WEIGHT BEARING-INDUCED MODULATION OF THE SOLEUS H-REFLEX IN HUMANS : EFFECT OF STATIC TILT AND ADDITIONAL WEIGHT LOAD DURING UPRIGHT STANDING

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Abstract

The purpose of this study was to investigate the effects of weight bearing conditions using static tilt condition and additional weight load on the soleus H-reflex in humans. Eight healthy subjects were tilted from the supine position to the standing position. In addition, they kept upright standing without and with a weight load of 50% of the body weight. No background activities in the muscle or changes in the recruitment profiles were observed. The effect was −9.1 (95%CI: −15.1 to −3.1)%Mmax under the static tilt condition, and −1.9 (−4.8 to 1.0)%Mmax under the additional weight load condition. The effect under the static tilt condition positively related to the effect under the additional weight load condition. It is suggested that weight bearing-induced proprioceptive input and tonic vestibular input increase presynaptic inhibition of soleus Ia afferents during upright standing in humans.


key word : soleus H-reflex, weight bearing, static tilt, upright standing, human

Introduction

The soleus H-reflex is highly modifiable by postural conditions1−7). The mechanism of postural modulation of the H-reflex has been explored before by examining the recruitment profiles2−7) and heteronymous facilitation4) in humans. Ascending inputs from the sensory nervous system and descending inputs (including postural set) generated by supraspinal mechanisms converge directly onto spinal motoneurons and indirectly via interneurons in the spinal cord. Static tilt experiments have been conducted to investigate the effect of tonic vestibular input on the soleus H-reflex in humans1,4−6). Physical stimulations, such as pressure and weight loading of the body, have been employed to investigate the effects of proprioceptive input on the spinal excitability8−11). However, there are still methodological difficulties in directly comparing postural conditions5). The purpose of this study was to investigate the effects of weight bearing conditions using static tilt condition and additional weight load on the soleus H-reflex in humans.

Methods

The subjects of this study were seven healthy males and one female, ranging in age from 19 to 40 years and having no neurological disorders. Their height and weight were [mean (SD)] 171.9 (± 2.8) cm and 61.7 (± 6.8) kg, respectively. The experiment was conducted with the approval of the local ethics committee of our institution, and informed consent was obtained from all of the subjects prior to their participation in the study. The experimental procedures for creating the static tilt condition and additional weight load condition are described in detail in our previous papers7,8). The subjects wore a pair of shaded goggles, and the angle of the ankle joint was fixed at 90°, in a relaxed position. The order of the experiments was randomly assigned to the subjects. In the static tilt condition, the subjects were maintained in the upright standing position on a tilting bed. The body was then tilted from the supine posture (0°; control condition) to the standing position (85°; study condition) while the back was fully supported. In the additional weight load condition,
the subjects stood on a force plate (OR6-5-2000, AMTI Inc.) and wore special clothes attached to lead weights suspended by pulleys. The weight load was monitored and adjusted at 100% (control condition) of the subject's body weight. The clothes were then released to yield a 50% additional weight load (study condition). The soleus H-reflex was recorded in the right leg with a pair of surface Ag/AgCl electrodes. Constant-current square pulses (1 msec duration) were applied at the popliteal fossa, using an isolator (SS-10J, Nihon Kohden) and an electric stimulator (SEN-3301, Nihon Kohden) in an incremental manner. The background activities in the right soleus, tibialis anterior, and vastus lateralis muscles were monitored. The EMG signals were digitized at 2 kHz and a peak-to-peak amplitude of the H wave and M wave were calculated by a data acquisition system (DataShuttle Express, Amtec Co., Ltd., Japan). The amplitudes were normalized to the maximum M response in each condition for further analysis. To ensure reliability of the measurement, the small M waves (M-size) were compared between the conditions. The conditional effect size was calculated as the ratio of the measurement (H) under the study condition to that under the control condition. Linear regression analysis was conducted to statistically determine the relationship between the two effects under the two conditions (SPSS for Windows 14.0 J).

