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Research report

Corticomotor excitability changes during mirrored or asynergistic wrist movements

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HIGHLIGHTS

- The activation of the ipsilateral motor cortex changes with the difficulty of bimanual contraction tasks.
- MEPs and CSPs change dependent on bimanual contraction coordination tasks.
- More complex bimanual contractions appear to result in inhibitory drive between the cortices.

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ABSTRACT

The current study used transcranial magnetic stimulation (TMS) of the right primary motor cortex (M1) during bimanual contractions to examine facilitatory and inhibitory influences on the contralateral, target extensor carpi radialis muscle (ECR) during changes in the task demands of the ipsilateral (task) ECR. The bimanual contractions were either mirrored (isometric wrist extension bilaterally) or more difficult asynergistic (asymmetric [wrist extension paired with wrist radial deviation]) contractions. TMS-induced motor evoked potentials (MEPs) and cortical silent periods (CSPs) were recorded during the execution of visually guided ramp and hold tasks. It was of interest to determine whether or not asynergistic contractions, representing a more difficult bimanual coordination task, resulted in differing patterns of activation and inhibition than mirrored movements. Asynergistic contractions were found to have differing effects on the target ECR than mirrored contractions. Foremost among these differences were the presence of enhanced inhibitory mechanisms. During asynergistic bimanual contractions the MEPs of the target ECR did not increase to the same degree and cortical silent period durations were longer. Findings indicate that bimanual mirrored and asynergistic contractions result in differing patterns of corticomotor excitability.

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1. Introduction

Bimanual coordination is an essential part of everyday life. Simple activities such as holding a jar in one hand while unscrewing the lid with the other necessarily involves complex muscle synergies and interhemispheric interactions for controlling bimanual forces and coordination [1,2,3]. Since bimanual coordination and related interhemispheric interaction are altered following stroke and other central nervous system disorders [4,5,6] an understanding of underlying mechanisms might result in better rehabilitation outcomes. Even though the execution of bimanual tasks has been studied extensively, the mechanisms used by the central nervous system (CNS) to control and stabilize bimanual coordination remain elusive and equivocal findings remain unresolved.

Results have been consistent that unimanual hand movements of varying complexities result in facilitation of the primary motor cortex (M1) ipsilateral to the task hand [7,8,9]. This effect, however, changes once the non-task (target) hand begins to move. Further, altering the type or complexity of the bimanual movement results in differing patterns of cortical facilitation and inhibition. For instance, Ghacibeh et al. [10] reported that unimanual tasks, regardless of complexity, resulted in facilitation of the ipsilateral cortex when the homologous target muscle (i.e. the muscle being recorded from secondary to transcranial magnetic stimulation (TMS) stimulation of the contralateral primary motor cortex) was at rest. However, when the target hand performed a pegboard task and the task hand rotated a coin, this facilitation was significantly less. Similarly, Sohn et al. [11] showed that phasic contractions

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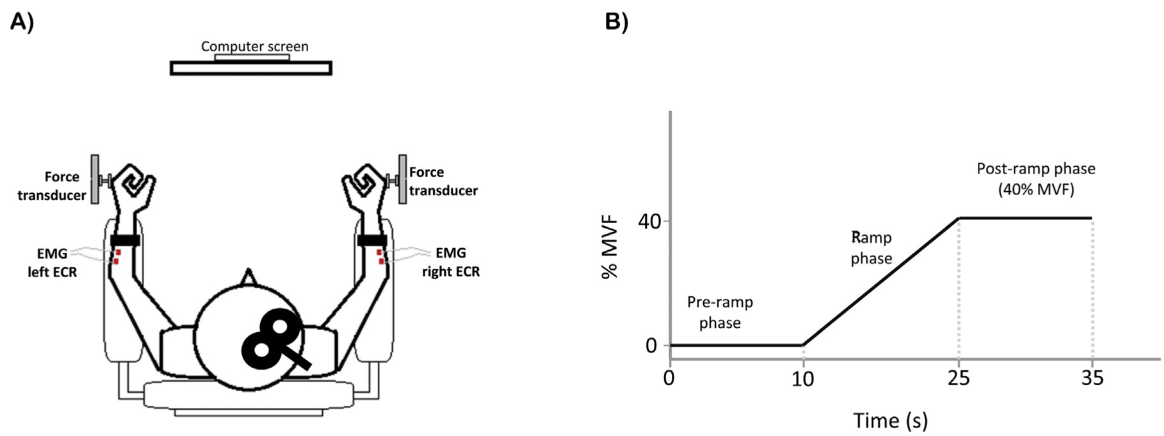

