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Hylonome

Original Article

Vibration paradox and H-reflex suppression: is H-reflex suppression results from distorting effect of vibration?

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Abstract

Vibration paradox is that an increase in muscles activity coexists with the inhibition of H-reflex during vibration. The H-reflex suppression may be due to the movement of stimulating electrode during vibration. The aim of this study was to test this hypothesis. Fifteen healthy young adult males participated in this study. The soleus myoelectrical activities were evaluated by surface electromyography (SEMG). The vibration was applied only to the left leg and the H-reflex of soleus muscle was measured in the right leg to prevent the probable measurement errors caused by the movement of stimulating electrode. The H_{max}/M_{max} ratio of the right soleus isolated from vibration effects significantly decreased during the left leg vibration. As a result, this study shows that the H-reflex is suppressed during the vibration and the movement of the stimulating electrode has no role on the suppression of H-reflex.

Keywords: Vibration, Tonic Vibration Reflex, Hoffmann Reflex, Electromyography, Neuromuscular Performance

Introduction

The reflex activity observed during the isolated vibration applied to muscle belly or tendon is explained with the Tonic Vibration Reflex (TVR)[1-4]. TVR activates the muscle spindles, thereby enhancing the excitatory drive reflex of the alpha motor neurons via Group Ia afferent[2-4]. Although, the direct evidence is lacking, many articles claim that the effect of whole body vibration (WBV) on neuromuscular performance can be explained through TVR[3,5-7].

H-reflex is obtained by electrically stimulating Ia afferents bypassing the muscle spindle unlike from TVR. It has been reported that H-reflex suppresses during isolated muscle/tendon vibration. The myoelectrical activity has also been reported to increase during vibration[8-16]. It seems paradoxical that an increase in the myoelectrical activity coexists with the H-reflex suppression during vibration. This contradiction is defined as the vibration paradox[14].

H-reflex suppression has been explained by presynaptic inhibition of Ia afferents[8,11,13-16]. However, H-reflex suppression during vibration may be questionable due to the mechanical oscillatory effect of vibration on the stimulating electrode.

The mechanical oscillatory effect of vibration on the recording electrodes is well known. The relative movement between myocutaneous tissues and recording electrodes during the vibration may be the source of error for surface electromyography (SEMG) recordings. It is strongly recommended that SEMG records is filtered to eliminate the motion artifacts[9,10,12,17,18]. The stimulating electrode is also exposed to the same movement. The relative movement between the peripheral nerve and stimulating electrode may affect the H-reflex amplitude. If the optimal distance between peripheral nerve and stimulating electrode changes, the amplitude of H-reflex might decrease. In the previous studies, there were no precautions against to this potential problem. For the precise confirmation of suppression of H-reflex during vibration, the H-reflex amplitude can be measured by isolating the stimulating electrode from the mechanical oscillatory effect of vibration.

Our hypothesis is that H-reflex is not suppressed during WBV when distorting effects of vibration is eliminated. If this hypothesis is valid, the vibration paradox is solved. First of all, we showed an increase in the myoelectrical activity during WBV. Then, we tested our hypothesis in this study.

The authors have no conflict of interest.

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Material and method

Participants

Fifteen volunteers participated in this study. The inclusion criteria were being young male adult and being dominant right side. The exclusion criterion was inability to tolerate WBV. There was no subject who is unable to tolerate WBV. The average age of the subjects was 19.8 (18-25) years. The average height and the body mass index of the subjects were respectively 175.6±4.4 cm and 21.9±2.7 kg/m^2.

All participants gave written informed consent to the experimental procedures, which were in accordance with the Declaration of Helsinki and were approved by the local ethics committee (Istanbul University Istanbul Medical Faculty Clinical Research Evaluation Committee, Istanbul; 2011/06).

Experimental setup

H-reflex and the surface EMG (SEMG) of the right soleus were recorded before, during and after WBV. First of all, soleus muscle resting potentials were recorded and then the SEMG were recorded during the subjects voluntarily contracting their soleus muscles. This measurement was conducted to confirm the previous studies findings that the myoelectrical activities increase during different contraction and vibration combinations. After 15 minutes of rest, H-reflex measurements of subjects were taken. Firstly, to confirm the previous studies findings that soleus H-reflex suppresses during vibration, the right soleus H-reflex measurements were taken when the right leg was exposed to vibration. Then, to test our hypothesis, H-reflex measurements were taken from the right legs when only the left legs of subjects were exposed to vibration. In both of the H-reflex measurement cases the stimulating electrode was fixed well.