Results

No background activities in the muscles were detected and the recruitment profiles within each subject were constant (Figure). The H-reflex was significantly inhibited by the static tilt (P = 0.01) while the small M was constant (P = 0.41). Loading with additional weight slightly, but not significantly, inhibited the reflex (P = 0.16) while the small M was constant (P = 0.24). The mean conditional effect size under the static tilt condition was -9.1% (95% confidence interval: -15.1% to -3.1%), whereas that under the additional weight load condition was -1.9% (-4.8% to 1.0%). The effect under the static tilt condition (X) positively related to the effect under the additional weight load condition (Y = 0.55X + 0.49, P = 0.01, adjusted R² = 0.64).

Discussion

The study investigated the effect of weight bearing on the soleus H-reflex in humans. The results of the study that showed that static tilt from the supine to the standing inhibited the soleus H-reflex was consistent with the results of previous studies. The dominant factors under this condition are tonic vestibular inputs and proprioceptive inputs. Chan and Kearney demonstrated that rapidly
adapting cutaneous inputs had no effect on the amplitude of the H-reflex. However, the effect of proprioceptive inputs from the sole of the foot and ankle and knee joints was reported. In this study, the test reflex was elicited without any background activities in the soleus or tibialis anterior muscles. Therefore, the effect was considered to be mediated by the vestibulospinal tract and tonic proprioceptive input from the spine, joints and soles without any homonymous or heteronymous effect.

Our study results revealed that an additional load of 50% of the body weight slightly inhibited the H-reflex during standing. The magnitude of the additional weight sufficient to inhibit the H-reflex circuit has not yet been systematically clarified. Ali and Sabbahi reported that no change in the strength of the H-reflex was observed until an additional load of 20% of the body weight. In our study, the reflex was not inhibited in two of the eight subjects when the small M-size was controlled at a constant between the control and additional weight load condition. They also showed little inhibition of the reflex in the static tilt condition. Nakazawa et al. showed that the H-reflex was inhibited as the weight load was increased in the ankle and knee joints. It is conceivable that the large variation of the loading effect among the subjects depended on an inter-subject variability of sensitivity of the joint receptors.

We attempted to investigate the relationship between the conditional effect of static tilt and that of additional weight loading using the same method of H-reflex testing. Differences in the evaluation methodology of the H-reflex may critically influence the results. We confirmed the consistency of the H-M recruitment profile by normalizing both the size of the response and the stimulation intensity. In addition, the normalized test H-reflex amplitude and the corresponding small M-size were simultaneously compared and no change in the M-size was observed. The present results were independent from differences in the method of stimulation and recording, because these were the same for all conditions.

We found a significant positive relationship be-
tween the magnitudes of the soleus H reflex under the two weight bearing conditions. That is, the effect of the static tilt condition positively influenced that in the additional weight load condition. It has been reported that GABA_A-mediated presynaptic inhibition of the soleus Ia afferents increases from the supine to the standing position^{4}. Therefore, it is speculated that the additional weight load induces presynaptic inhibition and suppression of the soleus H-reflex to allow the upright posture to be stabilized. On the other hand, muscle activation produces low frequency depression mediated by GABA_B^{5}. In the present data, we assessed the H-amplitude in the absence of background EMG activities in the soleus muscle. Therefore, the inhibition of the reflex under the two conditions is considered to be mainly attributable to GABA_A-mediated presynaptic inhibition. Further study is needed to elucidate the origin of presynaptic inhibition and its mediators because direct evidence has not been established in humans.

The results of this study suggest that tonic vestibular input and whole body proprioception may be possible triggers for the presynaptic inhibitory circuit of soleus Ia afferents during upright standing. In conclusion, it is suggested that weight bearing–induced proprioceptive input and tonic vestibular input increase presynaptic inhibition of soleus Ia afferents during upright standing in humans.

References