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Original Paper

Posture Induced Changes in the Maximal M-wave and the H-reflex Amplitude

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Abstract

The purpose of this study was to investigate posture induced changes in the H-reflex and maximal M-wave (M_{max}) amplitude in soleus muscle (SOL). The hypothesis of the present study is that both H-reflex amplitude and M_{max} amplitude change with posture. Nine healthy males were tested under two randomly administered conditions; prone and standing position. The ankle joint angle was set at the same angle in each postural condition by monitoring the electrical goniometer. H-reflex was elicited in the SOL from the right leg every 5 seconds using electrical stimulation to the tibial nerve in the popliteal fossa. Surface electromyography (EMG) was recorded from the middle surface of the SOL and the tibialis anterior muscle (TA) using silver bipolar electrodes. Absolute values of H_{max}, M_{max} amplitude and H_{max}/M_{max} ratio in each postural condition obtained from the H-M recruitment curve were compared. All H_{max}/M_{max} ratios, H_{max} amplitudes and M_{max} amplitudes were significantly lower in the standing position. The hypothesis of the present study was verified, and M_{max} amplitude in the SOL was inhibited by the standing posture. There is a possibility that M_{max} amplitude is changed in conjunction with the posture induced physiological response.

Introduction

The Hoffmann reflex (H-reflex) is a technique in neurophysiology that can evaluate the motor output of humans. It is possible to use H-reflex in humans non-invasively and with unanesthetized subjects. H-reflex is the action potential that can be evoked by electrical stimulation of the peripheral nerve. During percutaneous stimulation of the peripheral nerve, the Ia afferents that innervate muscle spindle sensory receptors will be recruited before the smaller diameter motor axons because of their larger diameter. H-reflex amplitude is considered to be the index of the activities in the spinal cord as a final common pathway and used to evaluate the effects of the upper spinal organs and the input from sensory systems [1-5]. When the peripheral nerve is stimulated by high-intensity electrical stimulation, the direct motor response (from the point of stimulation to the neuromuscular junction; M-wave) can be evoked in the test muscle. The maximal M-wave (M_{max}) amplitude indicates that all α-motoneurons of the innervated muscles

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were fired. In previous studies, M-wave amplitude was used as an index of the stimulus intensity [6-9], and M_{max} amplitude was used as a base to normalize H-reflex amplitude [8-14]. Change of H-reflex amplitude is dependent on the number of α-motoneurons recruited by Ia afferents. Previous studies reported the effects of Ia inhibition [2] and presynaptic inhibition [9] based on the changes of H-reflex amplitude. In contrast, it is considered that M_{max} amplitude is not changed because the maximal direct motor response represents the activity of the whole motoneuron pool. However, a recent study reported that changes of M_{max} amplitude in the SOL occurred with changes in the ankle joint angle and the level of muscular contraction [15], and suggested that M_{max} amplitude is influenced by peripheral factors at the recording site such as muscle length and the level of voluntary muscular activation. It is reported that H-reflex amplitude evaluated as a percentage of M_{max} amplitude in the standing position is significantly lower than that of the sitting position [6, 16]. However, there is a possibility that M_{max} amplitude changes with posture. If M_{max} amplitude changes with posture, careful attention is required to evaluate and to construe the activities of the spinal cord in relation to posture. Therefore, the present study investigated posture induced changes in H-reflex and M_{max} amplitude. The hypothesis of the present study is M_{max} amplitude is changed with posture.

Methods

1. Subjects

Nine healthy males (Age: 22.6 ± 1.7 yrs, Height: 175.1 ± 4.5 cm, Weight: 67.8 ± 6.6 kg; Mean ± SD) volunteered to participate in this study. All subjects gave their informed consent and the experiment was approved by the Ethics Committee on Human Experiments at the Kawasaki University of Medical Welfare.