Whole-body vibration

Vibrations (40 Hz, 2.2 mm vertical displacement) were performed on a PowerPlate® Pro5 (PowerPlate® International Ltd, London, United Kingdom) WBV platform. Participants were barefooted, and no sponge or foam was placed between the vibration platform and their feet.

Electrophysiological studies

Surface electromyography measurements

During all experiment period, the participants were asked to stand upright with their knees locked on the vibration platform.

The SEMG measurements were taken in six phases;

Record-1: In this phase, 30 seconds of resting position right soleus SEMG records were taken. The subjects were asked to stand on the WBV platform upright with the both feet while the knees were fully extended. When the subjects stand on upright, the soleus muscles may contract to provide stability and then it may not be possible for soleus muscle to relax. Three precautions were taken to overcome this problem.

i. It's asked the subjects to fully relax when they stand on the platform.

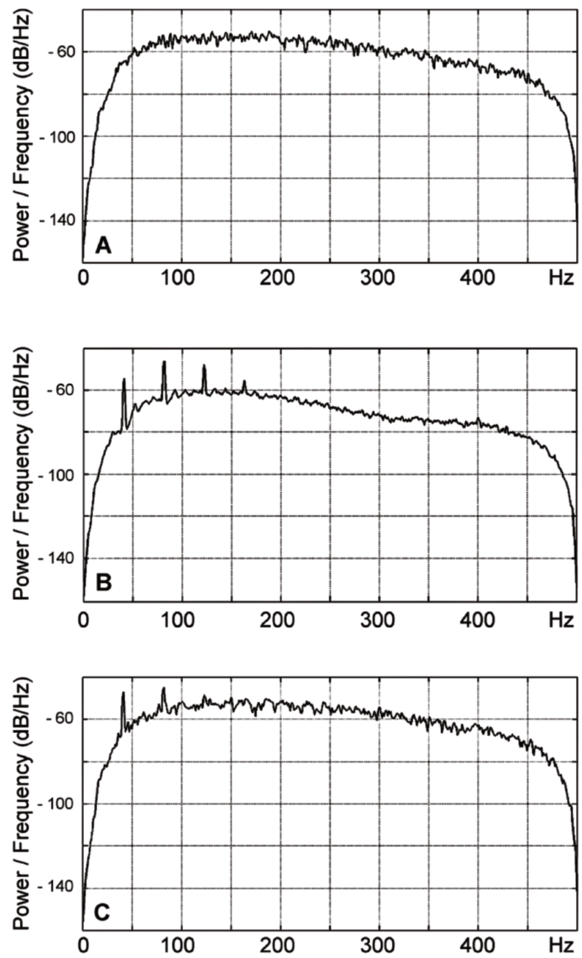

Figure 1. Power spectrogram density (PSD) analysis for the right soleus SEMG records. A) Maximally isometric contracting soleus muscle, B) Vibration response of resting position soleus muscle, C) Vibration response of maximally isometric contracting soleus muscle.

ii. The participants were asked to use the handles of the platform to maintain their balance.

iii. The base of support (distance between the heels) was adjusted as wide as possible. The distance between the heels was 30 cm.

Record-2: The measurement was taken when the subjects were in dynamic position. During the dynamic position, the subjects stood up only on their right foot and they were asked to rise up their right heels (Right Soleus Maximal Isometric Contraction - MIC). Meanwhile, they also asked to keep their right knees fully extended and grip the handle of the WBV device. Three 5 seconds duration of MIC records were taken. The resting duration between MIC records kept as 10 seconds.

Record-3: The measurement was taken when the subjects were in static position during WBV. The subjects were exposed to 30 seconds of WBV. WBV may impair the sense of balance and the muscles may be activated to restore balance. To overcome this issue, the same precautions in Record-1 were also taken into account during this record. Moreover, the subjects were applied a trial protocol to make them familiarized to the vibration (40 Hz, 4 mm amplitude, 15 s) before Record 3.

