34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

A New Approach to Assess the Spasticity in Hamstrings Muscles using Mechanomyography Antagonist Muscular Group

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***Abstract*— Several pathologies can cause muscle spasticity. Modified Ashworth scale (MAS) can rank spasticity, however its results depend on the physician subjective evaluation. This study aims to show a new approach to spasticity assessment by means of MMG analysis of hamstrings antagonist muscle group (quadriceps muscle). Four subjects participated in the study, divided into two groups regarding MAS (MAS0 and MAS1). MMG sensors were positioned over the muscle belly of *rectus femoris* (RF), *vastus lateralis* (VL) and *vastus medialis* (VM) muscles. The range of movement was acquired with an electrogoniometer placed laterally to the knee. The system was based on a LabVIEW acquisition program and the MMG sensors were built with triaxial accelerometers. The subjects were submitted to stretching reflexes and the integral of the MMG (MMG_{INT}) signal was calculated to analysis. The results showed that the MMG_{INT} was greater to MAS1 than to MAS0 [muscle RF (p = 0.004), VL (p = 0.001) and VM (p = 0.007)]. The results showed that MMG was viable to detect a muscular tonus increase in antagonist muscular group (*quadriceps femoris*) of spinal cord injured volunteers.**

I. Introduction

SPASTICITY is a neurological impairment in upper motor neuron syndrome [1] which may result from several pathologies as stroke, multiple sclerosis, amyotrophic lateral sclerosis (unstable), cerebral palsy, brain injury and spinal cord injury [1-3]. It causes sensorimotor modifications due to changes in the corticospinal tracts [4, 5] and in reciprocal inhibition circuits, i.e. hypertonia and hyperreflexia [6] of voluntary muscle (alpha) and involuntary (gama) on the affected area of the central nervous system [7].

Spasticity involves since the loss of skill activities of daily living until deformations in the limbs involved [8-13] [14].

Modified Ashworth scale (MAS) is employed for ranking spasticity and has six levels of classification (0, 1, +1, 2, 3 and 4) that greatly depend on physician skill [1, 7, 15, 16] [17]. Mechanomyography (MMG) [18] is a technique that can be viable to muscular tissue assessment, including the evaluation of spasticity level in agonist side [19]. Krueger et al. [20] and Scheeren et al. [21] used MMG in agonist and antagonist forearm sides for wrist movement, and results indicated that the antagonist sensor could detect wrist movements generated by agonist muscles. Therefore, the goal of this paper is to introduce a new approach to assess spasticity in hamstrings using antagonist muscular group in spinal cord injured volunteers (SCIV).

Manuscript received March 29st, 2012. This work was supported by CAPES, CNPq and SETI-PR, Brazil.

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II. Methods

A. Subjects

This study was approved by Human Research Ethics Committee of Pontifícia Universidade Católica do Paraná (PUCPR) under register 2416/08. A physical evaluation was performed to check the power skill (from 0 to 5), reflex (from 0 to 5), spasticity (MAS from 0 to 4) and American Spinal Injury Association (ASIA) impairment scale (from A to E). During the period of tests, the volunteers did not use any drug that could change their motor condition. The demography of volunteers involved in the research (N=4) is shown in Table I. The volunteers were divided in two groups, with MAS level 0 (N=2) and MAS level 1 (N=2).

TABLE I
CLINICAL EVALUATION OF SPINAL CORD INJURED VOLUNTEERS

MAS	Age	Spinal Cord Injury				Motor System	
		ASIA	Etiology	Level	Months	Power	Reflex
0	43	B	Cancer	T10(C)	3	0	2
	25	A	Automobile	T5(C)	24	0	2
1	28	A	Automobile	T3(C)	60	0	0
	41	D	Fall	T11(I)	11	5	4

MAS: modified Ashworth scale (0-4) [17]; ASIA: American Spinal Injury Association impairment scale (A-E) [22]; C: complete; I: incomplete; Power (0-5) [23]; Reflex (0-5) [23].

B. Measuring Apparatus

MMG sensors were positioned over the muscle belly of *rectus femoris* (RF), *vastus lateralis* (VL) and *vastus medialis* (VM) muscles using double-sided adhesive tape. The sensor placed on RF was equidistant between the anterosuperior iliac spine and top of the patella. The sensor over VL was equidistant between the greater trochanter and the lateral condyle of the femur, while the sensor over VM was placed in medial third distal tight region, as illustrated in

Fig. 1. An electrogoniometer, placed laterally to the knee, acquired the range of movement.

