoting neural plasticity.

When evaluated the reorganization of central nervous system with magnetic resonance functional during the therapy of bilateral symmetrical movements, the non-paretic hand's movement have increased the activation of the uninjured hemisphere[25]. The bilateral training lead to an increased recruitment of sensory-motors areas of the contralateral hemisphere and the ipsilateral cerebelum. This recruitment is frequently explained due to the existence of cortico-spinal fibers that do not cross in the pyramidal decussation and are latent in healthy people. Its functional relevance is not yet clear. In patients with motor deficiency after stroke, the rehabilitation with specific bilateral repetitive therapy of upper extremity appears to induce the reorganization in the neural networks contralateral to the lesion, in brain hemisphere and cerebellum, and can operates by recruitment of these brain areas in order to supply functional benefits[24].

The literature in this area - studying motor control, especially in upper extremities - is still scarce. There are a little amount of researches looking for difference in the non-plegic side; in order to understand exactly what occurs in terms of motor control, more studies should be conducted. This study contributes to understand that the non-plegic side is not normal when compared with a control group, so it should be considered that although the patients have diagnostic of unilateral stroke, we can not ignore that there may be a microdamage contralateral to the plegia not observed on imaging studies, which may explain in part the observed changes in the electromyography spectrum.

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