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ELECTRICAL ACTIVITY EVALUATION OF SELECTED MUSCLES OF A WHEELCHAIR USER USING ELECTROMYOGRAPHY - A CASE STUDY

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Abstract. *It is recurrent among wheelchair users complaints of chronic pain and also those resulting from repetitive use of the upper limbs. In general, in order to treat these pains, strengthening exercises and muscle rehabilitation are recommended. However, there is still low adherence of wheelchair users or people with reduced mobility in strengthening routines mainly due to the lack of specific equipment. In order to develop and design such an equipment, it is necessary to collect parameters and variables related to muscular activities, since the metabolic and clinical conditions of a wheelchair user are altered as a function of their injury. By this concept, understanding the muscles activity for those involved in the motor gesture of propulsion of a wheelchair, as well as whether the bilateral muscular activity is symmetrical or asymmetric is an essential parameter for the design. The objective of this study was to evaluate the electrical activity of selected muscles involved in the wheelchair propulsion process using electromyography and to verify if this activity is symmetrical or asymmetrical on the right and left sides of the body as well as to have a general overview of which muscles will be more demanded. With this analysis a better understanding of the intrinsic needs for the design of a resistance training equipment of upper limbs for wheelchair users and / or persons with reduced mobility can be achieved. Preliminary results showed asymmetry concerning electrical activity. The most activated muscles on the left side were the long head triceps and the deltoid acromial part whereas on the right side the most activated ones were the brachioradialis and deltoid clavicular part considering those muscles selected for analysis.*

Keywords: *People with disabilities, Muscular Activity, Electromyography, Resistance Training, Wheelchair.*

1. INTRODUCTION

Wheelchair users generally present chronic pain that directly affects their quality of life (Widerström-noga et al., 2001). Studies of (Zanca et al., 2013) have shown that from 50% to 90% of patients undergoing physical rehabilitation suffer from pain at the beginning of the rehabilitation process.

In addition to these injuries, there is still a high incidence of damage and lesions to the upper limbs of wheelchair users. These damages occur, in large part, through the constant effort demanded in the most varied daily activities of this population (Boninger et al., 2005). To bring some relief to these injuries, the author recommends the adoption of muscle-strengthening exercises as an integral part of the wheelchair user's life but not only that; the training should be progressive, individualized and of sufficient intensity to increase strength and muscular endurance as well as stimulate the primary muscles involved to avoid pain and fatigue. Such observations are also corroborated by other authors as (Murloy et al., 2011).

One of the barriers to the adoption of resistance training as part of the wheelchair's life is the lack of equipment designed specifically for this purpose. In this case, a pattern of muscle activation similar to that used in the propulsion of the wheelchair as shown by the studies of (Rimmer et al., 2004); which would reduce the incidence of injury since the same muscles used in propulsion are being activated following the principle of specificity. According to this principle, the demands must be compatible with the event for which one is training including the predominant energy system, movement patterns and muscle groups activated during the execution of the task affecting the performance of the practice (Foss and Keteyian, 2000) directly.

In order to initiate the design of such equipment, it is necessary, firstly, to evaluate the pattern of muscular activation in a propulsion gesture of the wheelchair. According to (Rankin et al., 2011), this understanding has important implications for the development of training techniques as they would help reduce muscle demand in the upper limbs during propulsion by improving rehabilitation outcomes. For this reason, these authors applied dynamic simulation of the propulsion gesture of a wheelchair aimed to establish how the individual muscles deliver, absorb, and transfer mechanical energy during the task. The results pointed out massive participation of the shoulder muscles (mainly during the first third of the rim push phase), brachioradialis and triceps long head muscles at the beginning of the recovery phase. However, the study reinforced that this condition was tested unilaterally assuming that the differences in muscle function are likely to be small.

