

Excitability of spinal neural function during motor imagery in Parkinson's disease

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Summary

We analyzed thenar muscle F-waves after stimulating the median nerve at the wrist in subjects during two motor imagery conditions: holding and not holding the sensor of a pinch meter between the thumb and index finger. Our aim was to determine whether mental simulation without the muscle contraction associated with motion can increase the excitability of spinal neural function in patients with Parkinson's disease (PD).

F-waves of the left thenar muscles were examined in 10 patients with PD under resting, holding and motor imagery conditions. For the holding condition, the subjects held the sensor of the pinch meter between their thumb and index finger. For the motor imagery conditions, the subjects were asked to imagine a 50% maximal voluntary isometric contraction holding and not holding the sensor of the pinch meter between their thumb and index finger (motor imagery "with"/"without sensor").

Persistence during motor imagery under the "with sensor" condition increased significantly compared with persistence during resting ($n=10$, $z=2.2509$, $p=0.0244$, Wilcoxon test). The F/M amplitude ratio during motor imagery under the "with sensor" condition increased significantly compared with that during resting ($n=10$, $z=2.1915$, $p=0.0284$, Wilcoxon test).

Motor imagery under the "with the sensor" condition increased excitability of the spinal neural output to the thenar muscles. Because excitability of the spinal neural output to the thenar muscles during motor imagery "with the sensor" was significantly higher than that during resting, we suggest that movement preparation for a motor imagery task is important in patients with PD.

KEY WORDS: F-wave, motor imagery, Parkinson's disease

Introduction

Motor imagery, the mental rehearsal of a motor act without overt movement, has been shown to improve motor performance in healthy subjects (Pascual-Leone et al., 1995). It also aids in the recovery of motor function following stroke (Ryding et al., 1993; Stevens and Stoykov, 2003). The effects of motor imagery have been discussed in many neurophysiological studies using motor-evoked potentials (MEPs), the Hoffman reflex (H-reflex), T-waves and F-waves. Results have shown that corticospinal excitability during motor imagery may result from an increase in MEP amplitude, as measured by transcranial magnetic stimulation (TMS) (Hashimoto and Rothwell, 1999; Li et al., 2004). However, other studies did not show increases using H-reflex, T-waves and F-waves as indices of excitability of spinal neural function during motor imagery (Oishi et al., 1994; Jeannerod, 1995; Kasai et al., 1997; Hale et al., 2003).

Motor imagery may be more precisely defined as imagery that produces spatial and temporal modulation of motor cortical function that mirrors the modulation observed during the actual performance of a task, without activation of spinal neural function.

If motor imagery is used as part of a patient's rehabilitation, it has the potential to increase the function both of the motor cortex and of spinal neurons. In turn, increased spinal neural function can result in improved muscle function. Our goal in motor imagery research is to find the optimal way to improve the excitability of spinal neural function in the clinical setting, and one of the best ways to do this is to use motor imagery that is similar to actual motion.

In a previous study by our group (Suzuki et al., 2013), healthy subjects were required to establish 50% maximal voluntary contraction (MVC) during isometric con-

traction of the opponens pollicis muscle, i.e. while holding the sensor of a pinch meter between their thumb and index finger. Next, we tested F-waves of the left thenar muscles after stimulating the left median nerve at the wrist during only holding of the pressure sensor of the pinch meter between the thumb and index finger (holding condition). And then, the subjects were asked to imagine the same contraction under the two conditions: holding the pressure sensor of the pinch meter between the thumb and index finger (“with sensor”) and not holding the pressure sensor (“without sensor”). During these motor imagery conditions, we tested F-waves of the left thenar muscles after stimulating the left median nerve at the wrist. F-waves result from backfiring of α -motor neurons after antidromic invasion of the propagated impulse across the axon hillock (Kimura, 1974). Their occurrence reflects excitability changes in the spinal motor neurons, as reported in patients with spasticity (Odusote and Eisen, 1979) and in healthy subjects performing isometric contraction (Suzuki et al., 1993). Persistence during the holding condition and during motor imagery under the “with sensor” condition was significantly better than that observed during relaxation. In addition, the amplitude ratio of F/M during motor imagery under the “with sensor” condition was significantly greater than that observed during relaxation. The fact that both persistence and amplitude ratio during motor imagery under the “with sensor” condition were higher than during motor imagery under the “without sensor” condition indicates that movement preparation for a motor imagery task involving 50% MVC isometric contraction of the opponens pollicis is very important in healthy subjects. In this study, using the motor imagery conditions reported in our previous study, we tested F-waves of the left thenar muscles after stimulating the left median nerve at the wrist in patients with Parkinson’s disease (PD).