Record-4: The measurement was taken when the subjects were performing MIC during vibration. The subjects were exposed to 60 seconds vibration.

In order to record SEMG, Ag/AgCl electrodes [KENDALL ® Arbo] with a disc radius of 10 mm were placed 20 mm apart on the right soleus muscle belly on shaved skin cleaned with alcohol in accordance with SENIAM recommendations[19]. The ground electrode was placed on the lateral malleolus. SEMG recordings were done using a wireless data acquisition system (PLUX - Wireless Biosignals, S.A., Lisbon, Portugal). The sampling frequency was selected as 1 kHz. The average room temperature was 23.9 (23-26)°C.

All the data were analyzed offline using MATLAB (TheMathworks Inc., Natick,MA). SEMG records were filtered with an 80-450 Hz band-pass filter to eliminate the effect of motion artifact. Subsequently, SEMG data were full-wave rectified[18].

The root-mean-square values (RMS) were calculated from the filtered SEMG signal. Normalization was achieved by calculating RMS as a percentage of MIC during right heel rose up (Record-2). The normalized RMS values were obtained by using the equation 1.

$$\frac{RMS\ (\text{Record} - \text{n}) \times 100}{RMS\ (\text{Record} - 2)} \qquad \text{(Eq. 1)}$$

Fast Fourier transform (FFT) analysis was used to determine the frequency components of the recorded signals. Power spectral analyses were conducted using Hanning window and 50% overlapping. The FFT length was set to 1024 points. Dominant peaks at the vibration frequency were visually inspected in the filtered and rectified SEMG power spectrograms (Figure 1).

H-reflex measurements

A data acquisition system [POWERLAB® ADInstruments, (Oxford, United Kingdom] was used for obtaining soleus H-reflex. The detection electrodes were placed on the skin surface over soleus muscle. Electrical stimulation of the tibial nerve at the right popliteal fossa was done using an electrical current stimulator (FE155 Stimulator HC, ADInstruments, Oxford, United Kingdom). A bipolar stimulation electrode was used to stimulate the tibial nerve using a monophasic current (pulse frequency 1 Hz, pulse duration 0.5 ms). Before WBV, the optimal current amplitude necessary for the maximal H-reflex response was determined. The stimuli centered on the optimal current amplitude, 10 mA lower and 10 mA higher and then the optimal current amplitudes were used for eliciting H_{max} during WBV. During WBV, the subjects were stimulated 10 times to evoke H-reflex responses. M_{max} was elicited with using supramaximal stimulus for motor fibers. H_{max} was normalized to the M_{max} (H_{max}/M_{max}) to compare H-reflexes between subjects and conditions.

H-reflex testes were realized in two different positions:

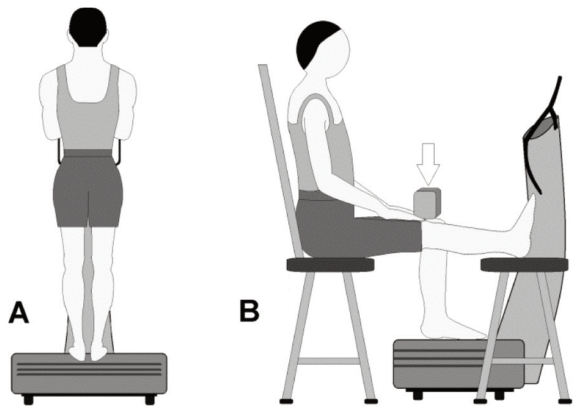

Figure 2. Positions of the subjects: A) Position-1, B) Position-2.

a. Position-1 (recording of the right soleus H-reflex for ipsilateral leg vibration): The subjects were asked to have their position like Record-1. The right soleus H-reflex measurements were taken when the right legs were exposed to vibration. In this position, H-reflex of right soleus was also tested before and immediately after WBV.

