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Research Report

The effect of motor imagery on gain modulation of the spinal reflex

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ABSTRACT

Motor imagery is well known to have a facilitatory effect on the corticospinal tract, but conflicting opinions have arisen concerning its effect on spinal reflex excitability. The purpose of this study was to clarify the effects of motor imagery on gain modulation of the spinal reflex by focusing on the physiological differences between the H-reflex and the stretch reflex. In experiment 1, there were three conditions: rest, motor imagery of ankle dorsiflexion (MI-DF), and motor imagery of ankle plantarflexion (MI-PF). The subjects were instructed to imagine 100% maximum voluntary isometric contraction (MI-100) in each direction of movement. To examine the effects of the imagined effort level on spinal reflex excitability, the subjects also imagined 50% maximum voluntary contraction (MI-50) in experiment 2. The soleus H-reflex and the stretch reflex amplitude and background EMG (bEMG) activity were measured. There were no significant differences in bEMG activity between the H-reflex and stretch reflex measurements. In experiment 1, although the H-reflex amplitude did not change significantly among the three conditions, the stretch reflex amplitude increased significantly under the MI-DF and MI-PF conditions compared to the rest condition. In addition, the stretch reflex amplitude under the MI-100 condition was significantly larger than that under the MI-50 condition in experiment 2. These results indicate that motor imagery has a selective facilitatory effect on stretch reflex pathways. Furthermore, this excitability change may occur in untargeted antagonist muscles as well as targeted agonist muscles and may depend on the imagined effort level.

1. Introduction

A number of studies have revealed that motor imagery facilitates the excitability of both the motor cortex (Porro et al., 1996; Roland et al., 1980; Roth et al., 1996; Stephan et al., 1995) and the corticospinal tract (Fadiga et al., 1999; Hashimoto and Rothwell, 1999; Kasai et al., 1997; Kiers et al., 1997). However, conflicting opinions have arisen concerning the excitability of the spinal reflex pathways during motor imagery. Yahagi et al. have reported that the H-reflex amplitude did not change while the MEP amplitude was significantly increased during motor imagery (Yahagi et al., 1996). They concluded that the excitability change occurred mainly at the cortical, not the spinal level. This interpretation is compatible with studies that have used

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transcranial magnetic stimulation (TMS) and the H-reflex or F-wave (Abbruzzese et al., 1996; Facchini et al., 2002; Kaneko et al., 2003; Kasai et al., 1997; Liepert and Neveling, 2009; Stinear and Byblow, 2003; Stinear et al., 2006a,b). In contrast to these results, some researchers using the H-reflex, tendon reflex, or stretch reflex have suggested that motor imagery has a facilitatory effect on spinal reflex excitability (Bonnet et al., 1997; Hale et al., 2003; Li et al., 2004).

We believe that there are two possible explanations for the discrepancy in these results. The first is the difference in the measurement methods employed to detect the spinal excitability change. Morita et al. have suggested that predicting the modulation of the stretch reflex based on the observations of H-reflex modulation is not straightforward due to the different sensitivities of the presynaptic inhibition between these two kinds of reflexes (Morita et al., 1998). Additionally, because the mechanically induced stretch reflex contains muscle spindles in its own reflex pathways, while electrically induced H-reflex does not, some researchers have concluded that the sensitivity of the alternation of the excitability of the gamma motoneuron pools differs between these two reflexes (Bonnet et al., 1997; Jeannerod, 1995). Moreover, it has previously been reported that the F-wave is much less sensitive to changes in the excitability of the alpha motoneuron pools than the H-reflex (Espiritu et al., 2003; Hultborn and Nielsen, 1995; Lin and Floeter, 2004). It is therefore possible that the F-wave failed to detect the small changes of the alpha motoneuron pools excitability.

The second explanation is that the results of some previous studies have included the background EMG during motor imagery (Bonnet et al., 1997; Hale et al., 2003). Since it is well known that the reflex amplitude is strongly influenced by background EMG (Burke et al., 1989), it is possible that their results may have been contaminated by this background EMG. Until now, however, no studies have noted these two points. Furthermore, only a few studies have examined whether the effects of motor imagery depend on the imagined direction of the movement (Li et al., 2004) or the imagined effort levels (Bonnet et al., 1997; Hale et al., 2003).

