Neuromotor Evaluation of the Upper Limb During Activities of Daily Living: A Pilot Study

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Abstract. Upper limb function impairment is one of the most common sequelae in stroke. Conventional evaluation methods, based on scales, do not provide an objective assessment of patient's performance. A pilot study was conducted to characterize neuromotor biosignals of the upper limb, during activities of daily living (ADLs). We use BiosignalsPlux® device to monitor the contraction pattern of the shoulder muscles in five ADLs with different motor patterns, through electromyography. Thus, the main purpose of this article is to describe the results of the application of these sensors in the characterization of the contraction pattern of the shoulder muscles during ADLs performed by healthy subjects. The results shows that the pattern of contraction of the shoulder muscles differs between ADLs directed at the midline and directed at the contralateral side; presents different behaviors in distinct ADLs directed at the midline; as well as in ADLs directed to the contralateral side.

Keywords: Neuromotor evaluation, upper limb, technology, activities of daily living, biomechanics.

1 Introduction

Functional deficits associated with the upper limb are one of the most frequent sequelae caused by cerebrovascular diseases, such as stroke. [1, 2]. About 50% of the subjects with this diagnosis are not completely independent after 6 months of the stroke episode [3]. The upper limb paresis is the most frequent and severe neuromotor deficit associated to stroke, being characterized by a decrease in muscle strength [4], and loss of autonomy in ADLs [5]. It is estimated that 37%-55% of subjects with stroke have deficits in the performance of these activities [6], related to the omission of small actions, changes in the sequence and in the quality of their performance, as demonstrated in studies related to the preparation of meals [7] and hygiene [8].

The methods used in clinical practice to assess upper limb neuromotor deficits in stroke patients continue to be based on qualitative assessment scales, which generates subjective trends [9] and does not allow an objective assessment of the performance or effectiveness of therapies [10].

1.1 Technologies for Studying the Human Movement in Stroke Patients

Many studies have been realized on human movement [11,12], both in terms of kinematics, kinetics, and biosignal analysis [13, 14, 15], however these studies in stroke patients have been performed essentially on the lower limb. Other studies, focusing on upper limb functionality in stroke patients, study kinetic and kinematic parameters, using only optoelectronic motion analysis systems, during simulated tasks of transporting cylindrical objects and not during ADLs. [16]. In other studies, full-body suits with inertial measurement unit sensors (3D accelerometer, 3D magnetometer, and 3D gyroscope) are used to measure kinematic parameters in ADLs [17]. There are still studies that analyze the motor pattern of the upper limb in stroke patients, while performing tasks such as drinking water from a glass, but the evaluation is again directed to the analysis of kinematic parameters [18,19].

Although the cited studies used technology during the assessment, none of them analyzed the contraction pattern of the upper limb muscles in the real context of ADLs. For this, it is essential to analyze the amplitude of muscle activation through EMG.

EMG is the measurement of the electrical signal associated with muscle activity. Muscle excitation is then analyzed through the amplitude of the EMG signals, which means that the more motor units are recruited and the higher the firing rates, the greater the contraction by the muscle [20].

Through the EMG signal, muscle contraction and relaxation data are obtained, indicating whether the muscle is actively participating in the execution of the movement. The quality and precision of the generated signals also depend on the correct positioning of the electrodes in the muscles that we intend to analyze [21].

2 Technological Innovation for Digitalization and Virtualization in Life Improvement

The analysis of muscle contraction through EMG has a fundamental role in stroke patients, as these patients present significant changes in their movements [22] that can limit the range of motion of the shoulder and elbow during ADLs.

Stroke patients develop compensatory movements, based on altered movement patterns through the contraction of other muscles, which will compensate for the decrease in strength, alteration of tone, among others [23]. Prolonged use of altered movement patterns has a negative impact on joint alignment [24], limiting range of motion and contributing to muscle contractures and weaknesses [25], impairing the rehabilitation process.

To verify the existence of inadequate pattern of muscle activation during ADLs, it is necessary to know the normal pattern of muscle activation in these activities through EMG, in healthy individuals, however, in the literature, there is no data on this.

It is essential that the data related to the muscle activation amplitude can be submitted to a digitalization and virtualization process, to be presented and visualized in graphs representing the muscle activation pattern, both in healthy subjects and later in stroke patients.

It is only possible to interpret the increase and decrease in muscle activation amplitude, that is, muscle contraction and relaxation, as well as the sequence of muscle amplitude activation peaks during the activities itself, in the different ADLs, through the visualization of the data.