Upon these facts, the objective of this study was to perform an initial analysis of muscular activation of selected muscles of a wheelchair user during the propulsion motor gesture of a wheelchair bilaterally using electromyography (EMG) and also to evaluate whether this activity is symmetrical or not. With the visualization of such muscular activation pattern, it will be possible to highlight the intrinsic needs for the development of resistance training equipment with specific characteristics for the wheelchair user.

2. METHODOLOGY

2.1 EMG data collection

The electromyographic signal (EMG) is an electrical signal originated from the depolarization of the membranes of the muscle cells allowing then record the behavior of muscle activity during a particular movement or effort (Ocarino et al., 2005). According to (Silva, 2009), EMG is one of the main tools for the analysis of muscle activation.

Following the data generated by (Rankin et al., 2011) that verified the contributions of shoulder and elbow flexors during the push and recovery phase at the right side of the body, some muscles were selected in order to have the EMG signal collected. The choice considered the number of channels available in the electromyography as a first case study. Using the EMG technique, the shoulder muscles right deltoid acromial part (DAD) and left deltoid acromial part (DAE), right deltoid clavicular part (DCD) and left deltoid clavicular part (DCE) were analyzed; also the elbow flexors right triceps brachii long head (TRD) and left triceps brachii long head (TRE), right brachioradialis (BRD) and left brachioradialis (BRE).

For data collection, a 12-channel EMG1232WF electromyograph (EMG System do Brasil Ltda) was used with data transmission via wi-fi, 16-bit resolution, and external luminous trigger. The sample rate was set at 2000 Hz. For the analysis of the results, the files were exported, and a 20-500 Hz bandpass filter was applied to the data according to recommendations of (Delsys, 1996), and a Chauvenet criterion was used in order to eliminate discrepant points in the signal. For this criterion, if the difference of the point value from the mean of the signal was higher than 3,66 the standard deviation, then this value was eliminated from the sample.

The electrodes used were 3M® disposable Ag / AgCl (silver / silver chloride) single active, differential and circular with center-to-center distance of 20 mm, gain of 20X and RRMC > 120dB - that were coupled to an adhesive with solid gel (hydrogel) and applied to the skin after cleaning with 70% alcohol and trichotomy. It was also used as a reference electrode fixed on the manubrium of the sternum bone in order to reduce the effect of electromagnetic interference and other noise during the acquisition of the electromyographic signal. The electrode positioning follows the recommendations (SENIAM - Surface Electromyography for the Non-Invasive Assessment of Muscles) as follows:

- **Deltoid muscle acromial part (DA)**: The electrodes should be placed from the acromion to the lateral epicondyle of the humerus in the elbow region, in a such a way that correspond to the more significant volume part of the muscle, in the direction of the line between the acromion and the hand.
- **Muscle deltoid clavicular part (DC)**: The electrodes are placed in the distal and anterior part of the acromion in the direction of the line between the acromion and the thumb.
- **Triceps brachii long head (TR)**: The electrodes should be placed at 50% of the line between the posterior crest of the acromion and the ulna olecranon at 2-finger-widths medially to the line.
- **Brachioradialis muscle(BR)**: In the muscular womb 4 cm below the lateral epicondyle of the humerus, on the anterolateral aspect of the forearm (PEREIRA, 2015).

Fig. 1 presents the positioning of the electrodes in the volunteer according to the recommendations of SENIAM. For the data collection, a volunteer was selected following the approved protocol of ethics committee number CAAE 82185617.2.0000.5152.

