Neuroscience Letters 633 (2016) 252–256

Contents lists available at ScienceDirect

Neuroscience Letters

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

Research article

Effect of muscle relaxation in the foot on simultaneous muscle contraction in the contralateral hand

Kouki Kato (Research Fellow)[a,b,*], Kazuyuki Kanosue[a]

[a] Faculty of Sport Sciences, Waseda University, Saitama, Japan
[b] Japan Society for the Promotion of Science, Japan

HIGHLIGHTS

- Effect of voluntary muscle relaxation of one limb on muscle activity of contralateral other limb.
- Muscle relaxation of right foot induces decrease in muscle activity and force magnitude of right hand.
- Muscle relaxation of right foot induces decrease in muscle activity and force magnitude of left hand.
- Muscle relaxation of foot right foot dorsiflexor influences muscle activity of not only the ipsilateral hand extensor but also the contralateral hand extensor.

ARTICLE INFO

Article history:
Received 12 July 2016
Received in revised form 9 September 2016
Accepted 13 September 2016
Available online 28 September 2016

Keywords:
Coordination
Contralateral
Inhibition

ABSTRACT

We investigated the effects of foot muscle relaxation and contraction on muscle activities in the hand on both ipsilateral and contralateral sides. The subjects sat in an armchair with hands in the pronated position. They were able to freely move their right/left hand and foot. They performed three tasks for both ipsilateral (right hand and right foot) and contralateral limb coordination (left hand and right foot for a total of six tasks). These tasks involved: (1) wrist extension from a flexed (resting) position, (2) wrist extension with simultaneous ankle dorsiflexion from a plantarflexed (resting) position, and (3) wrist extension with simultaneous ankle relaxation from a dorsiflexed position. The subjects performed each task as fast as possible after hearing the start signal. Reaction time for the wrist extensor contraction (i.e. the degree to which it preceded the motor reaction time), as observed in electromyography (EMG), became longer when it was concurrently done with relaxation of the ankle dorsiflexor. Also, the magnitude of EMG activity became smaller, as compared with activity when wrist extensor contraction was done alone or with contraction of the ankle dorsiflexor. These effects were observed not only for the ipsilateral hand, but also for the contralateral hand. Our findings suggest that muscle relaxation in one limb interferes with muscle contraction in both the ipsilateral and contralateral limbs.

1. Introduction

Many actions in sports as well as in daily life require the simultaneous use of multiple limbs. Sports performance in games such as badminton [28], and playing such musical instruments as drums [7] or piano [37] all entail the production of correct, stable movements. In some cases, however, activity in a muscle of one limb interferes with the activity of muscles in other limbs. For instance, when cyclic movements of the *ipsilateral* upper and lower limbs are executed, moving the two limbs in an opposite direction is more difficult than moving the limbs in the same direction [2,5,17,25]. For *contralateral* limbs (e.g., right leg and left arm), relative accuracy and stability are increased during opposite directional movements as compared to movements involving ipsilateral limb combinations [10,22].

While muscle contraction is often emphasized in studies of multi-limb coordination, muscle relaxation is an equally important aspect of the coordination. Neuroimaging and neurophysiological studies using functional magnetic resonance imaging, electroencephalography, magnetoencephalography and transcranial magnetic stimulation (TMS) demonstrate that muscle relaxation requires cortical activation in the primary motor cortex (M1) and supplementary motor area (SMA). Thus, muscle relaxation involves an active process rather than merely the end of contraction

* Corresponding author at: Faculty of Sport Sciences, Waseda University, 2-579-15 Mikajima, Tokorozawa, Saitama 359-1192, Japan.
E-mail address: kouki0104@gmail.com (K. Kato).