This pilot study aims to develop a protocol to analyze the activation pattern of the EMG activity of the shoulder muscles during ADLs, as well as to explore the characteristics of this same pattern (amplitude and sequence of muscle activation peaks). To this end, the main shoulder muscles were identified [26] and the ADLs most prone to compensatory movements (eating, drinking, dressing or personal care) [27].

The question of this investigation focuses on exploring the applicability of this protocol in identifying the normal pattern of muscle activation in different ADLs. Subsequently, this protocol will be validated in a larger sample, to answer a research question related to the doctoral project, that is, to explore and know the normal pattern of activation amplitude of the main shoulder muscles in ADLs.

3 Materials and Methods

2.1 Participants in Clinical Investigation

This protocol was applied to a female participant, right-handed, aged 38 years, selected by convenience, who met the established criteria. As exclusion criteria, diagnosis of neuromotor, cognitive or language deficits, left hand dominance and changes in visual acuity not compensated by glasses or contact lenses were defined. Ethical and confidentiality principles were guaranteed, the volunteer joined the study after reading and signing the informed consent.

2.1 Measurement System

A device for collecting EMG signals, the Biosignalsplux®, was used. This device was connected by wireless with the OpenSignals (r)evolution Software®, this software was used for data acquisition, visualization, and processing, being a specific software for PLUX® biosignal hardware platforms [30]. In this study, 6 channels were used to record bipolar EMG related to 6 different muscles. Each bipolar signal was recorded from electrodes placed 2 cm apart. [31].

The electrodes were placed according to the agonist muscles of the main shoulder movements (Table 1), namely the Pectoralis Major, Anterior Deltoid, Middle Deltoid, Posterior Deltoid, Upper Trapezius and Lower Trapezius responsible for flexion, extension, abduction, adduction, elevation, and depression of the scapula [26]. Signal was collected at a sample frequency of 1000Hz. [32].

Table 1. Agonist muscles of the main shoulder movements.

Muscle	PM	AD	MD	PD	UT	LT
Shoulder movements	ADD	F	ABD	E	SE	SD
Electrode's position						

Abbreviation: PM, Pectoralis Major; AD, Anterior Deltoid; MD, Middle Deltoid; PD, Posterior Deltoid; UT, Upper Trapezius; LT, Lower Trapezius; ADD; Adduction; ABD, Abduction; F, Flexion; E, Extension; SE, Scapular elevation; SD, Scapular depression.

2.3 Experimental Procedure

The volunteer was instructed to perform two types of activities: directed to the midline (drinking from a cup, eating soup and brushing teeth) and directed to the contralateral side (brushing the hair on the left side of the head and washing the left upper limb). The materials chosen consisted of a cup, a tablespoon, a bowl, a toothbrush, and a hairbrush.

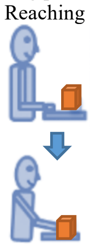
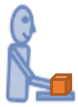
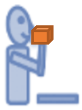
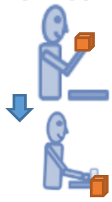
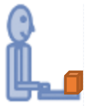
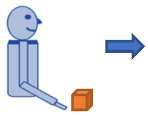
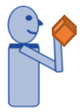
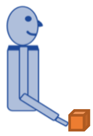
In all activities directed at the midline, the objects were placed 20 cm from the edge of the table and aligned with the midline of the subject's body. The subject was seated in a chair (40 cm high), next to a table (75 cm high), with knees and hips flexed at 90º, with the upper limbs resting on the table, shoulder in neutral position, elbow flexed at 90º, forearm in pronation, wrist in neutral position and fingers in extension.

In all the activities directed to the contralateral side, the subject was only seated in a chair (40 cm high), with knees and hips flexed at 90º, with the upper limbs supported on the thighs, shoulder in a neutral position, elbow flexed at 45º, forearm and wrist in neutral position and fingers semi-flexed. Within these activities, only brushing the hair contemplated an object (the brush), which was already in the subject's hand, when the activities began.

As these activities consist of complex movements of the joints of the upper limbs, it is important to distinguish their phases [33, 34]. These phases are represented in Table 2, as well as the respective movements performed by the shoulder [26].

Regarding the signal processing of the EMG activity, the MATLAB® software was used. The signal was then imported into this software, and the channels related to the EM activity signal were selected for each of the activities. After selecting a module of 5700 points (part of the signal to be analyzed), the frequency was transformed into units of time (s), the average of the signal was subtracted, the signal was placed in absolute values, the moving average was applied. at the same. To know the peaks of the activation amplitude of each of the analyzed muscles and the moment in time that they occur in the activity, the maximum values were requested.

Table 2. Activity phases in ADLs.