b. Position-2 (recording of the right soleus H-reflex for contralateral leg vibration): During this phase, the right soleus H-reflex measurements were taken when only the left leg was exposed to vibration. In this position, H-reflex of right soleus was also tested before and immediately after WBV. The subjects were seated on a chair in front of the vibration platform as their left knees and hips 90 degrees flexed. The left foot placed on the vibration platform. The chair is mechanically well isolated. The right lower extremities of the subjects were positioned as their hips 90 degrees flexed and their knees fully extended. The right foots were placed on another mechanically well isolated chair which had the same height with the chair the subjects sitting on. The bottoms of the chairs were coated with 3 cm thick of rubber for mechanical isolation. Upper surfaces of the chairs were also covered with 15 cm of sponge. After positioning the subject as explained above, the left thigh of the subject was loaded with a weight that is half weight of the subject (Figure 2). So that it was tried to keep the load on the feet when the subjects were standing upright on the vibration platform and the load on the left foot when the subjects were sitting on the chair almost equal.

Contralateral soleus H-reflex measurement was realized to observe the suppression of the soleus H-reflex under the conditions when the mechanical oscillatory effect of vibration was minimized. For the acceleration measurements, a very light (<3 g) three axis MEMS piezo-accelerometer (LIS344ALH full-scale of ±6 g linear accelerometer, ECOPACK) was taped onto the both soleus muscles. The acceleration along the longitudinal soleus axis was measured. The acceleration measured on the left soleus in position 1 was 2.9 (0.7-4.7) g. It was 2.7 (1.9-3.7) g in position 2. The acceleration measured on the right soleus in position 2 was 0.07 (0.05-0.09) g.

SEMG records	Normalized RMS data (%)
MIC [-] WBV [-] (record-1)	54.3±24.0
MIC [+] WBV [-] (record- 2)	100.0±0.0
MIC [-] WBV [+] (record- 3)	85.3±31.9
MIC [+] WBV [+] (record- 4)	128.9±21.4
F(2-42)	38.8
P value	<0.0001
MIC: maximal isometric contraction,	*WBV: Whole-body vibration*

Table 1. The effects of vibration on the right soleus myoelectrical activities.

(I) factor1	(J) factor1	Mean Difference (I-J)	P value*
MIC [-] WBV [-]	MIC [+] WBV [-]	-45.7	<0.0001
	MIC [-] WBV [+]	-31.0	0.015
	MIC [+] WBV [+]	-74.6	<0.0001
MIC [+] WBV [-]	MIC [-] WBV [+]	14.6	0.577
	MIC [+] WBV [+]	-28.8	0.001
MIC [-] WBV [+]	MIC [+] WBV [+]	-43.5	<0.0001

** Adjustment for multiple comparisons: Bonferroni.*

Table 2. The pair wise comparisons of electromyographic activities of right soleus muscle.

