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MOTOR CORTEX EXCITABILITY IS NOT DIFFERENTIALLY MODULATED FOLLOWING SKILL AND STRENGTH TRAINING

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Abstract—*Aim:* A single session of skill or strength training can modulate the primary motor cortex (M1), which manifests as increased corticospinal excitability (CSE) and decreased short-latency intra-cortical inhibition (SICI). We tested the hypothesis that both skill and strength training can propagate the neural mechanisms mediating cross-transfer and modulate the ipsilateral M1 (iM1). *Methods:* Transcranial magnetic stimulation (TMS) measured baseline CSE and SICI in the contralateral motor cortex (cM1) and iM1. Participants completed 4 sets of unilateral training with their dominant arm, either visuomotor tracking, metronome-paced strength training (MPST), self-paced strength training (SPST) or control. Immediately post training, TMS was repeated in both M1s. *Results:* Motor-evoked potentials (MEPs) increased and inhibition was reduced for skill and MPST training from baseline in both M1s. Self-paced strength training and control did not produce changes in CSE and SICI when compared to baseline in both M1s. After training, skill and MPST increased CSE and decreased SICI in cM1 compared to SPST and control. Skill and MPST training decreased SICI in iM1 compared to SPST and control post intervention; however, CSE in iM1 was not different across groups post training. *Conclusion:* Both skill training and MPST facilitated an increase in CSE and released SICI in iM1 and cM1 compared to baseline. Our results suggest that synchronizing to an auditory or a visual cue promotes neural adaptations within the iM1, which is thought to mediate cross transfer. © 2015 Published by Elsevier Ltd. on behalf of IBRO.

Key words: corticospinal excitability, short-latency intra-cortical inhibition, cross-transfer, visuomotor skill, metronome-paced strength, cross education.

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Abbreviations: AMT, active motor threshold; cM1, contralateral motor cortex; CS, conditioned stimulation; CSE, corticospinal excitability; EMG, electromyography; iM1, ipsilateral M1; M1, primary motor cortex; MEPs, motor-evoked potentials; MPST, metronome-paced strength training; MVC, maximal voluntary isometric contraction force; *rms*EMG, root mean squared EMG; SICI, short-latency intra-cortical inhibition; SPST, self-paced strength training; TMS, transcranial magnetic stimulation; TS, test stimulation.

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INTRODUCTION

The acute improvements in neuromuscular performance following a single session of motor training have been attributed to early adaptations within the central nervous system (CNS) (Muellbacher et al., 2001; Carroll, 2012). These acute adaptations can be observed with various measurement techniques, including, but not limited to magnetic resonance imaging (MRI) (Gerloff et al., 1998a; Thaut et al., 2002) and transcranial magnetic stimulation (TMS) (Perez et al., 2004; Kidgell and Pearce, 2010). In particular, the primary motor cortex (M1) can be modulated by skill and strength training which manifests as an increase in corticospinal excitability (CSE) and a decrease in short-latency intra-cortical inhibition (SICI) (Perez et al., 2004; Perez and Cohen, 2008; Weier and Kidgell, 2012). Isometric, ballistic and visuomotor skill training studies have consistently reported an increase in CSE following a single bout of training (Hasegawa et al., 2001; Muellbacher et al., 2001; Ziemann and Hallett, 2001; Zoghi et al., 2003; Perez et al., 2004; Camus et al., 2009; Rogasch et al., 2009; Hinder et al., 2010; Lee et al., 2010; Pearce and Kidgell, 2010; Smyth et al., 2010; Cirillo et al., 2011; Schmidt et al., 2011; Kouchtir-Devanne et al., 2012). However, to date, only two studies have examined the early neural responses (i.e. motor cortical responses) to the effects of a single bout of strength training (Hortobagyi et al., 2011; Selvanayagam et al., 2011). Furthermore, the results from these two studies were conflicting, with one study reporting an increase in CSE (Selvanayagam et al., 2011), while the other study reported no changes in CSE and SICI (Hortobagyi et al., 2011).

Although the two acute studies present conflicting results, short-term strength training studies that have used externally paced repetitions have reported increased CSE, (Kidgell et al., 2011; Goodwill et al., 2012). In addition, when skill training (i.e. visuomotor tracking) is externally paced with a metronome, an increase in CSE is observed (Ackerley et al., 2011). Previous skill training studies have demonstrated that the synchronization to an audible cue (metronome-pacing) or a visual cue (visuomotor tracking) stimulates use-dependent plasticity and activates neural pathways specific to the task, whereas a self-paced training task does not (Gerloff et al., 1998b; Perez et al., 2004; Ackerley et al., 2011). Furthermore, imaging studies have shown broader regions of cortical and sub-cortical activation in self-paced movements, compared to metronome-paced movements where specific cortical regions are activated (Gerloff et al., 1998b). In this context, specific repeated activation of regions such as the M1, supplementary motor area and the premotor cortex may manifest as changes in CSE (Gerloff et al., 1998b; Thaut et al., 2002; Lu et al., 2012). On this basis, it seems reasonable to hypothesize that strength training that is paced to a metronome, may modulate similar neural pathways that are important for motor performance that are often observed following metronome-paced skill training (Ackerley et al., 2007, 2011).