ADL´s directed at the midline			
Phases	1.Starting position to Reaching	2.Grasping	3.transporting to the mouth
			
Drinking from a cup	ADD, F	ADD, F, SE	F, ABD, SE
Eating soup	ADD, F, SE	ADD, F, SE	F, ABD, SE
Brushing teeth	ADD, F, SE	ADD, SE, F	F, ABD, SE
Phases	4.Introduced in the mouth	5.Return to pick up point	6.Return initial position
			
Drinking from a cup	F, ABD, SE	ADD, E, SD	E, SE, ABD
Eating soup	F, ABD, SE	ADD, E, SD	E, SE, ABD
Brushing teeth	F, ABD, SE	ADD, E, SD	E, SE, ABD
ADL`s directed at the contralateral side			
Phases	Starting position to Reaching	1.Grasping	2.Transporting to the contralateral side
	Does not occur, starts with the upper limb on top of the thigh with the object in hand		
Hair brushing		ADD	F, ADD, SE
Washing upper limb		ADD	F, ADD, SE
	3. Reaching the contralateral side	4. Return to the thigh	5. Return initial position
			
Hair brushing	F, ADD, SE	ABD, E, SD	ABD, E, SD
Washing upper limb	F, ADD, SE	ABD, E, SD	ABD, E, SD

Abbreviation: ADD, Adduction; ABD, Abduction; F, Flexion; E, Extension; SE, Scapular elevation; SD, Scapular depression.

4 Results

The results of this study are summarized in Tables 3 and 4. It is verified that the ADLs of drinking from the cup and eating the soup show similar amplitude activation patterns (Table 3). However, soup eating activity (Fig. 1) presents a second amplitude peak relative to the upper trapezius.

In the activity of brushing teeth, the activation pattern differs from previous activities.

Table 3. Results of peak muscle activation amplitude in ADLs directed to the midline

Results of peak muscle activation in ADLs directed to the midline					
Drinking from the cup		Eating soup		Brushing the teeth	
Amplitude of contraction (mV)	Time of amplitude peak (s)	Amplitude of contraction (mV)	Time of amplitude peak (s)	Amplitude of contraction (mV)	Time of amplitu de peak (s)
AD 1881	PM 2,22	AD 1695	UT 2,12	UT 1017	AD 2,55
UT 1515	UT 2,35	UT 1124	LT 2,17	AD 828	MD 2,56
MD 1079	MD 2,45	MD 974	PD 2,24	MD 679	UT 2,56
LT 654	PD 2,50	LT 602	MD 2,24	LT 428	PD 2,67
PD 427	AD 2,55	PD 439	AD 2,27	PD 297	PM 2,76
PM 314	LT 2,92	PM 356	PM 2,28	PM 276	LT 2,85

Abbreviation: PM, Pectoralis Major; AD, Anterior Deltoid; MD, Middle Deltoid; PD, Posterior Deltoid; UT, Upper Trapezius; LT, Lower Trapezius.

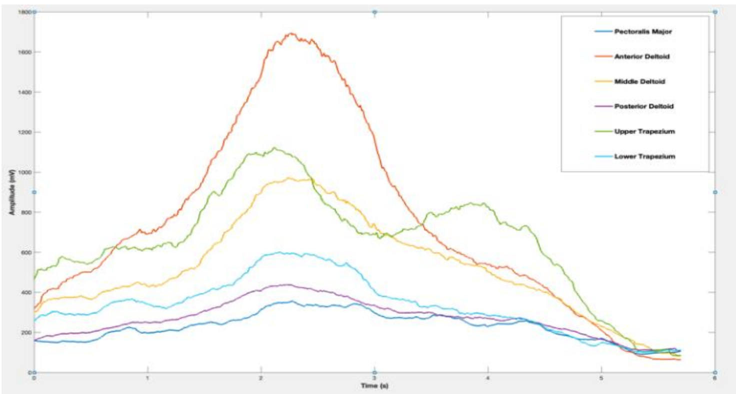


Fig. 1. Amplitude pattern of muscle activation over time of eating soup activity.

It is verified that the activities of washing the arms and brushing the hair have similar activation amplitude patterns (Table 4), but in the arm washing activity, there is also a second activation peak.

Table 4. Results of peak muscle activation amplitude in ADLs directed to the contralateral side.

