Journal of Electromyography and Kinesiology 20 (2010) 406–412

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Enhanced stretch reflex excitability in the soleus muscle during passive standing posture in humans

Sachio Shimba [a], Noritaka Kawashima [b,c,d,*], Yuji Ohta [e], Shin-Ichiroh Yamamoto [a], Kimitaka Nakazawa [b]

[a] Graduate School of Engineering, Shibaura Institute of Technology, 307 Fukasaku, Minuma, Saitama 337-8570, Japan
[b] Department of Rehabilitation for Movement Functions, Research Institute, National Rehabilitation Center for Persons with Disabilities, 4-1 Namiki, Tokorozawa, Saitama 359-8555, Japan
[c] Lyndhurst Center, Toronto Rehabilitation Institute, 520 Sutherland Dr., Toronto, Ontario M4G 3V9, Canada
[d] Japanese Society for Promotion of Science, 1-8 Chiyoda, Tokyo 102-8472, Japan
[e] Faculty of Human Life and Environmental Science, Ochanomizu University, 2-1-1 Otsuka, Bunkyo, Tokyo 112-8610, Japan

ARTICLE INFO

Article history:
Received 31 July 2008
Received in revised form 10 February 2009
Accepted 4 April 2009

Keywords:
Stretch reflex
H-reflex
Upright standing
Task-dependent modulation
Posture

ABSTRACT

The purpose of this study was to test whether the spinal reflex excitability of the soleus muscle is modulated as posture changes from a supine to a passive upright position. Eight healthy subjects (29.6 ± 5.4 yrs) participated in this study. Stretch and H-reflex responses were elicited while the subjects maintained passive standing (ST) and supine (SP) postures. The passive standing posture was accomplished by using a gait orthosis to which a custom-made device was mounted to elicit stretch reflex in the soleus muscle. This orthosis makes it possible to elicit stretch and H-reflexes without background muscle activity in the soleus muscle. The results revealed that the H-reflex amplitude in the ST was smaller than that in the SP condition, which is in good agreement with previous reports. On the other hand, the stretch reflex was significantly larger in the ST than in the SP condition. Since the experimental conditions of both the stretch and H-reflex measurements were exactly the same, the results were attributed to differences in the underlying neural mechanisms of the two reflex systems: different sensitivity of the presynaptic inhibition onto the spinal motoneuron pool and/or a change in the muscle spindle sensitivity.

1. Introduction

It has been well established that body-weight-supported stepping training (BWSST) on a treadmill is beneficial to restore the functional gait of individuals with spinal cord injuries (Behrman and Harkema, 2000; Dietz et al., 1995, 2002; Harkema et al., 1997; Wernig et al., 1995). The concept of BWSST, as a newly developed neurorehabilitation strategy, is based on the following neurophysiological background: sensory inputs accompanied with assisted stepping would activate spinal neural circuits generating locomotor patterns. The sensory afferent input, accordingly, is the key element of this training, and that is the reason that the stepping is assisted manually or mechanically in BWSST. The assisted stepping is assumed to evoke sensory inputs similar to those evoked during normal walking. However, it is unclear and more study is needed to show how the sensory inputs act on the spinal neural circuits chronically and acutely in BWSST. To answer this question, the influence of a passive upright posture on the spinal reflex system is investigated in the present study as the first step, since BWSST is generally performed in a passive upright posture.

The spinal reflex system studied here is the stretch reflex of the ankle extensor muscle, which is one of the simplest and best known reflexes in the human motor control system. Previous studies have reported that the Hoffman reflex (H-reflex) of the ankle extensor muscle, which is an electrical analog of the stretch reflex and is elicited by electrical stimulation to the Ia afferent nerve, is suppressed in the upright standing posture as compared to those in sitting (Hayashi et al., 1992), lying prone (Koceja et al., 1993), or standing with back support (Katz et al., 1988). Since both the short latency stretch and H-reflex have a monosynaptic spinal reflex pathway, one may think it is reasonable to assume that stretch reflex also show similar modulation manner to that of H-reflex. However, previous studies reported that either reflex pathway has a different modulation manner during walking (Sinkaer et al., 1996) and a different sensitivity to presynaptic inhibition on the spinal motoneuron pool. It is therefore likely that each H- and stretch reflex has different modulation manner to the motor task. To the best of our knowledge, there is no study which examined the difference of the postural-dependent modulation between stretch and H-reflex within same experimental design.

* Corresponding author. Address: Department of Rehabilitation for Movement Functions, Research Institute, National Rehabilitation Center for Persons with Disabilities, 4-1 Namiki, Tokorozawa, Saitama 359-8555, Japan. Tel.: +81 42 995 3100; fax: +81 42 995 3132.
E-mail address: kawashima-noritaka@rehab.go.jp (N. Kawashima).

1050-6411/$ - see front matter
doi:10.1016/j.jelekin.2009.04.003

The purpose of this study is to test whether the spinal reflex excitability of the soleus muscle is modulated as the human body position changes from a supine to an upright passive posture. In order to elicit the stretch reflex responses during upright standing posture, we made a perturbation device mounted on the lower leg portion of a gait orthosis (Fig. 1a). This device enabled us to obtain stretch reflex responses in the ankle extensor muscles while the subjects maintained a standing posture. Importantly, this device provides an additional advantage for the comparison of the reflex responses between standing and supine postures, that is, the elimination of the effect of background EMG activity (BGA) on the reflex responses. Because no EMG activity was observed in the healthy subject during upright standing while wearing the orthosis, we can compare the reflex amplitude between standing and supine postures.