2. Experimental set up

Subjects were tested under two randomly administered conditions; prone and standing position. For the prone position, subjects lay on the experimental bed. For the standing position, subjects were required to stand in a relaxed position, with their arms held comfortably at their side, their feet shoulder-width apart, and to look at a target set at eye level and completely supported on the floor. The ankle joint angle was set at the same angle in each postural condition. The angle was measured using an electrical goniometer (SG 150W, Biometrics).

In each postural condition, H-reflex was tested in the right leg. H-reflex was elicited in the SOL every 5 seconds by single square pulse electrical stimulations of 1ms duration to the tibial nerve in the popliteal fossa (Stimulator: SEN-3301, Isolator: SS202-J, Nihon Koden, Japan). Surface electromyography (EMG) was recorded on the middle surface of the SOL and tibialis anterior muscle (TA) using silver disk bipolar electrodes (5 mm diameter, interelectrode distance 2 cm). EMG signals were amplified through a bio-amp system (JB-210J, Nihon Koden, Japan) and band pass filtered 0.08-10,000 Hz. After the full-wave rectification of EMG data, integrated EMG for 50 ms prior to electrical stimulation were calculated as the EMG activity. In order to decrease the interelectrode resistance, the skin was shaved, rubbed with sand paper and cleaned with alcohol before attaching the electrodes. The interelectrode resistance was less than 5 kΩ both before and after the experiment. M_{max} was defined as the M-wave at the time of verifying the peak out in amplitude with the increases of stimulus intensity. H-M recruitment curves (Figure 1) were constructed from data recorded at each postural condition to identify the maximal H-reflex (H_{max}) and M-wave (M_{max}) amplitude.

3. Statistics

All the data were expressed as mean ± standard deviation (SD). The paired *t*-test was used to compare the data between prone and standing condition. The statistical significance was set to $P < 0.05$.

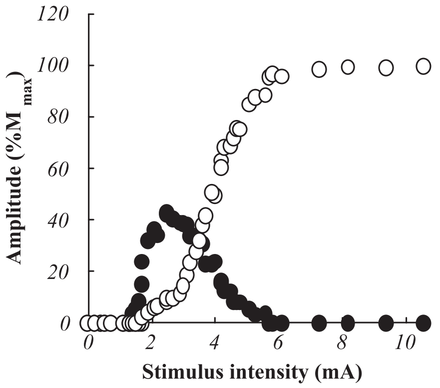

Fig. 1 Typical example of H-reflex and M-wave recruitment curve with the electrical stimulation from a single subject. Filled circle indicates the relationship between stimulus intensity and H-reflex amplitude. Open circle indicates the relationship between the stimulus intensity and M-wave amplitude. Amplitude was expressed as a percentage of the absolute value of M_{max} in each postural condition.

Results

For the 50 ms prior to electrical stimulation integrated EMG in both SOL was significantly higher in the standing position than in the prone position (Prone: 100 ± 0 %, Standing: 143.7 ± 36.2 %; Figure 2). There was no significant difference in the integrated EMG of the TA during the 50 ms prior to electrical stimulation (Prone: 100 ± 0 %, Standing: 97.2 ± 8.2 %; Figure 2). The H_{max}/M_{max} ratio during the standing position was significantly lower than that of the prone position (Prone: 69.8 ± 11.6 %, Standing: 60.5 ± 14.1 %, $P < 005$; Figure 3). H_{max} amplitude during standing position was significantly lower than that of the prone position (Prone: 7.6 ± 2.0 mV, Standing: 4.8 ± 1.4 mV, $P < 0.05$; Figure 4). M_{max} amplitude during standing position was significantly lower than that of the prone position (Prone: 11.0 ± 2.9 mV, Standing: 8.5 ± 3.5 mV, $P < 0.05$; Figure 5).

