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Short communication

Spinal reflex in human lower leg muscles evoked by transcutaneous spinal cord stimulation

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ABSTRACT

The H-reflex is one of the most common and useful techniques in the field of motor control. However, the H-reflex technique also involves difficulty in data interpretation when stimulus intensity is high enough to stimulate both sensory and motor fibers (antidromic current). On the other hand, transcutaneous stimulation applied on the spinous processes is able to stimulate the dorsal root, resulting in selective stimulation of only sensory fibers without evoking a direct motor response and antidromic current on the motor fibers. The purpose of this study was to examine the maximal reflex response that can be elicited in the lower leg muscles using transcutaneous spinal stimulation. Seven subjects participated in the study. EMG signals were recorded from triceps surae (SOL, MG, LG) in the prone position. Transcutaneous stimulation was applied both to the spinous process (between T11 and T12, spinal stimulation, SS) and to the popliteal fossa (peripheral stimulation, PS). Using SS and PS, H_{max} amplitudes of triceps surae muscles were measured and standardized with M_{max}. H_{max} values in MG and LG by SS (31% and 41%) were significantly greater than those by PS (20% and 23%, respectively). Although not significant, H_{max} amplitude in SOL by SS (76%) was also greater than that by PS (60%). It is suggested that transcutaneous stimulation is able to evoke H-reflex without a direct motor response. H_{max} amplitudes traditionally measured by stimulation applied to a mixed nerve may underestimate the potential connectivity between the sensory and motor systems in humans.

1. Introduction

The Hoffmann reflex (H-reflex) has been extensively utilized for clinical and/or scientific purposes for decades (Zehr, 2002). The H-reflex constitutes an electrical analogue of the short latency stretch reflex, elicited by low threshold stimulation of a mixed peripheral nerve and inducing monosynaptic excitation of α motoneurons (Wolpaw, 2007), with a latency for the triceps surae muscles being approximately 30 ms. Electrical stimulation of a mixed nerve at or above motor threshold evokes a direct motor response known as the M-wave and is due to direct stimulation of motor axons. At high stimulus intensities the H-reflex is not observable due to the collision of antidromic volley on the motor axon and orthodromic afferent volley via the spinal cord.

Advantages in using the H-reflex technique are easy accessibility, relatively inexpensive equipment, and the noninvasive nature of the measurement; however, it is necessary to avoid confounding factors. Of these confounding factors, there involves difficulties and/or inappropriateness in data interpretation when antidromic current occurs. For example, even when a trial M-wave is included in H-reflex measurements to assess stimulus intensity, the effect of the antidromic volley caused by this M-wave is unknown. It is also suggested that H_{max} can be influenced by antidromic current in the motor axon (Funase et al., 1994). Since diameters in motor axons are smaller than those in group Ia fibers the presence of an M-wave indicates the possibility that afferent and efferent fibers are also stimulated, resulting in possible recruitment of Ib afferents that have suppressing effects upon the motoneuron pool (Misiaszek, 2003). It has been known that the H-reflex responses comprise monosynaptic and oligosynaptic transmission in the spinal cord (Burke et al., 1984). Therefore, the later component of the H-reflex responses may possibly be affected by recurrent inhibition. As a result of these issues the *H*/*M* ratio, which is frequently interpreted as an indicator of motoneuron excitability, most likely is confounded by antidromic current, resulting in an underestimation due to the attenuation of H_{max}. On the other hand, transcutaneous stimulation applied to the spinous processes is able to stimulate at the dorsal root level, resulting in selective excitation of the sensory fibers without evoking a direct motor response and subsequent antidromic current on the motor fibers (Courtine et al., 2007; Minassian et al., 2007). Reflexes evoked by this method have been called multisegmental monosynaptic responses (MMR, Courtine et

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al., 2007) or posterior root-muscle reflex (PRM reflex, Minassian et al., 2007). The purpose of this study was to investigate whether the maximal response of the lower leg muscles evoked by transcutaneous stimulation to the dorsal root is different from the H_{max} evoked by traditional peripheral stimulation to the mixed nerve.

2. Materials and methods

Seven college-age subjects participated in the study. The protocol used was approved by the university committee for the protection of human subjects and all subjects signed an informed consent prior to procedures. In order to measure H-reflex parameters, the peak-to-peak EMG amplitude of the H-reflexes and M-waves were measured. Subjects were tested in the prone position on a standardized testing table. Cushions were placed under their abdominal area, resulting in a slight convex bend of the torso. EMG signals were recorded from the right side soleus, medial, and lateral gastrocnemius muscles (SOL, MG, LG). Active bipolar electrodes were used for recording. The placement of the soleus EMG electrode was approximately 15 cm above the calcaneus and below the muscle fibers of the gastrocnemius muscle. For the medial and lateral head of gastrocnemius, electrodes were placed in the middle of the muscle bellies. Transcutaneous stimulation was applied both to the spinous process (spinal stimulation, SS) and to the peripheral nerve (peripheral stimulation, PS). For PS, a cathode electrode was placed in the right popliteal fossa and an anode electrode was placed above the right patella. Electrode gel was used for both stimulating and recording electrodes to reduce skin resistance. For clarification purposes, the parameters derived in the current study, such as H_{max}, will be distinguished by protocol differences (e.g., PS elicited H-reflex and SS elicited response). In the PS protocol the H-reflex recruitment profile including H_{max} and M_{max} amplitudes was assessed. For SS, a cathode electrode (8 mm diameter) was placed on the midline of spinous process between T11 and T12 and an anode electrode (4 cm diameter) was placed on the right side anterior iliac spine. Locations of T11 and T12 were identified by palpation. In the SS protocol, the recruitment profile of the SS elicited response and its maximal amplitude were measured and standardized with M_{max} which was recorded by the PS protocol. For both stimulation protocols, a constant current stimulator was used to deliver 2 ms square-wave pulses for each stimulation. The same stimulus intensities were repeated three times. The maximum stimulus intensity for the SS protocol was set at 100 mA. Stimulation was administered with random intervals of 10–15 s. A 2 ms width pulse was used since it was observed that this pulse more successfully saturated the reflex response of the SS protocol, compared with a 1 ms width pulse. The total number of reflexes evoked by both protocols for each subject was approximately 100–120. EMG signals were recorded at 2 kHz and filtered with 20–450 Hz bandpass butterworth filter. Dependent EMG variables (peak-to-