2. Methods

2.1. Subjects

Eight healthy male volunteers (29.6 ± 5.4 years) who had no history of neurological disorders participated in this study. The subjects gave their informed consent to the experimental procedures, which were conducted in accord with the Helsinki Declaration of 1975 and approved by the Ethics Committee of the National Rehabilitation Center for Persons with Disabilities, Tokorozawa, Japan.

2.2. Experimental setting

In order to elicit stretch reflex responses while subjects maintained a passive standing posture, a gait orthosis (ARGO: advanced reciprocating gait orthosis, Steeper Inc., UK) was used to assist a passive standing posture. A custom-made device was used to elicit a stretch reflex of the Sol muscle, which consisted of a spring, a ratchet, and an electromagnet (Fig. 1a). Details of the function of this device have been described elsewhere (Kawashima et al., 2006). Briefly, while an electromagnet that was placed posterior to the calf was in operation, we manually adjusted the tension of the spring that was attached to the forefoot to pull the toe upward. The magnet was then released, and the spring recoiled, causing a rapid dorsiflexion. The ankle angular velocity was measured by the potentiometer placed on the ankle joint of the orthosis.

2.3. Data recordings

The EMG activity of the Sol muscle was recorded with bipolar surface electrodes (Ag–AgCl, diameter 7 mm). Care was taken to exclude any artifact in the EMG signal (e.g., the skin was washed with a scrub gel and rubbed with sandpaper to reduce its resistance). The EMG signal was amplified (Amplifire; Nihon-Kohden, MEG-6108) with band-pass filtering from 5 to 1 kHz. Data of the stretch and H-reflexes were digitized with a sampling frequency of 1 k and 5 kHz, respectively, by an AD converter (WE7000 system, Yokogawa, Inc., Japan).

2.3.1. Stretch reflex

A rapid dorsiflexion was applied to the subject's ankle to induce the Sol stretch reflex response. Four different angular velocities were used to evaluate the increment of the stretch reflex electromyogram (EMG) amplitude with an increase in the angular velocity applied. The angular velocity was changed with changing the tension of the spring manually with a ratchet. The range of the

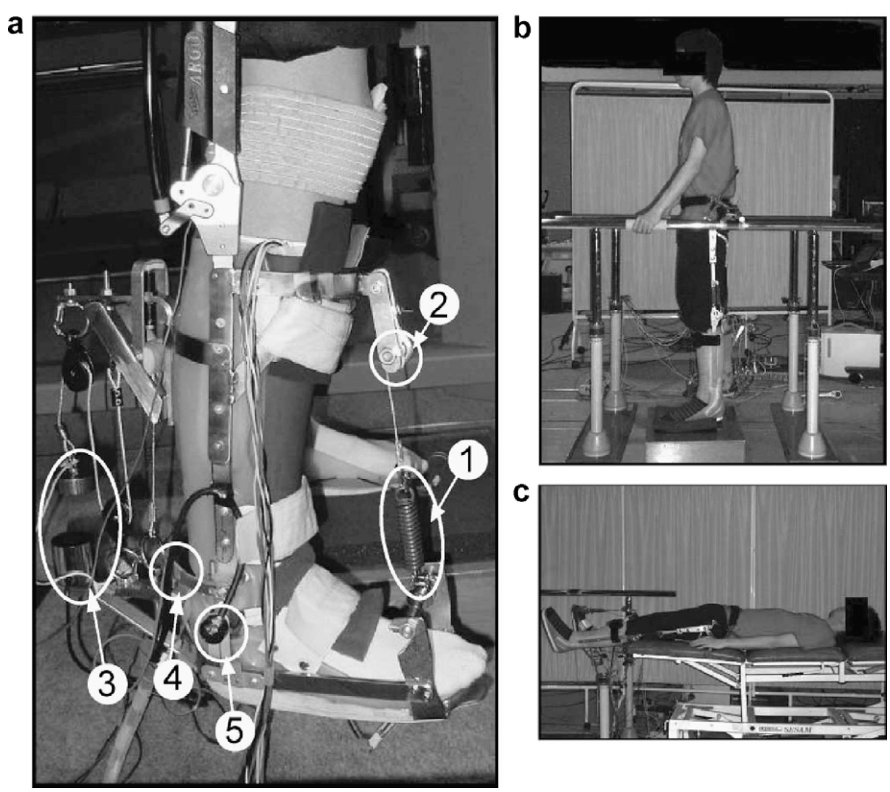

Fig. 1. Experimental setup. (a) Perturbation device that enables the user to impose rapid ankle dorsiflexion by improving the lower leg portion of a gait orthosis. The perturbation device consisted of (1) a spring that pulls the forepart of the foot to create tension in the ankle dorsiflexion direction, (2) a ratchet that regulates the tension of the spring, and (3) an electromagnet that exerts an antagonistic action on the spring. (4) An electrogoniometer was also placed on the center of the ankle joint to measure the ankle angle. (5) An eddy-current sensor was placed to detect the onset of the perturbation. This device was mounted on the orthosis (ARGO: advanced reciprocating gait orthosis®, Steeper, Inc., UK). During the experiment, (b) subjects were imposed passive standing and (c) supine postural conditions while wearing the orthosis.