Paired-pulse TMS techniques have been used to investigate the intra-cortical circuitry of the M1 to confirm that both visuomotor skill training and ballistic skill training reduces SICI following a single bout of training (Perez et al., 2004; Camus et al., 2009; Rogasch et al., 2009; Hinder et al., 2010; Cirillo et al., 2011; van den Berg et al., 2011). However, to date, only one study has examined the effects of a single bout of strength training on the intra-cortical circuitry of the M1 to reveal no changes in intra-cortical inhibition (Hortobagyi et al., 2011).

In addition to task-specific demands, an interesting observation is the phenomenon of cross-transfer (i.e. cross-limb transfer, cross education) of motor skills, whereby motor skill training of a single limb improves motor skill performance of the untrained limb. This phenomenon may also have a significant impact on neural adaptations confined to the M1 (Carroll et al., 2002; Munn et al., 2004; Jensen et al., 2005). For example, previous studies have shown that a single bout of unilateral skill training increases CSE and reduces SICI in both the trained (contralateral [cM1]) and untrained (ipsilateral [iM1]) M1's (Perez et al., 2004; Camus et al., 2009). There is also evidence to demonstrate that the cross-transfer of strength that occurs following 3 to 4 weeks of unilateral strength training is accompanied by increased CSE and reduced SICI in both the cM1 and iM1 (Kidgell et al., 2011, 2015; Goodwill et al., 2012). However, there has only been one study that has examined the early neural responses of both the CM1 and iM1 following a single bout of unilateral strength training (Hortobagyi et al., 2011). In this particular study, there were no changes in CSE or SICI. To date, the only study to have directly compared skill and strength training was conducted by Jensen et al. (2005), and it was demonstrated that skill training significantly increased CSE, while strength training did not, leading to the conclusion that skill and strength training involve different sites of adaptation within the CNS. However, this finding has not been systematically examined; therefore, the purpose of the present study was to compare the effects of a single bout of skill training and strength training on CSE and SICI. To do this, we examined the changes in CSE and SICI elicited by a single bout of a skilled task (i.e. visuomotor tracking), a metronome-paced strength training task and a self-paced strength training task. It was hypothesized that the magnitude of corticospinal plasticity would not be different following skill and strength training and that both skill and strength training can propagate the neural mechanisms mediating the cross-transfer of motor function and modulate the M1.

EXPERIMENTAL PROCEDURES

Participants

Forty-four participants (age of 26.1 ± 6.8 years; right-hand dominant, 24 males and 20 females) volunteered to participate in the study and were randomized into four groups (control $n = 10$; metronome-paced strength training $n = 11$; skill training $n = 12$; self-paced strength training $n = 11$). All participants provided written consent prior to participation of the study and were screened for any neurological and musculoskeletal disease or injury and allocated a participant ID number. Participants hand dominance was established by Edinburgh handedness inventory (Oldfield, 1971). There was one left-hand dominant participant in each group. The study was approved by the Deakin University Human Research Ethics Committee and was conducted in accordance to the Declaration of Helsinki. No participants reported any discomfort or ill effects during and after the study.

Study protocol

Participants attended a familiarization session in order to adjust to TMS, completed one set of each exercise. Baseline measures took place after a 2-week washout period following the initial familiarization session. With reference to Fig. 1, at the commencement of the baseline session, single-and paired-pulse TMS was performed to measure baseline CSE and SICI from the cM1 and iM1. Depending on their group allocations, participants then completed four sets of their respective training paradigms (described in detail in the training below). Five minutes after the training session, single- and paired-pulse TMS was repeated to measure the acute changes in CSE and SICI in both M1s.

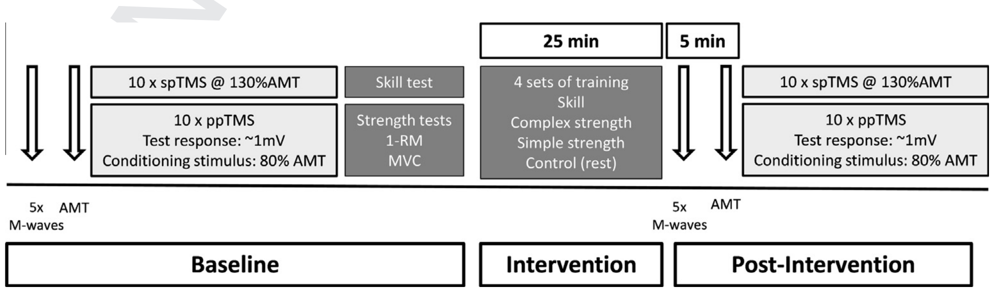

Fig. 1. Study overview.