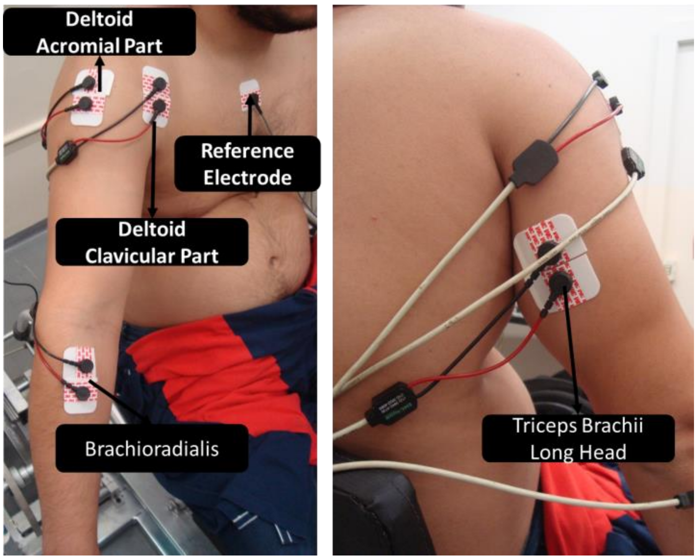

Figure 1. The positioning of the surface electrodes in the locations recommended by SENIAM for the selected muscles

2.2 Configuration of tests for data collection

According to (Forte et al., 2016), the propulsion rate in wheelchair athletes ranges from 32 to 86 propulsions per minute. In daily routines (Sawatzky et al., 2015), a rate of 60 propulsions per minute is recommended. Therefore, the rates selected for the volunteer to perform during tests were: 32, 60, and 86 propulsions per minute. Such rates were controlled by a metronome. Finally, the fourth rhythm of propulsion was established: the maximum rate achieved by the volunteer established in 110 propulsions per minute. For all rhythms, the volunteer was asked to perform the gesture for 60 seconds, during which the EMG signal was collected. If necessary, the volunteer could interrupt the exercise in case of fatigue. A minimum rest time of 5 minutes was established between the tests.

For the data collection, a unique mechanism was developed. This mechanism produces a resistance during the push and recovery phase and also allows to set the resistance level. This resistance is provided by a spring mechanism coupled do de shaft of the simulation rim and coupled to a chair. In order to perform the test, the wheelchair user has to be transferred to the mechanism. The rim is presented in Fig.2. As well as the positioning of the volunteer relative to the rim. The only difference between the propulsion gesture in the equipment and a real wheelchair is that the equipment propitiates resistance either in the propulsion phase and recovery phase. Thus, the volunteer’s hand keeps contact with the rim in both phases while in a wheelchair, this contact is kept only in the push phase.

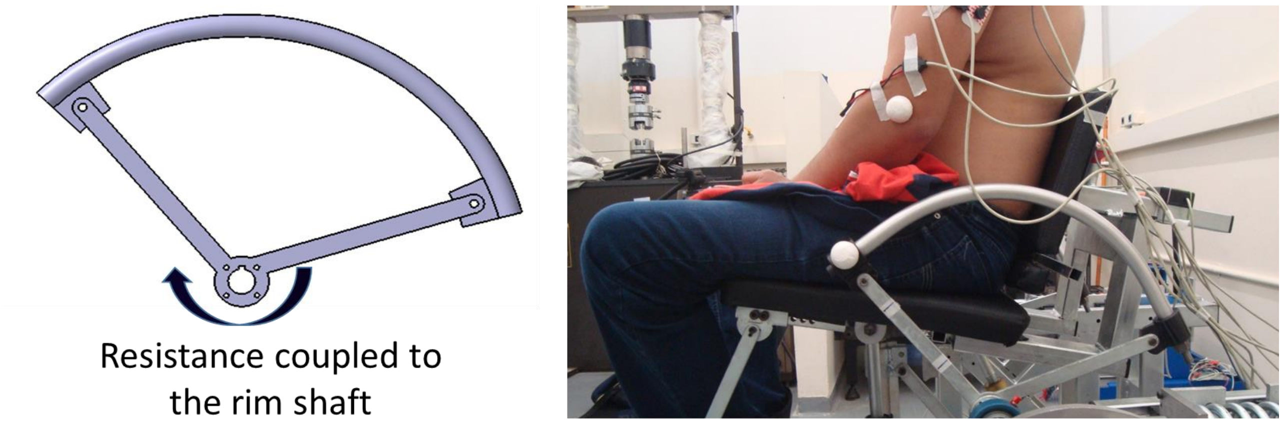

Figure 2 – Propulsion test rim designed for EMG data collection and positioning of the volunteer at the equipment.

