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Research article

Post-exercise cortical depression following repetitive passive finger movement

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HIGHLIGHTS

- We investigated if repetitive passive movement alters corticospinal excitability.
- Excitability of motor cortex (M1) decreased after repetitive passive movement.
- Range of passive movement did not influence the magnitude of M1 depression.

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ABSTRACT

This study aimed to clarify the influence of range of repetitive passive finger movement on corticospinal excitability. Thirteen healthy subjects participated in this study. Passive index finger adduction–abduction movements were performed from 15° abduction to 15° adduction, 15° abduction to 0°, 0° to 15° adduction, and 15° adduction to 30° adduction, each at 15°/s for 10 min on separate days. Motor evoked potentials (MEPs) elicited by transcranial magnetic stimulation and M- and F-waves were measured before and after each repetitive passive index finger movement protocol to evaluate changes in corticospinal excitability. MEP amplitude significantly decreased after all passive movements, while F-wave amplitude, F-wave persistence, and M-wave amplitude remained stable. These results suggest that cortical excitability decreases after repetitive passive movement. However, the range of repetitive passive movement does not markedly influence the magnitude of cortical depression.

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1. Introduction

The corticospinal excitability temporarily declines after light repetitive voluntary movement, termed Post-exercise cortical depression (PED) [2–4,18,19,22]. During the PED period, spinal excitability does not change as evidence by stability of the F-wave amplitude [4,22], while inhibitory cortical circuit transmission increases as revealed by greater short-interval intracortical inhibition (SICI) of motor evoked potentials (MEPs) in response to paired transcranial magnetic stimulation (TMS) [18,19]. Therefore, it is thought that PED results from inhibition of excitability in primary motor cortex (M1). In addition, PED fluctuates according to the frequency of voluntary movement, the strength of muscle contraction, and the type of muscle contraction [2,11,19]. Therefore, it was suggested that PED should increase with greater M1 activity during repetitive exercise [11,12].

Transient PED has also been observed after 10 min of passive finger movement, suggesting that proprioceptive feedback mediates this depression at the level of M1 [12,16]. However, this effect was not observed in other studies [7,8]. For instance, a study reported increased corticospinal excitability lasting 60 min following repetitive passive movement to the wrist joint [8]. It is unknown whether this difference is due to the involvement of separate target muscles, duration of movement, or passive movement parameters such as movement range and movement speed. The level of M1 activity was reported to influence PED, and corticospinal excitability during passive movement was affected by afferent inputs from muscle spindles [6,8]. Moreover, the firing rate of muscle spindles was reported to increase with the extension speed and amplitude of the muscle [10].

Abbreviations: FDI, first dorsal interosseous; MEP, motor evoked potential; MVC, maximum voluntary contraction; PED, post-exercise cortical depression; SICI, short-interval intracortical inhibition; TMS, transcranial magnetic stimulation.

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Therefore, as a first step, we investigated the effect of passive movement speed on PED after 10 min of passive movement [16]. As a result, unlike the hypothesis, no change in the PED magnitude was observed between high-speed (200°/s) and low-speed (20°/s) movements. As the next step, in this study, we examined the influence of repetitive passive joint movement range (extension amplitude of the muscle) on PED by comparing the MEP amplitude, F-wave amplitude and persistence, and M-wave amplitude before and after passive finger movement protocols with variable range but constant duration (10 min) and low-speed of movement (15°/s). Based on the above studies [6,8,10], we hypothesized that PED is enhanced by repetitive passive movement of a higher extension amplitude of the muscle.

2. Materials and methods

2.1. Subjects

Thirteen healthy subjects (5 males, 8 females; mean age ± standard deviation, 20.9 ± 0.28 years) participated in this study. Twelve participants were right handed and one was left handed. All subjects provided informed consent after a full verbal explanation of experimental protocols and study goals. Study protocols conformed to the Declaration of Helsinki guidelines and were approved by the ethics committee of the Niigata University of Health and Welfare.

2.2. Repetitive passive movements

Repetitive passive movement was induced by a dedicated apparatus capable of driving passive rhythmic finger movement under computer control. The movements examined were repetitive abduction–adduction movements of the right index finger: 1) from 15° abduction to 15° adduction (abd–add), 2) from 15° abduction to 0° (abd–mid), 3) from 0° to 15° adduction (mid–add), and 4) from 15° adduction to 30° adduction (add–add) (Fig. 1). When comparing ranges 1) and 2), the position of movement initiation was the same, but the range of motion was different. Therefore, range 1) showed higher amplitude of muscle extension than that of range 2). Moreover, when comparing ranges 2), 3), and 4), the range of motion was the same, but the position of movement initiation was different. Therefore, these conditions showed different muscle lengths during passive movements. Angular velocity was 15°/s and the duration was 10 min for all movement protocols.