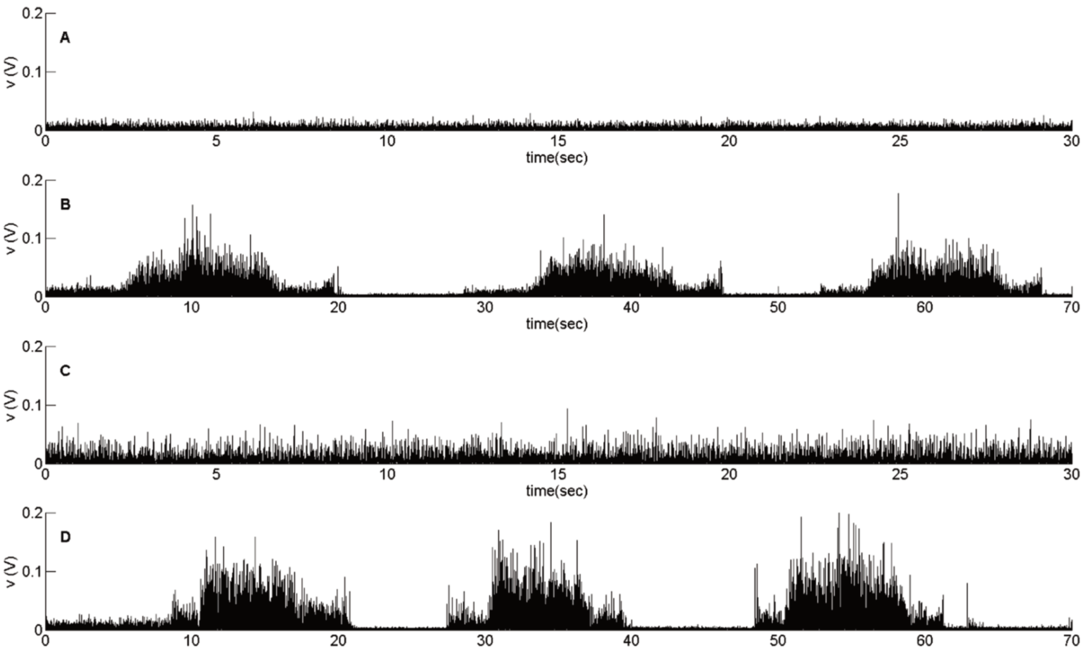

Figure 3. Myoelectrical activity; A) Resting, B) MIC, C) During WBV, D) During WBV + MIC.

Statistical analysis

The normal distribution of data was confirmed with the Kolmogorov-Smirnov test. Continuous variables were summarized as arithmetic means and standard deviations (SD). Measured values of the H_{max} and M_{max} before, during and after vibration were compared with general linear model repeated measures. The SEMG records were also compared with general linear model repeated measures. The Bonferroni test was applied for

Vibrated leg	Data	preWBV	during WBV	postWBV	F value	P Value
The right leg	M_{max} (μV)	3.17±1.40	3.07±1.47	3.09±1.55	F (2,28) = 0.925	0.408
	H_{max} (μV)	0.94±0.73	0.47±0.29	0.90±0.86	F (1.0, 14.8) = 8.501	0.010
	H_{max}/M_{max}	0.28±0.10	0.16±0.07	0.27±0.11	F (1.1, 16.1) = 29.706	<0.0001
The left leg	M_{max} (μV)	2.91±1.61	2.95±1.56	3.02±1.57	F (1.2, 16.7) = 1.724	0.209
	H_{max} (μV)	0.93±0.80	0.43±0.44	0.88±0.78	F (1.2, 16.6) = 17.813	<0.0001
	H_{max}/M_{max}	0.32±0.14	0.14±0.09	0.27±0.12	F (2, 28) = 29.827	<0.0001

Table 3. Effects of the right and left leg vibration on the right soleus H_{max}, M_{max} and H_{max}/M_{max} ratio.

Vibrated leg	Data	preWBV–during WBV	during WBV–postWBV	PreWBV–postWBV
Ipsilateral	H_{max}	0.011	0.065	1.000
	H_{max}/M_{max}	<0.0001	0.001	0.727
Contralateral	H_{max}	0.002	0.002	0.629
	H_{max}/M_{max}	<0.0001	<0.0001	0.204

Table 4. Significancy for pair wise comparisons (Bonferroni test).

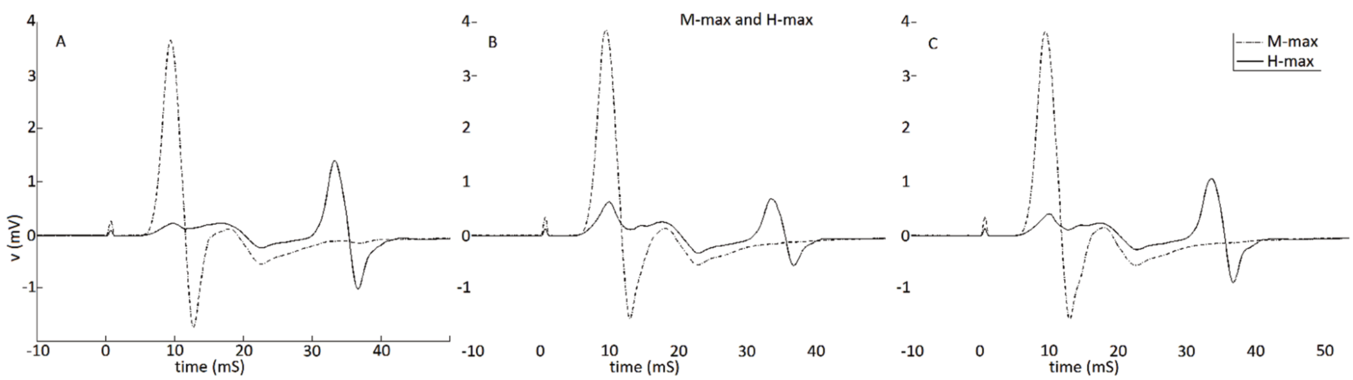

Figure 4. The right soleus H-reflex measurement in the Position-2. A) Before vibration, B) During vibration, C) After vibration.

pair wise comparisons (PostHoc analyses). The software package used for data management was PASW Statistic 18.