Information on signal amplitude in both time domain and frequency domain are used for the quantization of EMG signals. This amplitude represents the energy required in the movement in question (Soderberg and Kuenson, 2000). A time-domain EMG signal analysis, in agreement with (De Luca, 1997), is the parameter that best describes the level of muscle activity in maximal voluntary contractions is the RMS (root mean square).

For the calculation of the RMS of the signals, five windows of 5 seconds each were established in the signal chosen so that the intervals corresponded to a part of the signal free from significant interferences such as wire balance. These windows were applied within 25 to 30, 30 to 35, 35 to 40, 40 to 45, and 45 to 50 seconds on all signals from all the different muscles at each rate imposed.

3. RESULTS AND DISCUSSION

As stated before, five windows were applied to each EMG signal collected in each rate of propulsion. For each window, the RMS value was calculated. After the calculation of the RMS values, an average RMS and standard deviation were obtained relative to the five windows adopted.

The figures 3, 4, 5, 6 shows the signals collected in the various propulsion rates selected for the analysis. In Fig. 7 is presented an illustration of the effect of bandpass filter of 20-500 Hz and Chauvenet criterion for the right brachioradialis muscle at 110 propulsions per minute.

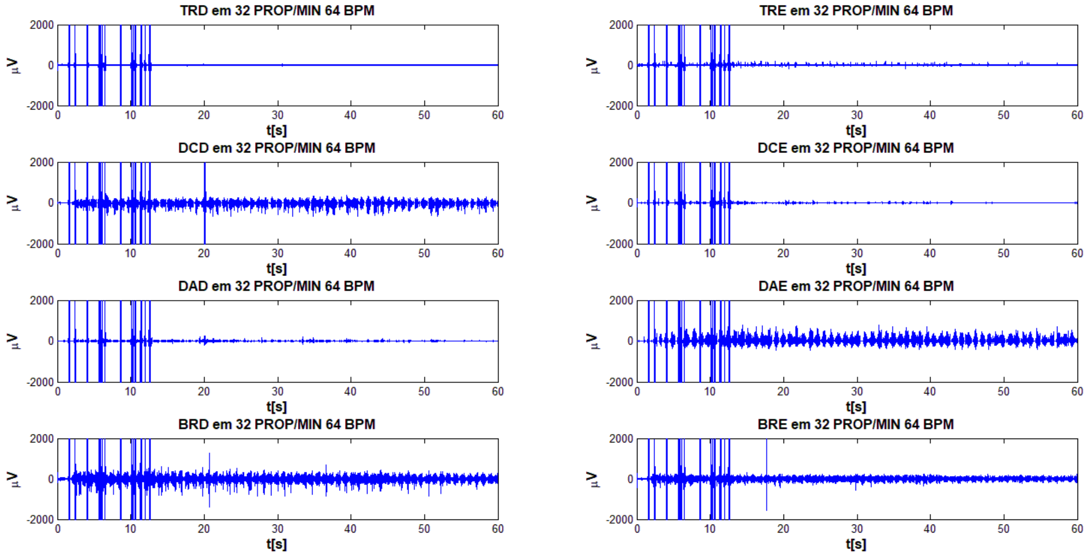

Figure 3 – EMG data collected at 32 propulsions per minute for the four muscles selected. The data are presented for the right and left the side of the volunteer