Results of peak muscle activation in ADLs directed to the contralateral side.			
Arm washing		Brushing the hair	
Amplitude of contraction (mV)	Time of amplitude peak (s)	Amplitude of contraction (mV)	Time of amplitude peak (s)
AD 2139	LT 1,24	AD 2553	UT 1,31
MD 984	UT 1,39	MD 1365	LT 1,51
UT 894	PM 1,63	UT 1294	PD 1,52
PM 732	AD 1,72	PD 579	PM 1,60
PD 571	PD 1,77	PM 489	AD 1,63
LT 238	MD 1,77	LT 409	MD 1,63

Abbreviation: PM, Pectoralis Major; AD, Anterior Deltoid; MD, Middle Deltoid; PD, Posterior Deltoid; UT, Upper Trapezius; LT, Lower Trapezius.

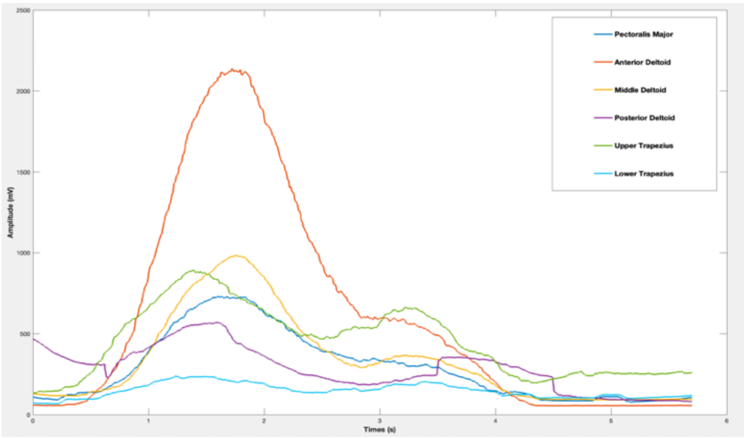


Fig. 2. Pattern of muscle activation amplitude over time of arm wash activity.

5 Discussion of Results and Critical View

The results are indicative that in all activities, are two marked phases: one of increasing the amplitude of muscle activation, corresponding to an increase in contraction and another of decreasing the amplitude, corresponding to a decrease in contraction of the muscle. Regarding the ADLs directed to the midline and considering table 2, and other studies that mention these same phases of activity [33, 34], it can be inferred that the phase of contraction corresponds to the first four phases of the activity. The phase of decreased contraction corresponds to the remaining phases.

Regarding the ADLs directed to the contralateral side and considering table 2, it can be inferred that the phase of contraction corresponds to the first three phases of the activity. The phase of decreased contraction corresponds to the remaining phases.

For midline-directed ADLs, the amplitude of muscle activation is similar between the drinking-by-a-glass and soup-eating activities, except for the Upper Trapezius muscle, which, in the relaxation phase, once again, shows an increase in the activation amplitude. According to the analysis of the movements performed in table 2, this peak may be associated with the demands of the activity itself, namely the last phase of the activity, the phase of returning to the initial position.

The activity of brushing the teeth differs from the previous ones, since there is a more prolonged amplitude of muscle activation in the time in which the activity takes place. being This difference is more evident in the Upper Trapezius, Anterior Deltoid and Middle Deltoid. These muscles, in the final phase of activity, also express an increase in the contraction.

For ADLs directed to the contralateral side, the amplitude of muscle activation is similar between washing the arm and brushing the hair, in most muscles involved in the phase of increased muscle activation. The largest difference is seen in the relaxation phase of the arm washing activity. As in previous activities, the Upper Trapezius, Anterior Deltoid and Middle Deltoid muscles again demonstrate an increase in the amplitude of activation.

Regarding the analysis of the time (s), in which the peaks of maximum amplitude occur during the 5.7 s of the course of activities. It is verified that all muscles in all ADLs directed to the midline, reach their peak of maximum activation amplitude between 2 and 3 seconds and ADLs directed to the contralateral side between 1 and 2 seconds.

6 Conclusion and Further Work

This study assumed a central importance in the testing of the experimental protocol, because although the related muscle groups of the shoulder involved in the ADL's are the same, the specificities of the activity point to the existence of different patterns of muscle contraction between the ADL's analyzed. Thus, the results are indicative of differences in the pattern of activation amplitude between ADLs directed to the midline, between ADLs directed to the contralateral side, as well as between these two groups of activities. They are also indicative of similarities between both ADLs directed to the midline and between ADLs directed to the contralateral side, about the time interval in which peaks of muscle activation occur during activities.

These results lead to the need for future work to understand whether these indications are valid in a larger sample, since the application to only one subject constitutes a limitation of the study. The use of EMG together with other technologies, such as accelerometry, for example, to complement the analysis of the shoulder muscle contraction pattern in ADLs is another suggestion for future investigations.

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