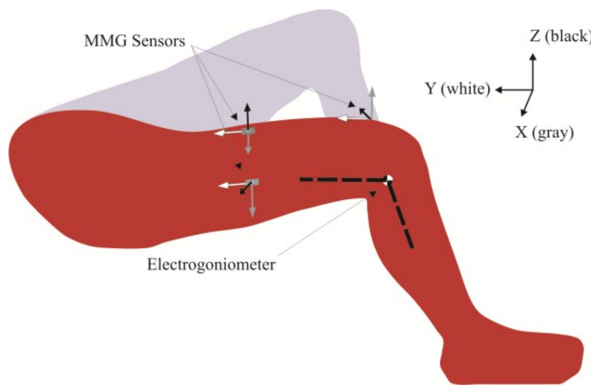

Fig. 1. Transducers placement and accelerometer axes orientation. Electrogoniometer fixed laterally to knee joint and mechanomyography sensors over the *rectus femoris*, *vastus lateralis* and *vastus medialis* muscle bellies.

C. MMG Sensor and Data Acquisition

The developed MMG instrumentation used Freescale MMA7260Q MEMS triaxial accelerometers with sensitivity equal to 800 mV/V at 1.5 G (G: gravitational acceleration). Electronic circuits allowed 10x amplification and 4-40Hz Butterworth third order filtering. A LabVIEW™ program was coded to acquire MMG signals. The acquisition system contained a DT300 series Data Translation™ board working at 1kHz sampling rate. The modulus signal was computed from the three individual MMG sensor axes.

D. Research Design

The volunteers were seated on an adapted chair with the hip and knee angles set to 70º [24] and 90º, respectively. The maximum knee extension angle was defined as 0º. The volunteers were advised to keep the body muscles completely relaxed during the protocol, thus avoiding the interference of movement artifact on MMG sensors. Three stretching reflexes were performed by physicians with approximately 90º.s^{-1}, starting with knee angle ranging from approximately 90º (knee joint flexed) to 5º (almost full knee joint extension) with 20s rest time between consecutive stretching reflexes. Eight windows of analysis were extracted from the second stretching reflex. The analysis window length (AWL) was 0.5s long. The first AWL began 0.5s before the stretching reflex followed by the subsequent seven AWLs encompassing 4.0s of signal analysis. The MMG integral (MMG_{INT}) was computed for all AWLs using the trapezoidal rule integration method.

E. Data Presentation and Analysis

The data results were exhibited in graphical format (box-plot). The statistics was performed with the software PASW Statistics® version 18.

For the statistical test the sum of eight AWLs was used to compare the two groups (MAS0 and MAS1) with Mann-Whitney test. The p value lower than 0.05 was adopted as statistically significant.

III. Results

Room temperature was 21.72ºC ± 2.29ºC, and humidity was 60.5% ± 3.69%. Fig. 2 shows the eight AWLs for both groups and muscles (RF, VL and VM). In Fig. 2 to windows 2 and 3 in MAS0 a motion artifact is registered during the onset of movement. Fig. 3 shows the mean MMG_{INT} values of both groups and muscles (RF, VL and VM). The results showed that MMG_{INT} was always greater to MAS1 than to MAS0 ($p < 0.01$) for all muscles.

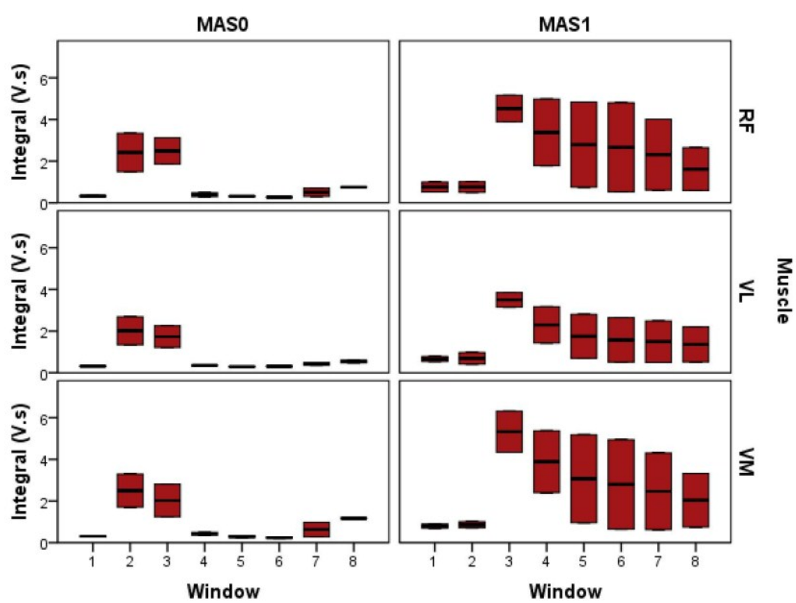

Fig. 2. Analysis window length (0.5s) during the protocol to group with modified Ashworth scale (Ashworth) 0 and 1 split into muscles *rectus femoris* (RF), *vastus lateralis* (VL) and *vastus medialis* (VM).