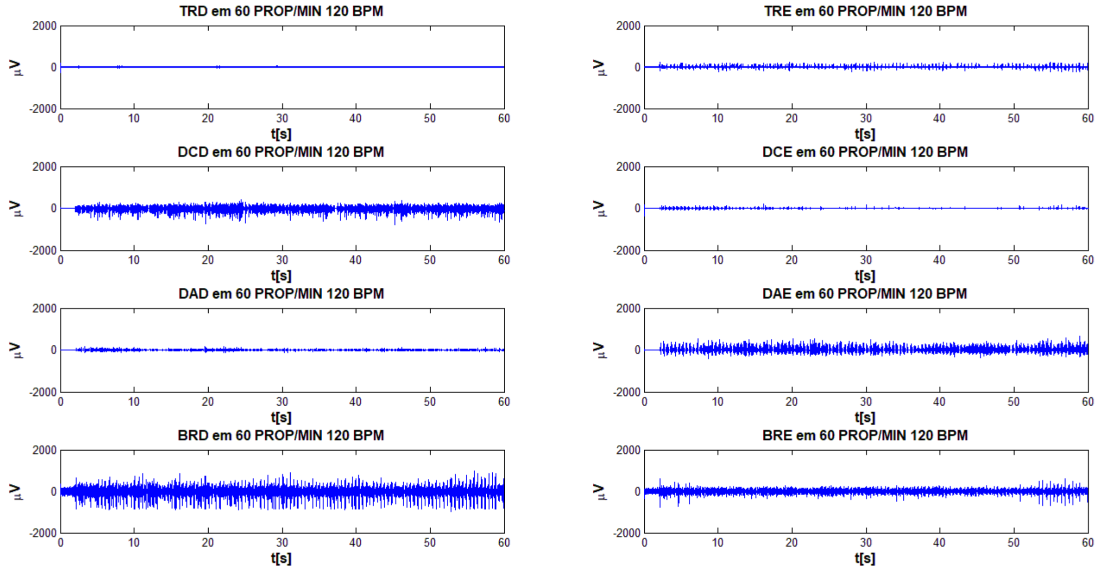

Figure 4 - EMG data collected at 60 propulsions per minute for the four muscles selected. The data are presented for the right and left the side of the volunteer