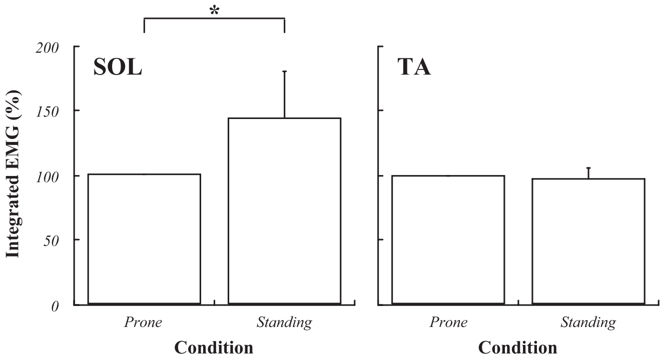

Fig. 2 Integrated EMG for 50 ms prior to electrical stimulation in soleus muscle (SOL) and tibialis anterior (TA). Data were expressed as a percentage of the values in the prone position in each muscle.
Asterisk indicates a significant difference ($P < 0.05$)

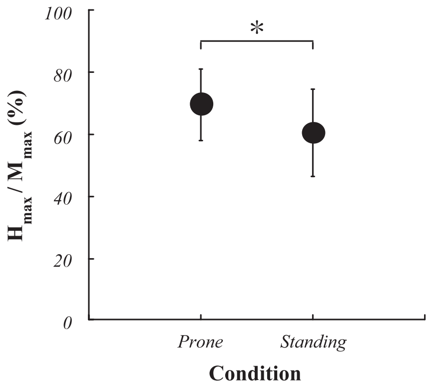

Fig. 3 H_{max} / M_{max} ratio in both postural conditions.
Asterisk indicates a significant difference ($P < 0.05$)

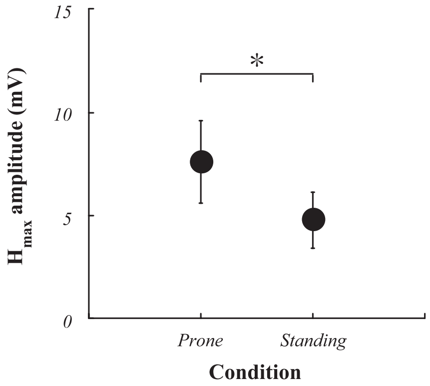

Fig. 4 Absolute values of H_{max} amplitude in both postural conditions.
Asterisk indicates a significant difference ($P < 0.05$)

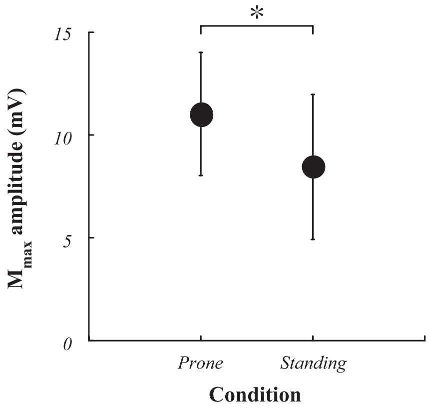

Fig. 5 Absolute values of M_{max} amplitude in both postural conditions.
Asterisk indicates a significant difference ($P < 0.05$)

Discussion

It is reported that H-reflex amplitude in the standing position is significantly lower than in the supine position [17]; furthermore there is no significant difference in H-reflex amplitude between the supine position and sitting position [18]. In the standing position, efferent input from upper centers to the leg muscles and afferent input from peripheral receptors, like the muscle spindle in stretch reflex, occur in order to maintain the standing posture. However, it is thought that no such inputs occur in the prone position. Based on these phenomena, it could be argued that the depression of reflex gain caused by an increase in the presynaptic inhibition of the Ia terminal in the standing position induces the inhibition of H-reflex amplitude.

