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Ipsilateral motor activation during unimanual and bimanual motor tasks ☆

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Abstract

Objective: To test for the presence and possible asymmetry of ipsilateral motor activation during unimanual and bimanual motor tasks.
Methods: Twelve right-handed healthy subjects underwent motor evoked potential (MEP) measurement of one hand (target-hand) while the other hand (task-hand) performed different motor tasks. The target-hand was either at rest (first experiment) or performed a Perdue PegBoard task (second experiment). The task-hand was either at rest, performed a simultaneous pegboard task, or rotated a coin (second experiment).
Results: In the first experiment, the motor task resulted in significant increase in MEP area in the target-hand, regardless which hand was the task-hand, with a greater increase when the left hand was the task-hand. In the second experiment, ipsilateral motor activation was not present for either hand, however, when the right hand was the task-hand, performance of continuous coin rotation by the right hand resulted in a significant decrease in the MEP area of the left hand.
Conclusions: Hemispheric asymmetry and task-dependence of ipsilateral motor cortex activation supports the postulate that motor activity may start bilaterally with subsequent interhemispheric inhibition. Furthermore, in right-handers, the left motor cortex is either more active in ipsilateral hand movements or exerts more effective inhibitory control over the right motor cortex than vice versa.
Significance: We suggest that hemispheric asymmetry in ipsilateral motor control is a factor in determining motor dominance in right-handed individuals.

Keywords: Ipsilateral motor cortex; Interhemispheric inhibition; Motor dominance; Transcranial magnetic stimulation; Motor evoked potentials

1. Introduction

The role of ipsilateral cortical activity in the control of hand and finger movements remains controversial. Several experiments demonstrate increased activation of the ipsilateral motor cortex in association with unilateral motor tasks. For example, motor evoked potentials (MEPs) elicited in a relaxed contralateral hand muscle are facilitated during voluntary contraction of the ipsilateral homologous muscle (Hess et al., 1986; Muellbacher et al., 2000; Rossini et al., 1987; Stedman et al., 1998; Tinazzi and Zanette, 1998; Zwarts, 1992). In addition, some functional magnetic resonance imaging (fMRI) studies have described activation of ipsilateral motor cortex during unilateral motor tasks (Kim et al., 1993; Rao et al., 1993).

The left hemisphere might play a greater role in ipsilateral motor control than the right hemisphere (Ziemann and Hallett, 2001). Ideomotor apraxia, an inability to correctly perform the spatial and temporal components of learned skilled movements, occurs predominantly with left hemisphere lesions (Liepmann, 1920), and limb-kinetic apraxia,

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a loss of the ability to make precise, independent, but coordinated finger movements (Liepmann, 1920), is present in the ipsilesional hand after left but not right hemisphere strokes (Hanna-Pladdy et al., 2002). Furthermore, an fMRI study showed that activation of ipsilateral motor cortex appeared predominantly when right-handed subjects used their left hand (Kim et al., 1993). Transcranial magnetic stimulation (TMS) has also been used to show that activation of ipsilateral motor cortex occurs more prominently in the left hemisphere than in the right hemisphere, particularly during performance of complex sequences of finger movements (Ziemann and Hallett, 2001). TMS has also been used to demonstrate interhemispheric inhibition between homologous motor cortices, such that stimulation of one hemisphere's motor cortex inhibits the subsequent response to TMS of the opposite hemisphere's homologous motor cortex. In right-handed subjects, this phenomenon is more prominent when TMS of the left motor cortex is used to inhibit the right motor cortex than when TMS of the right motor cortex is used to inhibit the left motor cortex (Ferbert et al., 1992; Netz et al., 1995).

The exact neural structures and pathways involved in ipsilateral motor control are not fully understood. While spinal pathways might play a role, a definite contribution of the ipsilateral motor cortex was demonstrated by paired-pulse TMS experiments (Muellbacher et al., 2000) and by transcranial electrical stimulation (TES) of the motor cortex or brain stem (Stedman et al., 1998; Tinazzi and Zanette, 1998). The mechanism by which the motor cortex influences the ipsilateral spinal motor neurons remains unclear. This influence may occur via transcallosal interneurons that transmit a modulatory sub-motor-threshold signal from the primarily active motor cortex to the contralateral motor cortex, modulating the level of activity of that motor cortex. Alternatively, at the initiation of an action, there might be activation of the motor cortex in both hemispheres, but the motor cortex that is on the same side as the active hand might be subsequently partially inhibited by the motor cortex on the side opposite the active hand by mean of interhemispheric pathways (Wassermann et al., 1994; Ziemann et al., 1999).

Based on this brief review it appears that several questions about ipsilateral motor control remain unanswered. In this study, we wanted to learn whether ipsilateral motor activation persist when both hands are simultaneously active and whether the nature of the motor tasks performed by either hand influence the degree of ipsilateral activation.

2. Methods

2.1. Subjects

Twelve healthy volunteers (mean age 25.8 ± 5.4 years, five women, seven men) participated in the study. The study was approved by the Institutional Review Board of the University of Florida and all subjects gave written informed consent. All subjects were right-handers according to the Annett Handedness Scale (mean score: 19.2 ± 2.6) (Annett, 1970).

2.2. Experimental protocol

Each subject completed the entire experiment in a single session. In each of two experiments, we recorded MEPs in one hand while the subject performed motor tasks with the opposite hand. Each experiment was repeated for the right and left hand separately. The hand undergoing MEP recording was designated "target-hand" and the opposite hand was designated "task-hand". In the first experiment, we recorded MEPs with the target-hand at rest and compared MEPs elicited with the task-hand also at rest (Condition 1) to MEPs elicited while the task-hand performed a pegboard task (Condition 2). In the second experiment, we recorded MEPs while the *target* hand performed a pegboard task and compared MEPs elicited while the *task* hand was at rest (Condition 3), while the *task* hand was rotating a coin (Condition 4), and while the *task* hand also performed a pegboard task simultaneously (Condition 5). The five experimental conditions are summarized in Table 1.

2.3. MEP recording

Muscle activity was recorded with surface EMG from the first dorsal interosseous (FDI) muscle of both hands using a Viking II electromyograph (Nicolet Biomedical, Madison, WI). EMG was band-pass filtered (50 Hz–2 kHz), digitized at a rate of 5 kHz and stored for off-line analysis.

2.4. Tasks

During the resting condition, audio feedback from the electromyograph was provided to ensure that the target-hand was fully relaxed. During the pegboard task, subjects were instructed to pick up small (1 cm long, 2 mm diameter) pegs from a well and place them in the holes of a Purdue Pegboard (Tiffin, 1968). During the coin rotation task (Condition 4), subjects held a quarter in the thumb, index

Table 1
Experimental protocols

Experiment	Condition	Task-hand	Target-hand
1	1	Rest	Rest
	2	Pegs	Rest
2	3	Rest	Pegs
	4	Coin	Pegs
	5	Pegs	Pegs

Target-hand: the hand undergoing MEP measurement during stimulation of the contralateral hemisphere. Pegs: inserting pegs in the Purdue Pegboard. Coin: rotating a quarter continuously in the thumb, index and middle finger. Experiment 1 consists of Conditions 1 and 2, with Condition 1 being the rest trial and Condition 2 being the active trial. Experiment 2 consists of Conditions 3, 4 and 5, with Condition 3 being the rest trial and Conditions 3 and 4 the active trials.