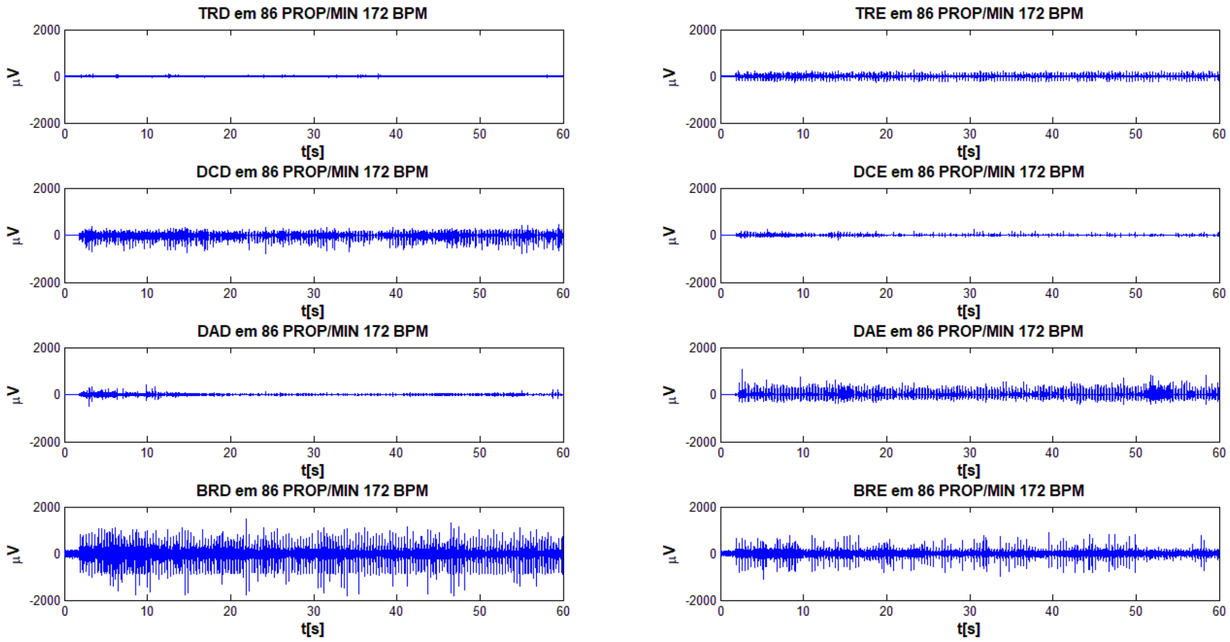

Figure 5 - EMG data collected at 86 propulsions per minute for the four muscles selected. The data are presented for the right and left the side of the volunteer.

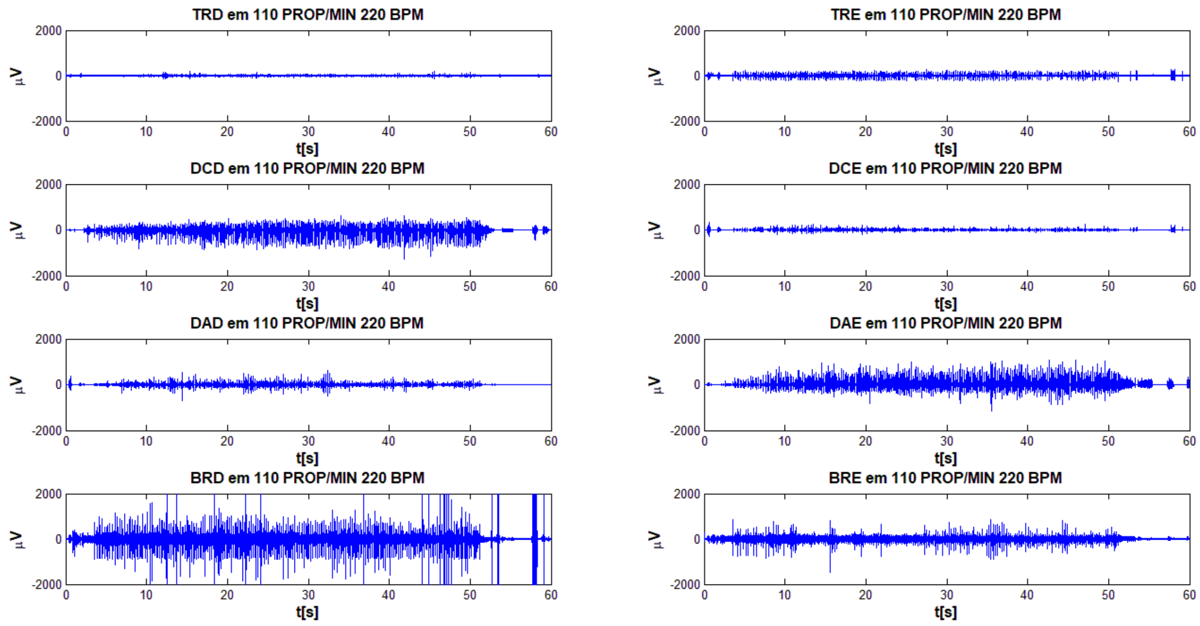

Figure 6 - EMG data collected at 110 propulsions per minute for the four muscles selected. The data are presented for the right and left the side of the volunteer