Materials and methods

Subjects

Ten patients with PD (2 males and 8 females; age range 38 to 81 years, mean age 63.9 years, standard deviation 11.0 years) participated in the study, and written informed consent was obtained from all of them. This study was approved by the Research Ethics Committee at Kansai University of Health Sciences (Ref. number 11-10). The experiments were conducted in accordance with the Declaration of Helsinki.

F-waves during motor imagery

The subjects were in a comfortable, supine position with both shoulder joints externally rotated. The skin was prepared with abrasive gel to keep the impedance below 5 K Ω . A Viking Quest electromyography

machine (Natus Medical Inc., CA, USA) was used to record F-waves. We tested F-waves of the left thenar muscles using a pair of disks attached with collodion to the skin over the thumb belly and the bones of the metacarpophalangeal joint of the thumb, after stimulating the left median nerve at the wrist during relaxation (resting condition) and under touch (holding) and two motor imagery conditions. The stimulating electrodes comprised a cathode placed over the left median nerve 3 cm proximal to the palmar crease of the wrist joint and an anode placed 2 cm more proximally. The maximal stimulus was determined by delivering 0.2 ms square-wave pulses of increasing intensity to elicit the largest compound muscle action potentials. Supramaximal shocks (adjusted up to the value of 20% higher than the maximal stimulus) were delivered at 0.5 Hz for acquisition of F-waves. The bandwidth filter ranged from 2 Hz to 3 kHz.

In the resting condition, we tested F-waves during relaxation which was confirmed by absence of EMG signal from the left thenar muscles. In the holding condition, the subject held the sensor of the pinch meter between the thumb and index finger. To obtain the motor imagery conditions, the subjects were first required to learn 50% MVC during isometric contraction of the opponens pollicis muscle, i.e. while holding the sensor of the pinch meter. In detail, the magnitude of MVC was numerically recorded on the pinch meter display and the subjects, after reaching 50% MVC, were instructed to keep the value recorded on the pinch meter display for one minute. Subsequently, the subjects were asked to imagine the contraction while holding the sensor of the pinch meter between their thumb and index finger (motor imagery under the “with sensor” condition) and, on a different day, while not holding the sensor (motor imagery under the “without sensor” condition).

Data analysis

F-waves from 30 trials were analyzed with respect to persistence, F/M amplitude ratio, and latency. Persistence was defined as the number of measurable F-wave responses divided by 30 trials at supramaximal stimulation. The F/M amplitude ratio was defined as the mean amplitude of all responses divided by the amplitude of the M-wave. Latency was defined as the mean latency from the time of stimulation to the onset of a measurable F-wave.

Statistical analysis for normal distribution was performed using the Komogorov-Smirnov and Shapiro-Wilk tests. Because the data were not recognized as showing normal distribution, the Wilcoxon test was used to compare results between resting and the other conditions.

Results

Persistence during motor imagery under the “with sensor” condition was significantly increased compared

with that during relaxation (n=10, z=2.2509, p=0.0244, Wilcoxon test, Fig. 1).

There were no significant differences in persistence between all the other conditions (Fig. 1).