Results

Compared with the right soleus resting activity (Record-1), the right soleus activity during MIC (Record-2) and the right soleus activity during WBV (Record-3) significantly increased. Voluntary contraction activity significantly increased during WBV (Tables 1, 2) (Figure 3).

Motor unit synchronization was observed at the vibration frequency and its harmonics in the spectrograms of filtered and rectified SEMG signals. The power spectrograms of Record-2 (the record taken from the right soleus during MIC), Record-3 (the record taken during vibration) and Record-4 (the record taken during MIC with vibration) are shown in Figure 1.

When vibration was applied to the right leg, H_{max} amplitude and the H_{max}/M_{max} ratio of the right soleus decreased during vibration. H_{max} amplitude and the H_{max}/M_{max} ratio of the right soleus also decreased during the left leg vibration (Tables 3, 4) (Figure 4).

Discussion

The results of our study confirmed an increase in the myoelectrical activity during WBV but our hypothesis. We found that the H-reflex suppressed during WBV when distorting effects of vibration was eliminated.

The motion artifact is a very important issue in the studies where the effects of vibration on myoelectrical activity are investigated. Some precautions are preferred to prevent the motion artifact that is happening because of the movement of measurement electrode and cables. Moreover, shielded cables are used to prevent the interference of environmental electromagnetical noises. It is recommended to filter the SEMG signals to remove the noises happening as a result of the movement of the recording electrodes[9,10,12,17,18]. In this study, we filtered all SEMG data with an 80-450 Hz band-pass filter. In the time domain, the filtered SEMG data clearly revealed an increase in myoelectrical activity during WBV with and without voluntary contraction. The present study findings are consistent with the reports of the previous studies[20-22].

In general, EMG signals are non stationary. However, vibration stimuli are stationary during WBV application. EMG spikes occurs 1:1 manner with vibration stimuli[23]. In that case the EMG signals recorded during the WBV might be accepted as the stationary signals. In the present study, the power spectral (FFT) analysis revealed that the motor units are synchronized with the vibration frequency and its harmonics both in static and dynamic positions when the vibration is applied (Figure 1). Briefly, both time and frequency domain analyses of filtered SEMG data clearly showed that vibration induces the myoelectrical activity.

The stimulating electrode is also exposed to the vibration based oscillatory movement during WBV. Because of the oscillatory movement the distance between stimulating electrode and the tibial nerve changes. In that case, the movement of the stimulating electrode may affect the amplitude of the H-reflex. We hypothesized that the H-reflex is not suppressed during WBV when distorting effects of vibration is eliminated. Then we tested this hypothesis. Firstly, right soleus H-reflex amplitude was measured when the subjects were standing upright on the vibration platform with both of the feet. It was detected that H_{max}/M_{max} decreased significantly during the vibration. Afterwards, the subjects were seated on a mechanically well isolated chair in front of the vibration platform to vibrate only the left leg and the right leg was fully extended on another mechanically well isolated chair (Figure 2). In this position of the subjects when the left leg was exposed to the vibration, the accelerations for left and right soleus muscles were 2.7 g and 0.07 sequentially. Thus the oscillatory movement of the stimulating electrode that was placed on the right tibial nerve during vibration was negligible. Notwithstanding this precaution, the H-reflex amplitudes of right soleus were significantly suppressed during the left leg vibration.

Conclusion

The stimulating electrode placed on tibial nerve is exposed to the oscillatory movement of vibration. The motion of stimulating electrode may affect H-reflex amplitude during vibration. For the first time in this study, H-reflex measurements are taken by considering this potential problem. The findings of this study showed that the H-reflex is suppressed when the oscillatory motions are eliminated. This study revealed that it is not necessary to have any other methodological prevention for reliable H-reflex measurement during vibration.

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