Therefore, to clarify the effects of motor imagery on the gain modulation of the spinal reflex, we recorded the soleus H-reflex and stretch reflex during three conditions: rest, motor imagery of ankle dorsiflexion (MI-DF), and motor imagery of ankle plantarflexion (MI-PF) in experiment 1, while assuring that no background EMG activity occurred as a result of the motor imagery. In addition, in experiment 2 we used two imagined effort levels of maximum voluntary contraction (MVC) (MI-100) and 50% MVC (MI-50) in order to determine whether the effects of motor imagery depend on the imagined effort level.

2. Results

2.1. *Experiment 1*

There was no statistically significant difference in the soleus and tibialis anterior background EMG activity of either the H-reflex or stretch reflex measurements among the three conditions (soleus H-reflex: $F_{2,11}=0.705$, $p=0.505$, soleus stretch reflex: $F_{2,11}=0.228$, $p=0.798$, tibialis anterior H-reflex: $F_{2,11}=0.804$, $p=0.460$, tibialis anterior stretch reflex: $F_{2,11}=1.200$, $p=0.320$: Table 1). Superimposed H-reflex raw data obtained from a single subject are shown in Fig. 1. Although the H-reflex amplitude was not changed (Rest=30.1±18.5%Mmax, MI-DF=31.7±17.6%Mmax, MI-PF=31.3±18.8%Mmax, $F_{2,11}=2.160$, $p=0.139$: Fig. 2A), it was shown that the stretch reflex amplitude was significantly greater in both the MI-DF and MI-PF conditions compared to the rest condition at angular velocities of 75 deg/s (Rest=4.62±3.87%Mmax, MI-DF=5.61±4.44%Mmax, MI-PF=6.46±4.51%Mmax, $F_{2,11}=11.621$, $p<0.001$) and 90 deg/s (Rest=5.83±3.78%Mmax, MI-DF=7.72±5.01%Mmax, MI-PF=8.30±4.19%Mmax, $F_{2,11}=8.653$, $p=0.002$), but not at 105 deg/s (Rest=6.18±3.55%Mmax, MI-DF=7.04±4.10%Mmax, MI-PF=7.50±3.34%Mmax, $F_{2,11}=2.501$, $p=0.105$) (Fig. 2B). Furthermore, the stretch reflex amplitude under the MI-PF condition was significantly increased compared to the MI-DF condition at 75 deg/s.

2.2. *Experiment 2*

In experiment 2, there was no significant difference in the H-reflex amplitude among the three imagined effort levels (MI-DF: Rest=31.3±19.2%Mmax, MI-50=31.1±18.5%Mmax, MI-100=33.6±18.0%Mmax, $F_{2,9}=1.059$, $p=0.3674$, MI-PF: Rest=31.3±19.2%Mmax, MI-50=32.6±19.0%Mmax, MI-100=32.8±19.5%Mmax, $F_{2,9}=1.181$, $p=0.330$: Fig. 3A). The stretch reflex amplitude was significantly larger in the MI-100 condition than in the MI-50 condition in both the imagined ankle dorsiflexion and plantarflexion directions (MI-DF: Rest=5.96±4.09%Mmax, MI-50=6.71±4.40%Mmax, MI-100=8.07±5.36%Mmax, $F_{2,9}=5.746$, $p=0.012$, MI-PF: Rest=5.96±4.09%Mmax, MI-50=7.18±4.82%Mmax, MI-100=8.23±4.16%Mmax, $F_{2,9}=10.295$, $p=0.001$: Fig. 3B).

3. Discussion

The remarkable results of the present study were that the stretch reflex amplitude markedly increased during the motor imagery condition even though the H-reflex amplitude was unchanged. These results are seemingly consistent with a previous study showing that the mechanically induced tendon reflex amplitude was increased more than the H-reflex amplitude during motor imagery (Bonnet et al., 1997). However, the results reported by Bonnet et al. were possibly confounded by a slight muscular contraction that actually occurred during motor imagery. In contrast to their results, trials in which any

Table 1 – Background EMG activity of soleus and tibialis anterior during the measurement of the H-reflex and stretch reflex under three conditions of rest, motor imagery of ankle dorsiflexion (MI-DF), and plantarflexion (MI-PF).

Task	Muscle	Condition		
		Rest	MI-DF	MI-PF
H-reflex	Soleus	2.90±1.36	2.98±1.38	2.98±1.28
	Tibialis anterior	2.46±0.86	2.55±0.92	2.52±0.87
Stretch reflex	Soleus	2.79±0.98	2.81±0.97	2.81±0.95
	Tibialis anterior	2.60±0.90	2.80±1.11	2.66±0.86