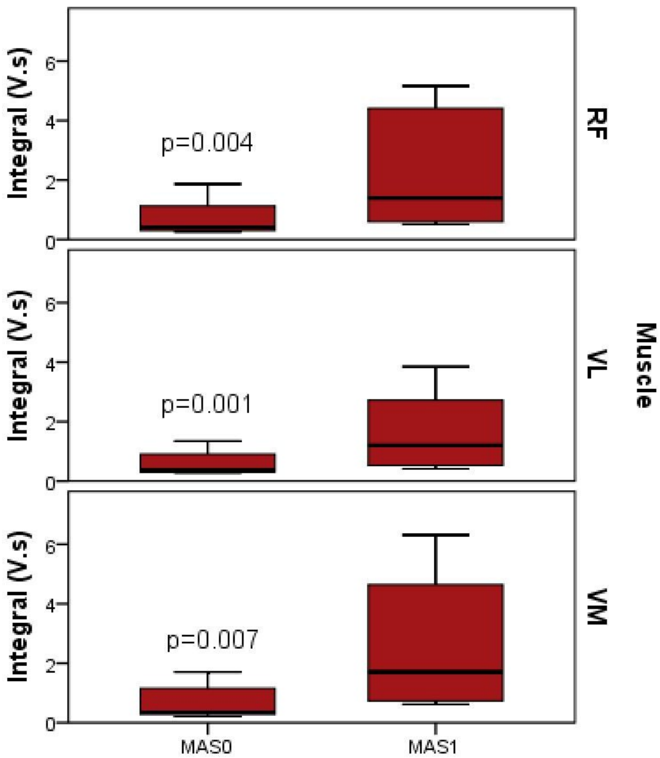

Fig. 3. Integral values of mechanomyography to both groups. The p value represents the statistical result in Mann-Whitney test. RF: *rectus femoris*; VL: *vastus lateralis*; VM: *vastus medialis*.

IV. Discussion

Spastic hypertonia involves an atypical increase in motoneuronal excitability and changes in muscle mechanical properties [4]. In this study we try to assess the spasticity in hamstrings using antagonist muscular group in SCIV. The stretching reflex performed by the physician creates a movement artifact that interferes with the MMG response. Such artifacts can lead to wrong results like those indicated by windows 2 and 3 in Fig. 2 for both muscles.

Krueger et al. [25] correlated the MMG_{INT} of quadriceps muscle with the knee angle range during angular passive movement. The results indicate that positive correlation occurs with healthy volunteers (HV) whereas negative correlation with SCIV. These correlations may be due to the incomplete relaxation of quadriceps muscle in HV, creating vibrations/pressure waves during passive movement, what is in accordance with Shinohara et al. [26].

In the present study, the variation of MMG_{INT} during the stretching reflex (fast passive movement) showed differences between SCIV MAS0 and MAS1. As can be seen in Figs. 2 and 3, the MMG_{INT} was always greater in group MAS1 than in MAS0 ($p = 0.004$, $p = 0.001$ and $p = 0.007$, respectively to RF, VL and VM muscles). Huang et al. [19] characterized the neural and mechanical components of *soleus* muscle spasticity, correlating them with MAS. The investigated group included healthy, spinal cord injured and post-stroke volunteers. The main result found by Huang et al. [19] was that the Spearman correlation between MMG amplitude and MAS was $\rho = 0.432$ (significance $p = 0.011$) although no significant correlation was determined between MAS and the median frequency. In our study the method employed was the measurement of the spasticity in antagonist muscular group. According to the statistical significance found, the results corroborate that our method is viable.

V. Conclusions

The MMG_{INT} was sensitive to the detection of spasticity in hamstrings muscles between groups with modified Ashworth scale 0 and 1. This finding indicates that mechanomyography is viable to detect the increase in muscle tonus of antagonist muscular group (*quadriceps femoris*) of spinal cord injured volunteers.

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