The F/M amplitude ratio during motor imagery under the "with sensor" condition was significantly increased compared with that during relaxation (n=10, z=2.1915, p=0.0284, Wilcoxon test, Fig. 2).

There were no significant differences in latency between all four conditions (Fig. 3).

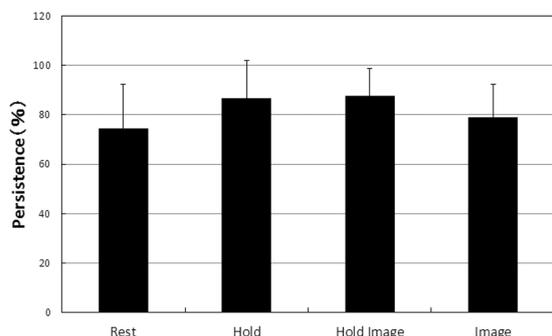


Figure 1 - Persistence during resting, holding and motor imagery under the "with sensor" condition and motor imagery under the "without sensor" condition.

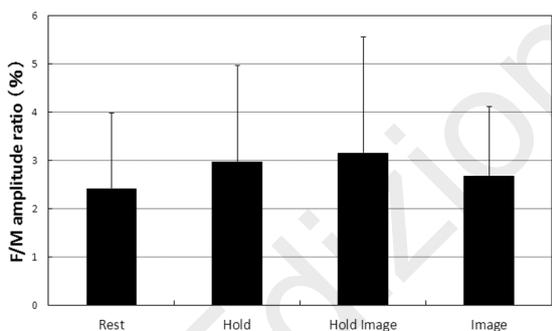


Figure 2 - F/M amplitude ratio during resting, holding and motor imagery under the "with sensor" condition and motor imagery under the "without sensor" condition.

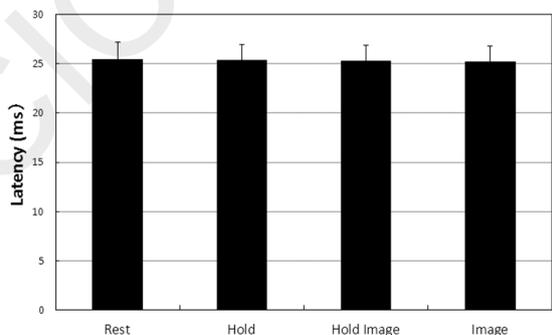


Figure 3 - Latency during resting, holding and motor imagery under the "with sensor" condition and motor imagery under the "without sensor" condition.

Discussion

Research on motor imagery can be conducted using various methods. In investigations based on MEPs obtained using TMS and single-photon emission computed tomography, it is presumed that motor imagery will be found to increase excitability in cortical regions including the motor area, supplementary motor area, premotor region and cingulate gyrus.

However, various studies have reported the influence of motor imagery on the excitability of spinal neural function. Kasai et al. (1997) reported that the amplitude of the H-reflex of the flexor carpi radialis muscle during motor imagery with wrist flexion was not increased, whereas that of MEPs was increased. Oishi et al. (1994) reported that amplitude of the H-reflex during motor imagery was reduced in a speed skater. These reports support the argument that motor imagery does not increase the excitability of spinal neural function. Conversely, Jeannerod (1995) reported that amplitude of the H-reflex and T-waves during pedaling with motor imagery was significantly higher than that during pedaling without motor imagery. Furthermore, the fact that the increase in amplitude of T-waves during motor imagery was significantly greater than the increase in amplitude of the H-reflex meant that excitability of spinal neural function induced by motor imagery was affected by the excitability of γ -motor neurons. Hale et al. (2003) reported that the amplitude of the H-reflex of the soleus muscle during motor imagery with ankle plantar flexion under 40%, 60%, 80%, and 100% MVC gradually increased with motor imagery training. These reports instead support the theory that motor imagery is effective in increasing excitability of spinal neural function.

