Changes of the evoked mechanomyogram during electrical stimulation

Kazunori Seki*, Takahide Ogura, Motohiko Sato and Masayoshi Ichie

Department of Restorative Neuromuscular surgery and Rehabilitation, Tohoku University Graduate School of Medicine, Sendai, Japan

Introduction

The biological signal detected by microphones or accelerometers when muscle surface displacement has occurred is named surface Mechanomyogram (MMG). It is a relatively new method to analyze the mechanical muscle activity and expected to provide useful information about the function of muscle and nerve in clinical. Particularly, compared to EMG, MMG is suspected to have a good advantage in detecting the muscle contraction during functional or therapeutic electrical stimulation (FES, TES), because it has possibility to not be affected by electrical artifact. Changes in MMG reflecting some characteristics of motor units when voluntary muscle contraction was performed has been described in several papers. However, short time muscle contraction evoked by electrical stimulation has not yet been examined precisely in the field of MMG. In this study we investigated if the recording of evoked MMG with a latency similar to H-reflex is possible, and if the changes of excitability of the spinal motor neuron during electrical stimulation (TES) can be identified by evoked MMG (H-MMG).

Methods

Nine healthy subjects (22~45 years old) participated in this study. Evoked EMG (M-wave, H-wave) and evoked MMG (H-MMG) were recorded from the soleus muscle in the left leg by means of evoking electrical stimulation (EES) to the tibial nerve at the popliteal fossa. All of the subjects kept a prone position with the left knee fixed at 30 degrees flexion and the left ankle fixed at 5 degrees plantar-flexion on the bed during recording. The left ankle was fixed to the isokinetic torquemachine (KINCOM) to monitor the isometric torque of plantar-flexion generated by evoked muscle activity. The MMG was detected by an accelerometer (MPS101, MEDISENS Inc.) fixed to the skin over the muscle belly between the pair of surface electrodes for EMG. The bandwidth and the sampling rate of the MMG were 0.1~1000Hz and 2000Hz. EMG was recorded at the same time as the MMG recording by an evoked potential measuring machine (Neuropack 4, Nihon Kohden Inc.) with a bandwidth of 30~3000Hz.

The first experiment was detecting the series of M-wave, H-wave and H-MMG in some levels of EES intensity, gradually increased from the level at which the H-wave began to appear. The H-MMG was defined as a wave appearing at the latency corresponding to a rise of the H-wave. Since all the waveforms of the evoked MMG were recognized to continue more than 200msec with gradual attenuation, we adopted only the wave within 100msec from a rising point and calculated peak-to-peak amplitude in this range.

The second experiment was measuring the change of both the H-wave and the H-MMG during TES in the two subjects. At first, successive fifteen records of the H-wave and the H-MMG were measured at rest with the EES intensity that could induce the most reliable waveforms of the H-MMG constantly. After the recording at rest, electrical stimulation as TES for 10 minutes was applied to the anterior tibial muscle with the surface electrodes. Both the H-wave and the H-MMG were recorded again during the latter half of the stimulating period. The electrical stimulation as TES consisted of repetition of alternating pattern with 5 seconds stimulation and 5 seconds rest. The parameters of TES included the stimulation frequency of 200Hz, the pulse width of 1msec and the intensity at the motor threshold. The H-wave and the H-MMG during TES were recorded in the stimulating phase and resting phase at the same rate, and each fifteen records was used for analysis.
Results

1) The wave of MMG with the latency almost similar to the H-wave could be clearly detected at the EES intensity with the level low enough to induce no M-wave, and it was possible to isolate such a wave as H-MMG. However, the H-MMG could not be identified at the EES intensities more than the level at which the M-wave began to appear. In these intensities, the evoked MMG first appeared at the latency corresponding to a rise of the M-wave and it overlapped with the waveforms appeared later. The evoked MMG consisted of multiple waveforms even in the range of 100msec and the amplitude of it was calculated using the difference between positive and negative peak in these waveforms. The amplitude of the H-MMG clearly recorded with no M-wave was normalized by the maximum amplitude of the evoked MMG recorded at the latency of M-wave. The mean percentage of maximum amplitude of the H-MMG normalized was 18.2 (12.6~22.2) %.

2) In the two subjects where recording of H-MMG during TES was performed, the EES intensity for recording was settled to the maximum level at which the H-MMG could be clearly isolated. It was confirmed that the successive recording of both the H-MMG and the H-wave at rest succeeded without any waveforms of MMG before the appearance of the H-MMG. The identification of H-MMG during TES was also possible (same as at rest), but no waveforms of the H-wave in the stimulating phase during TES could be counted successfully by the contamination of the electrical artifact. The mean amplitudes of H-MMG at rest and during TES (stimulating phase; s-phase and resting phase; r-phase) and the results of statistical analysis are as follows for each subject (A and B). A: 7.79mV (at rest) - 3.88mV (s-phase) - 8.89mV (r-phase), p<0.0001 in ANOVA, p<0.0001 (at rest > s-phase, r-phase > s-phase) in Scheffe. B: 2.58mV (at rest) - 1.46mV (s-phase) - 1.96mV (r-phase), p<0.0001 in ANOVA, p<0.0001 (at rest > s-phase) - p<0.01 (at rest > r-phase) - p<0.05 (r-phase > s-phase) in Scheffe.

Discussion

It was confirmed through this study that the MMG was not affected by the electrical interference and the successful recording of the H-MMG was possible without the electrical artifact even during the electrical stimulation.

The MMG, however, had some problems of the mechanical interference including the vibration of the sensor on the muscle belly and the extra contraction of the target muscle induced by the electrical stimulation. It was necessary for detecting an evoked MMG as H-MMG to settle the EES intensity at the level as low as possible not to induce an M-wave.

There was a base line fluctuation of MMG in the target muscle when the electrical stimulation (TES) was applied to the other muscle with intensities extremely over the motor threshold. These results show a limitation of the evoked MMG in that the intensity of both EES and TES needs to be settled in the low level to some extent when examining a change of MMG in the short range elicited by the electrical stimulation. While involving those problems, it is supposed that the evoked MMG, like H-MMG, is useful as well as H-wave in clinical use if the intensity of the optimal level can be chosen.

In the previous study with healthy adults, we had investigated the influence of the electrical stimulation as TES with the intensity under motor threshold on the excitability of alpha motoneuron. According to this study, the electrical stimulation under motor threshold with the frequency of 50~200Hz and the pulse width of 1msec inhibited the H-wave amplitude significantly at least 1sec after the stimulation lasting 5sec. However, the change of the H-wave during stimulation could not be observed because of the electrical artifact. In this study, the H-wave during the electrical stimulation with the same parameters as above could not be identified too, but the amplitude of the H-MMG in the stimulating phase during TES clearly decreased. This result suggests the evoked MMG is applicable to evaluation of the excitability change in the spinal motor neuron during TES with low intensity.
References


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