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Corticospinal properties following short-term strength training of an intrinsic hand muscle

Dawson J. Kidgell [a,b,*], Alan J. Pearce [b]

[a] School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia
[b] Institute for Sport, Exercise and Active Living (ISEAL), Victoria University, Melbourne, Australia

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ABSTRACT

Practicing skilled tasks that involve the use of the hand and fingers has been shown to lead to adaptations within the central nervous system (CNS) underpinning improvements in the performance of the acquired task. However, neural adaptations following a period of strength training in the hand is not well understood. In order to determine the neural adaptations to strength training, we compared the effect of isometric strength training of the right first dorsal interosseous (FDI) muscle on the electromyographic (EMG) responses to transcranial magnetic stimulation (TMS) over left M1. The specific aim of the study was to investigate the corticospinal responses, including latency, motor-evoked potential amplitude (MEP), and silent period duration (SP) following 4 week of strength training of the FDI muscle. Sixteen healthy adults (13 male, three female; 24.12 ± 5.21 years), were randomly assigned into a strength training ($n = 8$) or control group ($n = 8$). Corticospinal measures of active motor threshold (AMT), MEP amplitude, and SP duration were obtained using TMS during 5% and 20% of maximal voluntary contraction force (MVC) pre and post 4 week strength training. Following training, MVC force increased by 33.8% ($p = .01$) in the training group compared to a 13% increase ($p = .2$) in the untrained group. There were no significant differences in AMT, latency, or MEP amplitude between groups following training. However, in the trained group, there was a 16 ms reduction in SP duration at 5% of MVC ($p = .01$) and 25 ms reduction in SP duration at 20% of MVC ($p = .03$). These results demonstrate a task dependent adaptation in corticospinal inhibition via

* Corresponding author. Address: School of Exercise and Nutrition Sciences, Deakin University, 221 Burwood Highway, Burwood, 3125 Victoria, Australia. Tel.: +61 3 9251 7264; fax: +61 3 3 9244 6017.
E-mail address: dawson.kidgell@deakin.edu.au (D.J. Kidgell).

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a reduction in cortical SP duration that may in part underpin the strength increases observed following strength training.

1. Introduction

The contributions of the central nervous system (CNS) to improvements in strength are well documented (Duchateau & Enoka, 2002; Duchateau, Semmler, & Enoka, 2006; Folland & Williams, 2007). However, the mechanisms underlying these improvements are less well understood, particularly in the primary motor cortex (M1). While evidence for the muscle morphological changes that occur with strength training are clearly demonstrated through hypertrophy (Folland & Williams, 2007), the neural adaptations induced by strength training may be comprised of more subtle changes (Datta & Stephens, 1990) in many areas including supraspinal centers (Carroll, Riek, & Carson, 2002; Farmer, Swash, Ingram, & Stephens, 1993), descending neural tracts (Aagaard, Simonsen, Anderson, Magnusson, & Dyhre-Poulsen, 2002; Fimland, Helgerud, Gruber, Leivseth, & Hoff, 2009), spinal circuitry (Cannon & Cafarelli, 1987; Del Balso & Cafarelli, 2007; Kamen, 2004), and the motor end plate connections between motoneurons and muscle fibers (Staron, Karapondo, & Kraemer, 1994). Several investigations have reported maximal force increases of up to 15% within days following an exercise session (Berg, Larsson, & Tesch, 1997; Duchateau, 1995; Rogers & Evans, 1993; Schenck & Forward, 1965; Vandenborne, Elliot, & Walter, 1998; Yue, Bilodeau, Hardy, & Enoka, 1997), and up to 200% increase after 8 week, with no changes in the cross-sectional area of muscle (Folland & Williams, 2007). These results imply that the early stages of strength development may be due to some form of neural adaptation.

Although there is a general consensus that the CNS mediates this increase in strength following a period of strength training, there is considerable debate concerning the extent and nature of involvement of specific sites within the CNS. Recently, a number of studies have used transcranial magnetic stimulation (TMS) to determine whether the M1 contributes to strength development, providing a potential site for neural adaptations to strength training (Carroll et al., 2002; Griffin & Cafarelli, 2007; Hortobágyi et al., 2009; Jensen, Marstrand, & Nielsen, 2005). Given that the M1 is heavily populated with corticospinal cells that descend onto motoneurons located within the spinal cord (Porter, 1985), the use of TMS enables the assessment of corticospinal excitability and inhibition following specific training interventions. For example, Carroll et al. (2002) examined the effect of heavy load (70–85% of MVC) isometric strength training on corticospinal excitability following 4 week strength training of the first dorsal interosseous (FDI) muscle. Although strength training resulted in a 33% increase in strength, the strength training program did not modify the size of the TMS produced motor-evoked potential (MEPs). Carroll et al. (2002) also used transcranial electrical stimulation (TES) to stimulate subcortical structures and concluded that strength training does not affect the organization of the M1, suggesting that adaptations are confined to the spinal cord. Similarly, Jensen et al. (2005) had participants perform heavy load (80% of MVC) dynamic strength training (five sets of six to 10 repetitions) of the biceps brachii three times per week for 4 week. MEP amplitude at 5% of MVC and stimulus–response curves were constructed prior to and after the 4 week training intervention. Following training, muscle strength increased by 31%, however, maximal MEP amplitude produced by TMS at rest was reduced, suggesting a minimal role for the M1 and corticospinal pathway in strength development. In contrast to these findings, Beck et al. (2007) demonstrated increased MEP amplitude produced by TMS following 4 week of ballistic strength training in the soleus muscle, while Griffin and Cafarelli (2007) found a 32% increase in MEP amplitude with no change in peripheral nerve excitability, suggesting that strength training leads to a task-specific adaptation within the corticospinal tract. Therefore, strength training studies using TMS show either increased (Beck et al., 2007; Griffin & Cafarelli, 2007), reduced (Jensen et al., 2005), unchanged (Carroll et al., 2002), or task-specific modulation of corticospinal excitability (Beck et al., 2007).

Although the above mentioned TMS studies have tried to determine the effects of strength training on corticospinal excitability (by measuring MEP amplitude produced by TMS), changes in cortical inhibition may also be an important neural adaptation that contributes to strength development. Cortical inhibition refers to the neural mechanisms by which output from M1 is attenuated by inhibitory