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TIME LAG BETWEEN THE ONSET OF ELECTRICAL STIMULATION AND THE MUSCULAR RESPONSE

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SUMMARY

The time lag between electrical activity and the mechanical response of the muscle is termed electromechanical delay (EMD). The aim of this study was to measure the EMD of the muscles of one spinal cord injured (SCI) subject and one healthy subject (HS). The EMD was measured by the time between the onset of electrical voltage signal delivered to the *rectus femoris* muscle and the onset of the mechanomyography (MMG) signal response.

The difference between the EMD found for the SCI (723 ms) and the HS (23 ms) was 700 ms. This difference might be explained by physiologic changes that occurs after spinal cord injury such as skeletal muscle atrophy, changes in the conduction of nervous fibers and permanent functional denervation.

It is promising the use of MMG signal for clinical applications of a novel noninvasive diagnostic information about neuromuscular diseases. However, future studies are necessary to evaluate effectively the time lag applicability and limitations on muscle response in individuals with neurological disorders such as SCI.

INTRODUCTION

During both volitional and electrically induced contraction, there is a mechanical muscle response that can be measured by mechanomyography (MMG) [1, 2]. The time lag between electrical activity and the mechanical response of the muscle is termed electromechanical delay (EMD) [3] and it occurs due to (a) the neuromuscular synapsis latency and the propagation of the action potential over the muscle membrane; (b) the excitation-contraction coupling process and mechanical processes (force of elastic component) [3, 4]. Neuromuscular pathologies such as dystrophy and spinal cord injury increase the EMD of muscle and this lag would be identified by MMG [5].

The aim of this study was to measure the EMD by means of MMG in spinal cord injured (SCI) and healthy (HS) subjects.

METHODS

One male SCI person (age 24 yrs; body mass 85 kg) and one male HS subject (age 22 years; body mass 82 kg) performed the tests. This work was approved by the Pontifícia Universidade Católica do Paraná Human Research Ethics Committee (0002416/08). The participants were instructed

in detail about the test protocol, and they agreed to participate in the study. After signing the consent term the subjects were positioned on an adapted bench with hip and knee angles set to 70° and 90°, respectively. Self-adhesive stimulation electrodes (5 x 9 cm) were placed on the skin over supra-patellar (anode) and the femoral triangle region (cathode).

The MMG sensor was built with a high sensitivity Freescale MMA7260Q triaxial accelerometer (800 mV/V at 1.5 G; G: gravitational acceleration) and was fixed with double-face tape on *rectus femoris* muscle belly.

The mechanomyography (MMG) signal acquisition system was developed by Nogueira-Neto *et al.* [6] and all signals were analyzed with BioProc3 software. The obtained MMG signals were rectified and the threshold determination consisted in the average resting value + 3 standard deviations.

For the neuromuscular electrical stimulation (NMES) the electrical voltage waveform applied to the femoral nerve was a monophasic square wave, with pulse duration of 100 µs, pulse frequency of 1kHz, burst frequency of 50 Hz, burst duration of 800ms and pulse amplitude of 80V.

The adopted criterion to measure EMD was the interval between the onset of electrical stimulatory voltage and the onset of MMG response.

RESULTS AND DISCUSSION

After NMES application, there was a longer time lag in the muscle mechanical response of SCI subject (723 ms) when compared to the HS (23 ms), as shown in Figure 1 (a) and (b), respectively.

Orizio *et al.* [7] evaluated the EMD induced by myotonic dystrophy (MyD) in the *tibialis anterior* and found 90 ms for MyD patients and 65 ms for the age- and sex-matched controls. The EMD can be modified in some cases of neuromuscular diseases [8]. In this context, spinal cord injury is characterized as a disabling syndrome that compromises the function of the spinal cord, decreasing the diameter of skeletal muscle (fast and slow fibers) suffering atrophy after denervation [9], undergoing a rapid loss of

both mass and contractile force [10]. The variability of the muscle contractile and fatigable properties is inherent in SCI subjects and HS [11].

In individuals with neuromuscular diseases changes occur in the conduction of nervous stimuli which are responsible for motor and sensory transmission, processing and coordination signals [12]. These changes might also affect the firing rates strategy of motor units, and these factors would be a possible explanation for the EMD difference (700 ms) between the studied subjects (SCI and HS).

CONCLUSIONS

The performed experimental protocol allowed measuring the time lag between the electrical activity and the mechanical response of muscle excited by neuromuscular electrical stimulation. The results indicated that EMD is much longer for fibers of *rectus femoris* muscle in a SCI subject than in a HS.

It is promising the use of MMG signal for clinical applications of novel noninvasive diagnostic information about neuromuscular diseases, however future studies are necessary to effectively evaluate the time lag applicability and limitations on muscle response in neurological disorder individuals such as spinal cord injury.

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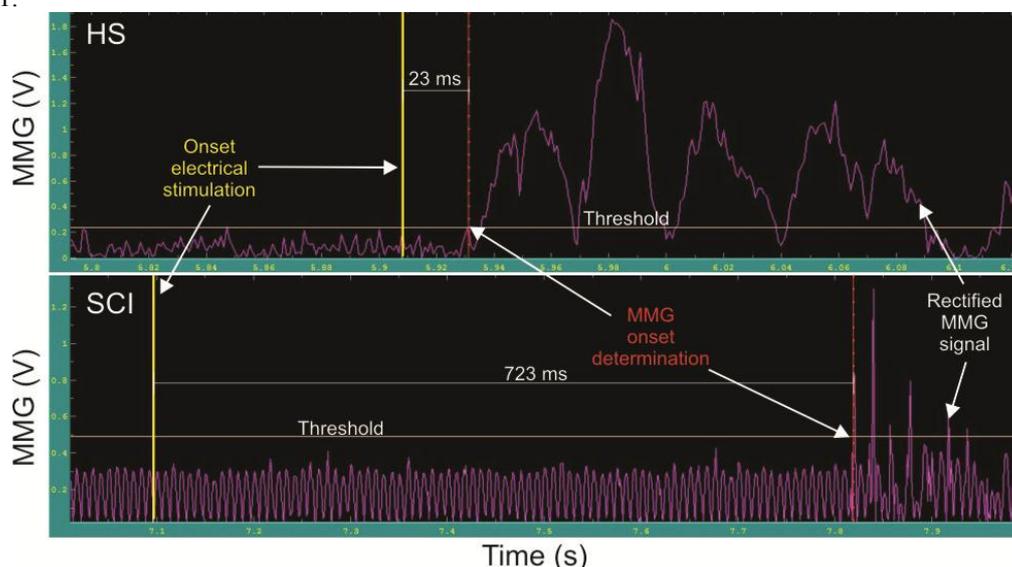


Figure 1: Latency between the onset of neuromuscular electrical stimulation and the muscle mechanical response for one spinal cord injured (SCI) and one healthy (HS) subjects.