2.3. Electromyography (EMG) recording

The surface EMG was recorded from the right first dorsal interosseous muscle (FDI) using an Ag/AgCl electrode in a belly–tendon montage. The signals were amplified ×100 by a pre-amplification system (A-DL-720-140, 4 Assist, Tokyo, Japan), digitized at 4 kHz by an A/D converter (PowerLab 8/30, AD Instruments, Colorado, USA), filtered (20-Hz high-pass), and stored on a personal computer for off-line analysis using Lab Chart 7 (AD Instruments).

2.4. Motor evoked potential (MEP) measurement

Motor evoked potential (MEP) amplitude was used as an index of corticospinal excitability before and after repetitive passive finger movement. A Magstim 200 (Magstim Co, Dyfed, UK) with a figure-eight TMS coil (diameter, 9.5 cm) was used to deliver stimuli to left M1. The optimal spot for eliciting MEPs was defined as the point where the TMS consistently evoked a large MEP from the right FDI. The optimal coil position was marked on a cap worn by the subject. Moreover, the position and orientation of the coil were monitored throughout the experiment by MRI using the Visor 2 TMS neuronavigation system (eemagine Medical Imaging Solutions GmbH, Berlin, Germany). The optimal spot of the FDI muscle was recorded, and the coil was manually held in place to maintain position. A stimulator output intensity evoking a 1-mV MEP from the relaxed FDI muscle in at least 5 of 10 trials was determined for each subject. TMS of this intensity were delivered 12 times at 0.2 Hz before (Pre), immediately after (Post 0), 5 min after (Post 5), and 10 min after passive movement (Post 10). We monitored the lack of contraction during MEP measurements and passive movements.

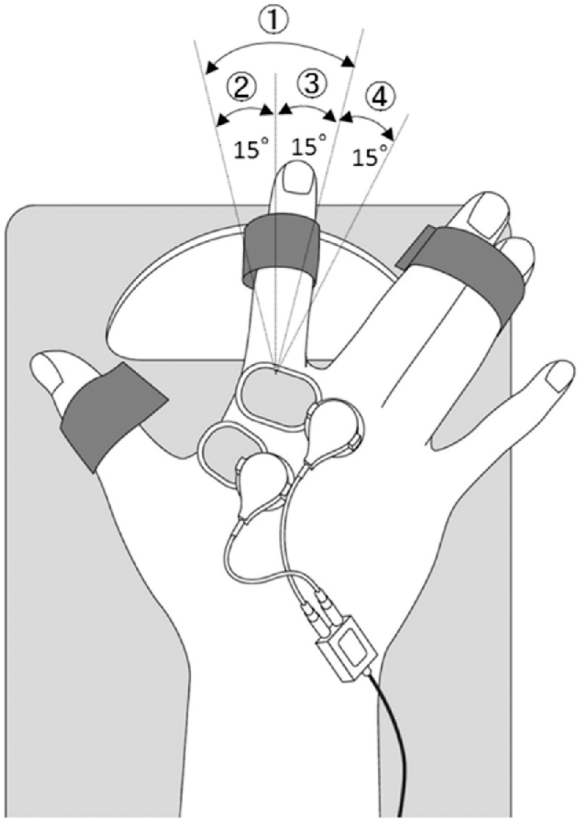

Fig. 1. Schematic illustration of the passive movement machine.
This machine enables arbitrary setting of passive finger movement range, velocity, and pause time.
① Repetitive passive movement from 15° abduction to 15° adduction (abd–add condition), ② repetitive passive movement from 15° abduction to the intermediate (mid) position (abd–mid condition), ③ repeated passive movement from the intermediate position to 15° adduction (mid–add condition), and ④ repetitive passive movement from 15° adduction to 30° adduction (add–add condition).

2.5. F-wave and M-wave measurements

F-wave amplitude, F-wave persistence, and M-wave amplitude recorded from the right FDI muscle were compared before and after passive movement in a separate experiment. Electrical stimulation was applied to the right ulnar nerve at the wrist through a bar electrode delivering 200-μs square-wave constant-current pulses generated by an electrical stimulator (SEN-8203, Nihon Kouden, Tokyo, Japan). The stimulation intensity was set to 110% of that inducing maximum M-wave amplitude (Mmax), and stimuli were delivered at 1 Hz. The F- and M-waves were measured 50 times at each time point (Pre, Post 0, Post 5, Post 10), and the F-wave persistence (%), Mmax amplitude, and F-wave amplitude/Mmax amplitude (F/Mmax) were calculated for each subject.

MEP or F-wave measurements after each passive movement protocol (abd–add, abd–mid, mid–add, and add–add) were also

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