http://dx.doi.org/10.1016/j.neulet.2016.09.019
0304-3940/

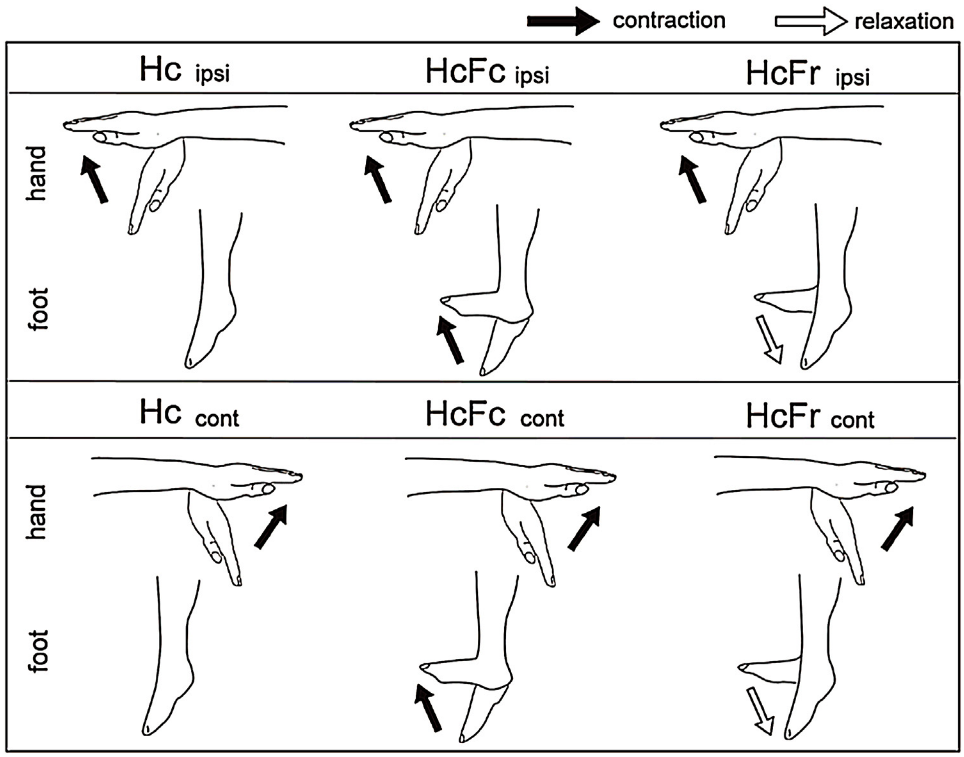

Fig. 1. Subjects performed 6 tasks of single or coordinated movements of both ipsilateral and contralateral limbs; wrist extension (contraction) (Hc), simultaneously doing Hc and ankle dorsiflexion (contraction) (HcFc), and simultaneously doing Hc and ankle relaxation from the dorsiflexed position (relaxation) (HcFr) in both ipsilateral ($_{ipsi}$) and contralateral ($_{cont}$) limbs. The black and white arrows indicate contraction and relaxation, respectively.

[19,14,30–34]. Recently, we demonstrated that muscle relaxation of the foot suppressed electromyographic activity (EMG) of *ipsilateral* hand muscles that were to simultaneously contract [13,15]. Moreover, we found that enhancement of intracortical inhibition in the hand area of M1 during muscle relaxation of foot [16], which might relate to decrease in EMG activity of the hand muscle. Muscle relaxation can thus produce an inhibitory effect on muscle activity in the ipsilateral limb. However, the effect of muscle relaxation on *contralateral* limbs has not been investigated.

The Go/No-go task has been widely utilized to investigate inhibitory processes involved with motor execution [27,35] and muscle relaxation. A TMS study demonstrated that corticospinal excitability for both ipsilateral (right) and contralateral (left) hand muscles decreased when the No-go task was executed with right foot as compared to that which occurred when the foot was at rest [1]. This indicates that the inhibitory effect might spread not only to the ipsilateral side but also to the contralateral side. While the No-go task involves cancelling a contraction which is about to be executed, muscle relaxation involves the cancellation of a contraction which has already occurred. In the present study, we utilized the same protocol as in our previous study [13] to investigate the effect of muscle relaxation of the foot dorsiflexor on hand EMG activity during simultaneous contraction of the contralateral hand extensor. We hypothesized that muscle relaxation of the foot dorsiflexor would suppress muscle contraction in both the ipsilateral and contralateral hand extensor.

2. Method

2.1. Subjects

Eleven right-handed subjects (9 males and 2 females), ranging in age from 21 to 32 years, voluntarily participated in this study. The subjects were fully informed about the purpose of the study and its procedures. Written informed consent was obtained from all subjects. This study was approved by the Human Research Ethics Committee in Faculty of Sport Sciences, Waseda University. The experiments were conducted in accordance with the Declaration of Helsinki.

2.2. Experimental setup and tasks

The subjects sat in an armchair with the right forearm supported in the horizontal plane. The hand was prone and secured to a device which enabled the hand to move freely but only in the sagittal plane. The chair was sufficiently high that the subjects could freely perform ankle dorsiflexion and plantarflexion without touching the floor. Electromyography (EMG) was recorded from the right and left forearm muscles (extensor carpi radialis, ECR) and two foot muscles (tibialis anterior, TA; and soleus, SOL). Two Ag-AgCl surface electrodes (1 cm diameter) were placed on the center of the muscle bellies following standard skin preparation. The ground electrode was placed over the right epicondylus lateralis. The electrode signals were amplified (model Fla03, Furusawa Lab Appliance, Japan; input impedance >100 MΩ, CMRR > 95 dB, bandwidth 5–500 Hz). The angles of the wrist and ankle were measured using goniometers (Shapesensor model s700, Measurand Inc, Canada) that were secured at the wrist and at the lateral side of the ankle. EMG and joint angle data were digitized via an A/D converter system (PowerLab 16/s, ADInstruments, Australia) at 1000 Hz for storage and later analysis.

The participants were asked to perform six tasks (Fig. 1): Task 1 (right hand contraction: Hc_{ipsi}), right wrist extension from the flexed (relaxed) position to the horizontal position; Task 2 (right hand contraction and right foot contraction: $HcFc_{ipsi}$), right wrist extension and right ankle dorsiflexion from the plantarflexed (relaxed) position to a moderately dorsiflexed position; Task 3 (right hand contraction and right foot relaxation: $HcFr_{ipsi}$), right