Fig. 1. Schematic representation of experimental set-up (panel A) and force production template (panel B) used during the execution of all experimental conditions. MVF, maximal voluntary force.

of the first dorsal interosseus resulted in inhibition of the contralateral homologous muscle whereas abduction of the abductor digiti minimi resulted in facilitation of its contralateral homologous muscle. Liepert et al. reported that low force phasic pinch grips reduced motor evoked potential (MEP) amplitudes of the contralateral resting homologous muscles but tonic pinch grips resulted in facilitation [12]. Increasingly, studies are reporting that interhemispheric facilitation or inhibition during bimanual movement appear to be task specific, influenced by the type of muscle contraction and whether the movement required involves symmetrical or asymmetrical coordination between the limbs [13,14,15,16].

To investigate the possible effects of different task demands on interhemispheric facilitation and inhibition the current study used a single-pulse TMS procedure during bimanual isometric contractions of the right and left extensor carpi radialis (ECR). Specifically, we examined and compared the effects of mirrored and asynergistic isometric contractions to TMS-induced motor evoked potentials (MEPs) recorded from the target ECR muscle. Mirrored movements involved simultaneous bilateral ECR isometric wrist extension contractions. It has been demonstrated that in-phase, symmetrical contractions tend to be more stable than other combinations and therefore easier to perform than other movement combinations [17]. Asynergistic contractions involved target ECR (ECRtgt) contraction into extension concomitant with task ECR (ECTtsk) contraction into radial deviation. This coordination task is more difficult to perform than mirrored movements and differs from studies that have examined 'asymmetrical' movement. Asymmetric movement has typically indicated bimanual contractions of homologous muscles in the same direction but with different force levels required between the two limbs [18,16].

The ECR muscle was chosen for this study due to its rather unique feature that, depending on the task to be performed, it can either act as (1) a proximal stabilizer of the wrist during finger movements or, (2) as a prime mover of complex dexterous wrist movements (e.g. joystick manipulation). In addition, this is a more proximal muscle than the more typically studied finger muscles. There is reason to believe its cortical and subcortical circuitry does not modulate similar to finger muscles. For instance, several investigators have found that the degree of inhibition is less for forearm muscles than for distal hand muscles during unimanual or bimanual contractions [19,11]. Sohn et al. suggested that this might represent the greater number of excitatory callosal projections of proximal muscles. Additionally, it is possible that there are a greater number of uncrossed projections from M1 to proximal upper extremity muscles than for more distal muscles [20].

Subjects were required to match forces to a visually guided target with both the ECRtgt and ECRtsk. Forces required gradually increased from rest to 40% maximal voluntary force (MVF) and thus required accurate force tracking to changing forces followed by a sustained tonic isometric contraction at 40% MVF. Changes in MEP peak-to-peak amplitudes and cortical silent periods (CSPs) caused by the differences in task demands (mirrored vs. asynergistic) were analyzed. The experimental design permitted comparisons in corticomotor excitability between the two conditions during low vs. higher force generation (to 40% MVF) and during ramping (phasic) vs. tonic isometric contractions. We hypothesized that mirrored contractions would result in MI facilitation of the ECRtgt and that the more complex asynergistic contractions would result in inhibition. Further, we hypothesized that these effects would be most pronounced during ramping contractions.

2. Methods

2.1. Subjects

Nineteen healthy, right hand dominant subjects (8 males, 11 females; mean age = 29.1 ± 8.3 years; range = 23–57) without any known neurological disorder volunteered for participation in this study. Exclusion criteria for participation in the study included previous history of epilepsy or seizure disorders, peripheral neuropathy (including loss/decreased sensation or motor function in the upper extremity [UE]), acute UE injury, recurring and or unexplained headaches, diagnosis of a concussion within the last 6 months up to date of participation in the study, metallic implants in head, spine, or UE, cardiac pacemaker, pulmonary disease, cerebral vascular accident or traumatic brain injury. Data recorded from three subjects were excluded from analysis secondary to an inability to comply with directions (e.g. maintain ECR totally at rest or maintain a steady 40% maximal voluntary force [MVF] throughout all trials) and/or to technical problems during the execution of experimental sessions (magnetic coil overheating). The experimental protocol was approved by the University of Montana Institutional Review Board, and was conducted in accordance with the Declaration of Helsinki.

2.2. Instrumentation

2.2.1. Transcranial magnetic stimulation (TMS)

A focal figure-eight TMS coil (Magstim 200, Company Limited; Whitland, Whales, UK) was used. The coil was held at the right M1 hotspot for the left extensor carpi radialis muscle (ECR), which