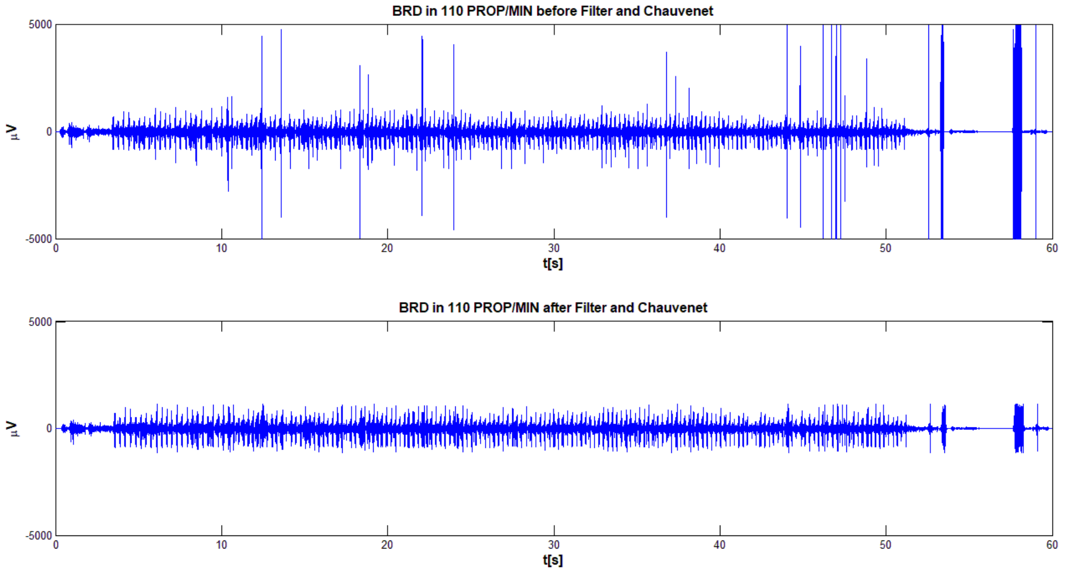

Figure 7 – Effect of band-pass filter and Chauvenet criterion in the EMG signal for the right brachioradialis muscle at 110 propulsions per minute

The figure 8 shows the average RMS values of the signals for each selected muscle at each of the imposed propulsion rhythm. The error bars are presented for the averages considering two standard deviations.