It has already been reported that H_{max}/M_{max} ratios that indicate the activities of spinal α-motoneuron in the SOL are influenced by ankle joint angle [19], and that this is greater when muscle length is shorter (plantar flexed position) and during voluntary contraction [15]. These data suggest that changes in H-reflex at short muscle length are not completely due to peripheral changes at the muscle, but also to central effects. However, as with previous studies, the current study demonstrated that H_{max}/M_{max} ratio was significantly lower in the standing position than in the prone position. It is hypothesized that excitabilities of the spinal cord were inhibited by the inputs induced in the standing posture such as afferent input from the muscle spindle, vestibular sensory input, or input from upper centers to antigravity muscles. The present result suggests that H-reflex amplitude is changed and influenced by both central and peripheral input, but that central inputs have a stronger effect than peripheral inputs.

H-reflex amplitude is an action potential of the reflexive component included in the monosynaptic reflex arc, and M-wave is an action potential of nonreflexive components. It is considered that Ia inhibition [2], Ib inhibition [20], recurrent inhibition [21, 22], presynaptic inhibition [9] and cutaneous reflex [7, 23] were one of the factors which influenced change in H-reflex amplitude. However, there are a few reports about M-wave that question the mechanism of change in M-wave or M_{max} amplitude. A previous study reported that M_{max} amplitude in the middle site of the SOL is larger when the ankle joint position produces a short muscle length (i.e plantarflexion), and smaller when the ankle joint position produces a long muscle length (i.e dorsiflexion) compared to a neutral ankle position [15]. Furthermore, M_{max} amplitude in the middle site of the SOL is elevated proportionately with the level of isometric muscular contraction. However, there are some contradictory reports that demonstrated that the changes of M_{max} in SOL and M_{max} amplitude occurring with ankle joint angle is not influenced by the level of muscular contraction [15] [24] [25]. In the present study, throughout the postural conditions the ankle joint angle was set at the same position. Thus, experimental conditions of the present study aimed to compare the conditions under muscular activation and that of less activation in the SOL given the same ankle joint angle. However, our results showed that M_{max} amplitude is significantly decreased in the standing position and thus contradicts the findings of the previous study [15] that found M_{max} amplitude increasing with the level of muscular contraction. This study investigated 10%, 20%, 30% maximal voluntary contraction (MVC) and the relaxed condition with the ankle joint angle set at 10 degrees (a slight plantarflexion from the neutral ankle joint angle) in the sitting position. Ankle joint angle in the present study was in the dorsiflexed position compared to the other study. These data suggest that ankle joint angle is one of the important factor when investigating the relationship between M_{max} amplitude and EMG activities during isometric muscular contraction in the SOL. Our data suggests that M_{max} amplitude is used to normalize the H-reflex amplitude and is changed in conjunction with the physiological response caused by posture. The present study clarified that H_{max} amplitude, M_{max} amplitude and H_{max}/M_{max} ratio were all inhibited in the standing posture when compared with results from the prone position. Based on these finding we suggest that it is necessary to consider changes in M_{max} amplitude casued by posture when conducting experiments of this kind. It is considered that change of M_{max} amplitude is an important case in point when evaluating the activities of spinal α-motoneuron using H_{max}/M_{max} ratios. The present results suggest the need for careful consideration of M_{amx} amplitude when setting the experimental conditions and determining the stimulus intensity in H-reflex studies. Moreover, there is the possibility that inhibition of M_{max} amplitude in the SOL caused by standing posture is a physiological response according to changes of posture. The hypothesis of the present study was verified, and thus a possible direction for future research is to investigate the influence of the afferent input to the spinal α-motoneuron pool using changes of M_{max} amplitude.

One limitation of the present study is that there is no index of changes in the peripheral factors in the standing posture with which to conclude that M_{max} amplitude is under the influence of peripheral changes. For example, synchronized measuring of the structural and mechanical changes in the SOL using ultrasonography could be used to investigate more distinct relations between M_{max} amplitude and peripheral factors. However, this was not undertaken during the present study.

Conclusion

M_{max} amplitude in the SOL is lower in the standing posture than in the prone position.

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