It is unclear whether motor imagery can also be successfully applied in the rehabilitation of patients with PD. Heremans et al. (2011) reported on 14 patients with PD (Hoehn and Yahr 1-3) and 14 healthy controls evaluated by means of an extensive imagery ability assessment battery consisting of two questionnaires, the Chaotic Motor Imagery Assessment battery and a test based on mental chronometry. Patients with PD performed the imagery tasks more slowly than the controls, but most patients' motor imagery vividness and accuracy were well preserved. These results are promising with regard to the potential use of motor imagery training in the rehabilitation of patients with PD. However, Yáñez et al. (1999) reported on 12 patients with PD who received 10 minutes of motor imagery training followed by a motor practice phase. In addition, a test battery for visual imagery abilities was administered in order to investigate possible relations between visual and motor imagery. Their patients showed no marked improvement following motor imagery. These authors concluded that "the deficits found in PD patients might also be related to their limited attentional resources and difficulties in employing predictive motor strategies".

In the present study, conducted to examine spinal neural function during motor imagery tasks in PD, we analyzed F-waves of the thenar muscles following

stimulation, in patients with PD, of the median nerve during two motor imagery conditions: the “with sensor” condition (in which patients imagined the contraction with a sensor held between the thumb and index finger) and the “without sensor” condition (in which they imagined the same contraction without the sensor). Persistence and F/M amplitude ratio during motor imagery under the “with sensor” condition were significantly increased compared with the values recorded during relaxation. As these parameters are indices of excitability of spinal neural function, it can be assumed that the motor imagery under the “with sensor” condition facilitated this excitability.

We believe that the volume of afferent pathways from proprioception and skin mechanoreceptors to the primary somatosensory cortex tends to increase more during holding condition and motor imagery under the “with sensor” condition than under the other conditions.

Vargas et al. (2004) reported that a proprioceptive signal enhanced corticospinal excitability during motor imagery. However, Mizuguchi et al. (2009) reported that responsiveness of the afferent mechanoreceptors to the primary somatosensory cortex did not change, even during the combination of motor imagery of squeezing a ball and that of actually touching it. Because only the holding condition tended to increase spinal neural function in the above study, it can be assumed that the excitability of spinal neural function during motor imagery under the “with sensor” condition in our study was caused by both proprioception and a degree of modulation along the corticospinal pathway, including the primary motor cortex itself.

On the basis of the findings of this study in patients with PD, we believe that the motor imagery task under the “with sensor” condition was effective due to increased excitability of spinal neural function, in line with the findings of previous research in healthy subjects (Suzuki, et al. 2013). In our previous study (Suzuki, et al., 2013), we reported that motor imagery under the “with sensor” and “without sensor” conditions at approximately 50% MVC isometric contraction of the opponens pollicis without overt motor output increased excitability of the spinal neural output to the thenar muscles in healthy subjects. In healthy subjects, motor imagery at approximately 50% MVC isometric contraction of the opponens pollicis was effective. Thus, both the previous study (Suzuki et al., 2013) and the present study which used a motor imagery task during rehabilitation of PD showed the importance of movement preparation for a motor imagery task.

However, the fact that we used only motor imagery tasks involving isometric opponens pollicis activity, and did not try other motor imagery tasks in these patients with PD, may be considered a limit of the present study. In the future, we would like to investigate several other motor imagery tasks in patients with PD.

In conclusion, motor imagery under both “with sensor” and “without sensor” conditions at approximately 50% MVC isometric contraction of the opponens pollicis, without overt motor output, increased the excitability of

spinal neural output to the thenar muscles in 10 patients with PD (2 males and 8 females; mean age, 64 years). Because persistence and F/M amplitude ratio during motor imagery under the “with sensor” condition were significantly increased compared with the values recorded during relaxation, movement preparation for a motor imagery task involving 50% MVC isometric contraction of the opponens pollicis can be considered very important.

Acknowledgments

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