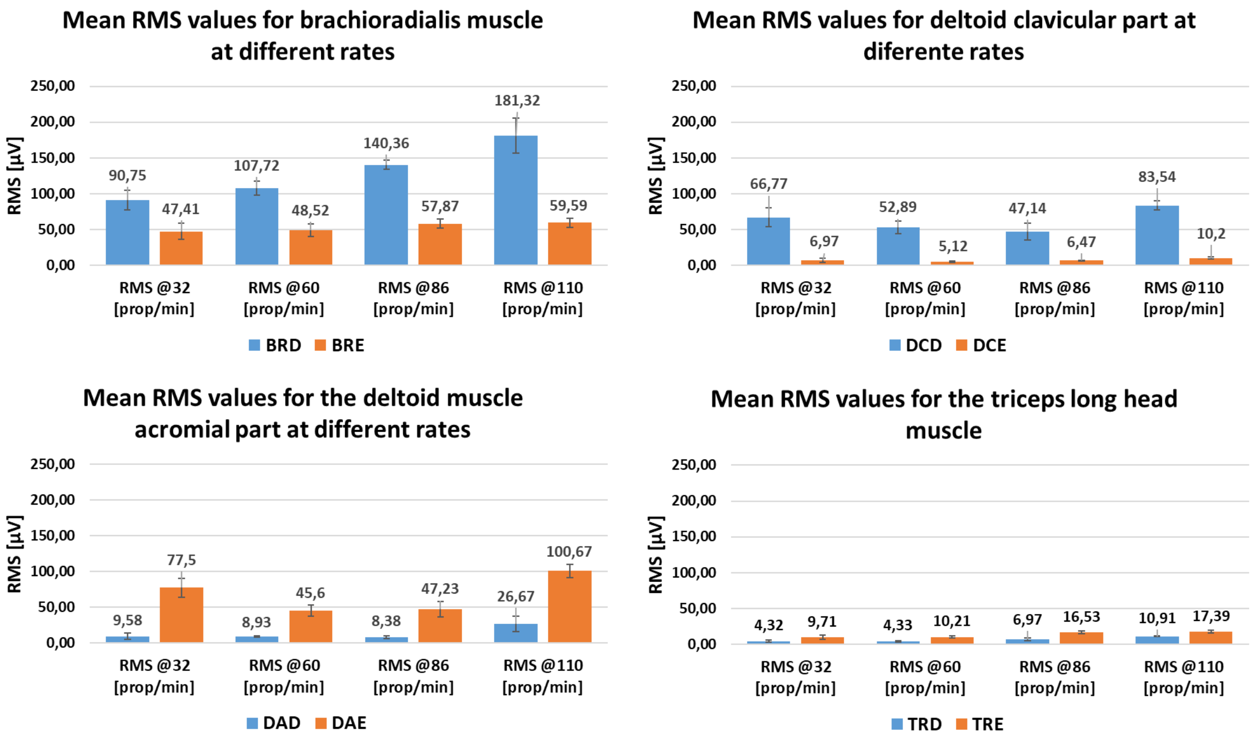

Figure 8 – Mean RMS values calculated using the window of 5 seconds adopted for the propulsion rates of 32, 60, 86 and 110 propulsions/min for the selected muscles

Contrary to what was stated by (Rankin et al., 2011), muscle activity is shown asymmetrically between the right and left sides of the wheelchair user.

It can be observed that there was an imbalance of the muscular activation during the effectuation of the motor gesture under resistance generated by the spring mechanism. While the deltoid muscles clavicular part and brachioradialis presented greater activations in the right side the deltoid muscles acromial part and tríceps braquii long head presented greater activation in the left side. The differences reached values of up to 121,73 μV between right and left side (mean RMS value 304% greater than left side) for brachioradialis at 110 (prop/min); 73,34 μV between right and left side for deltoid clavicular part (819% mean RMS greater for right side) at 110 (prop/min); 74 μV of difference for deltoid clavicular part (377% mean RMS greater for left side) at 110 (prop/min) and 6,48 μV for triceps long head (159% mean RMS greater for left side) also at 110 (prop/min).

Another fact to be evidenced is the tendency to increase the level of muscular activation with the rate of propulsion imposed on the movement motivated by the increase o recruitment of muscular fibers to maintain the rate of propulsion for that gesture.

This imbalance of activations between the left and right sides of the body may be related to the attempt to balance different levels of force in the left and right sides of the body. In order to investigate such information, it is necessary to analyze the level of strength of the volunteer in other tests such as the Maximum Voluntary Isometric Contraction (CIVM) concomitantly with the collection of EMG of the same muscles in this condition. Once the RMS signal at CIVM is collected, it can be used as a comparison factor for the RMS values obtained at different rates, in other words, to normalize the RMS values about the RMS values at CIVM.

The asymmetry o recruitment of these muscles analyzed demonstrates the need of a well-conducted resistance training of force in order to balance the activation and, also to prevent, upper extremity injuries, by (Murloy et al., 2011). Besides, the imbalance of muscular activation demonstrates that any attempt to develop a specific muscular training device for wheelchair users must consider and allow the application of different loads at right and left sides of the body and permit the execution of motion considering the specificity principle of the propulsion gesture of the wheelchair as stated by (Rimmer et al., 2004).

4. CONCLUSION

This study demonstrated the occurrence of bilateral muscular asymmetry. The data also point out that the first principle that resistance training equipment to be designed for wheelchair users should follow is to allow different resistance levels for the right and left arms during exercise. Also, the rate or velocity of execution directly affects the electrical activity of the muscles. In this way, the equipment will must be able to offer resistance to the movement considering the possibility of execution in variable velocities and accelerations what is not easily found in equipment available in the market. All these facts corroborate the need for specific training and rehabilitation equipment projects for wheelchair users or people with reduced mobility. Also, the study can be used as a reference for a better understanding of the muscular activation patterns of a wheelchair propulsion gesture.

5. ACKNOWLEDGMENTS

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