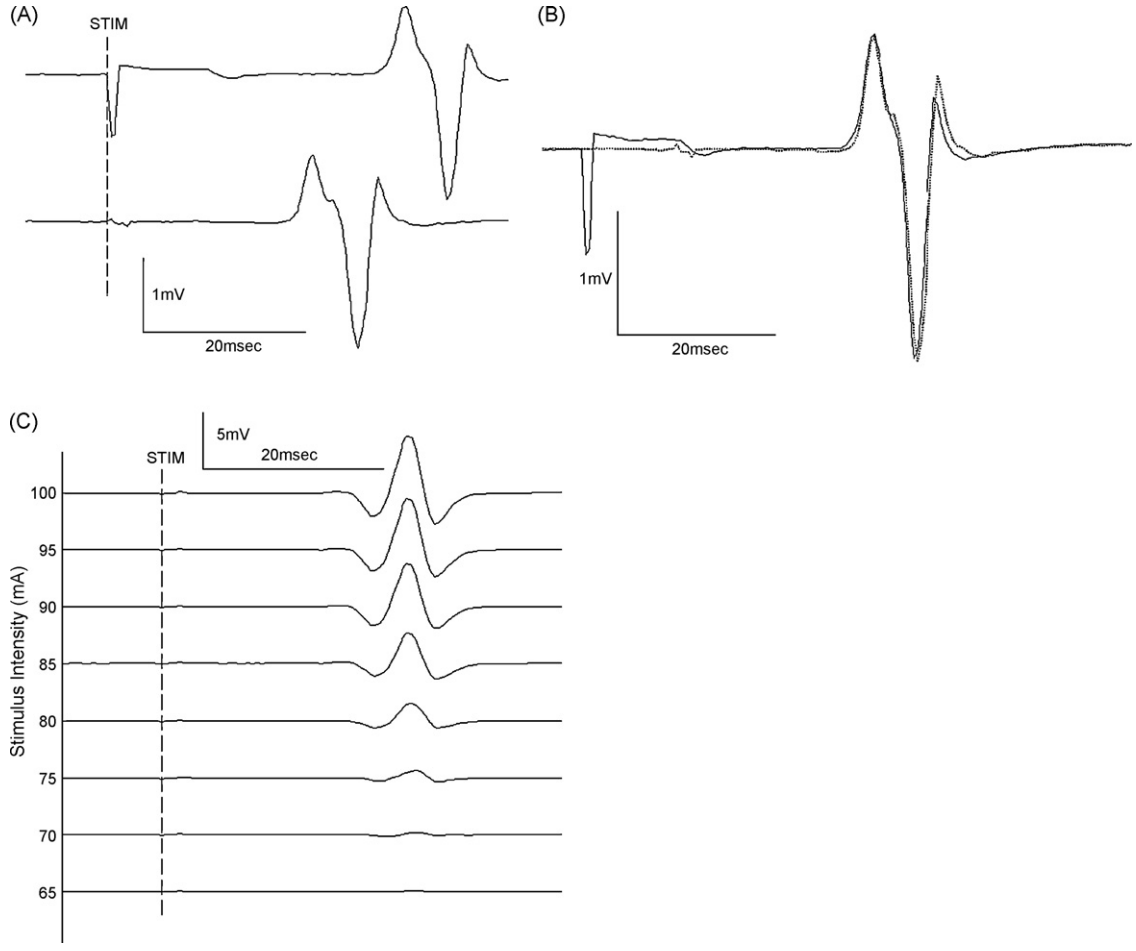

Fig. 1. Reflex traces of the soleus (SOL) muscle elicited with stimulation to the popliteal fossa (PS) and spinous processes (SS). (A) H-reflex by PS stimulation (top trace), and reflex response by SS stimulation (bottom trace). Signals were synchronized at the timing of stimulation. Note that the latency of the reflex response by the SS protocol was approximately 10 ms shorter than that by the PS protocol. (B) Single responses of SOL with similar amplitudes by both protocols were selected and superimposed with 11.5 ms delay to the SS elicited H-reflex (solid line: PS protocol, dashed line: SS protocol). Note that the shapes of two responses were similar. (C) Presents a series of trials in SOL with progressively greater stimulus intensities by the SS protocol in a single subject. All trials were synchronized at the timing of the stimulation. Note that phases of each trace are identical.