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Corticospinal responses of resistance-trained and un-trained males during dynamic muscle contractions

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ABSTRACT

Little is known regarding the modulation and the plasticity of the neural pathway interconnecting elements of the central nervous system and skeletal muscle in resistant-trained individuals. The aim of the study was to compare corticospinal and spinal responses measured during dynamic muscle contractions of the tibialis anterior in resistance trained (RT) and un-trained (UT) males. Nine UT and 10 RT male volunteers reported to the laboratory 24 h following a familiarisation session. Motor evoked potentials (MEPs) and the cortical silent period were evoked using transcranial magnetic stimulation at a range of contraction intensities and was delivered as the ankle passed 90° during shortening and lengthening contractions. The Hoffmann reflex (H-reflex) and V-waves were evoked with peripheral nerve stimulation. Despite the RT group being significantly stronger during shortening (28%; $P = 0.023$: CI = 1.27–15.1 N m), lengthening (25%; $P = 0.041$: CI = 0.27–17.0 N m) and isometric muscle actions (20%; $P = 0.041$; CI = 0.77–14.9 N m), no differences between the groups existed for corticospinal or spinal variables. Lack of detectable differences between RT and UT individuals may be linked to minimal exposure to task specific, isolated high intensity resistance training of the TA muscle.

1. Introduction

Morphological changes at the muscle accounts for some of the initial gains in strength associated with resistance training (RT), although neurological adaptations within the central nervous system (CNS) appear to be the predominant mechanism (Carroll et al., 2011; Folland and Williams, 2007; Griffin and Cafarelli, 2005; Sale, 1988). The H-reflex is used to access spinal excitability through changes in α-motoneuron excitability and/or a reduction in presynaptic inhibition (Aagaard et al., 2002). An acute period of RT has been shown to increase the H-reflex (Aagaard et al., 2002; Duclay et al., 2008; Holtermann et al., 2007; Lagerquist et al., 2006), whilst an increase in V-wave has been found following an acute period of RT (Aagaard et al., 2002; Del Balso and Cafarelli, 2007; Duclay et al., 2008). The V-wave reflects the level of efferent drive from the spinal α-motoneuron and is recorded during maximal contractions (Aagaard et al., 2002). To further understand the effect of acute RT on corticospinal adaptations, a number of studies (Beck et al., 2007; Carroll et al., 2009, 2002; Griffin and Cafarelli, 2007; Hortobágyi et al., 2009; Jensen et al., 2005; Kidgell and Pearce, 2010; Schubert et al., 2008) have used transcranial magnetic stimulation (TMS) to assess changes in cortical and spinal excitability/inhibition. However, despite the growing number of studies using TMS, research has not focused on modulation at multiple levels of CNS in individuals with a history of RT.

The exact nature and location of neurological adaptations that occur from chronic RT within the CNS (brain, spinal or muscle) are not well understood. Using the interpolated twitch technique, a greater neural drive (38%) to the muscle in RT individuals has been demonstrated (Fernandez del Olmo et al., 2006), which appears independent from modulations in corticospinal excitability. However, these TMS responses (Fernandez del Olmo et al., 2006) were standardised to force and did not express it relative to background electromyographic activity and hence not relative to the motoneuron pool. At a spinal level, a reduced Hoffmann reflex (H-reflex) has been reported (Casabona et al., 1990; Maffiuletti et al., 2001) in strength/power athletes who engage in significant levels resistance training, which are predominantly thought to be due to the transformation of fibre type from explosive ballistic movements (Koceja et al., 2004). Furthermore, despite these relatively few aforementioned studies, it is still not clear how the CNS is chronically modulated to support the morphological adaptations at the muscle. The combination of TMS and peripheral nerve stimulation (PNS) may help to understand the site of adaptation and quantify how the muscle is supported at different levels of

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the CNS. Additional information on the paucity of data relating to the CNS responses in chronically RT individuals may add greater clarity to whether adaptations in the CNS are an acute response to a previously unknown training stimulus or a continuously evolving adaptation.

On first appearance, it could be argued that neurological adaptations in the tibialis anterior (TA) may be limited. However, functional strength training (multiple joint exercises, including squat and bench press) has been shown to cause neural adaptations to single muscles in isolated actions (Fimland et al., 2009). Therefore it could be expected that even though the TA is not directly trained in a RT programme, functional RT will consequently cause an increase in maximal torque. The unique characteristics of TA make it is a good candidate to assess the corticospinal and spinal adaptations in chronic RT individuals. The accuracy needed for toe clearance during gate causes the TA to display unusually large monosynaptic peaks (Capaday et al., 1999) that, comparable to distal hand muscles (Petersen et al., 2003) and thus TMS responses, are easily recordable. The accessibility of the peripheral nerve ensures spinal responses are also obtaintainable. Furthermore, our laboratory has previously demonstrated that coricospinal and spinal measures are highly repeatable in the TA (Tallent et al., 2012a). Therefore, the TA is a good candidate to allow insight into adaptations at multiple levels of the CNS. The aims of the present study were to compare corticospinal and spinal responses measured during dynamic muscle contractions of the TA in RT and un-trained individuals.

2. Methods

2.1. Participants

The study was approved by the University's Research Ethics Committee in accordance with the Declaration of Helsinki. Ten resistance trained (RT) and 9 un-trained (UT) males (mean ± SD age, stature and mass was 22 ± 2 and 26 ± 3 years, 178.2 ± 6.2 175.0 ± 5.9 cm and mass 87.8 ± 7.6 75.4 ± 6.6 kg, respectively) volunteered to take part in the study before undergoing health screening for neurological disorders and potential adverse effects from TMS (Rossi et al., 2011) and providing written informed consent. The RT group had a history of no less than 3 years of heavy load resistance training exercise, consisting of 3 or more training sessions per week. The UT group were sedentary individuals. The TA of the dominant leg was assessed in both groups (Hebbal and Mysorekar, 2006); 18 of the 19 participants were right leg dominant. Participants were asked to abstain from caffeine ingestion in the 6 h preceding the trial and refrain from exercise in the 48 h prior to initially reporting to the laboratory.

2.2. Study design

Participants visited the laboratory on two consecutive days completing an identical protocol. Day one was used as a familiarisation session and day two to compare all TMS and PNS responses between groups. TMS responses were recorded at rest and during shortening and lengthening muscle contractions (15%, 25%, 50%, 80% of maximal voluntary contraction). Additionally, PNS responses were recorded at rest and during shortening and lengthening maximal voluntary contractions and 25% MVC. The presentation of contraction intensity (15%, 25%, 50%, 80% of maximal voluntary contraction), type (shortening and lengthening) and order (TMS and PNS) were randomised.

2.3. Experimental set-up

Contractions were conducted on an isokinetic dynamometer (Cybex Norm, Cybex International, NY, USA). The foot of the dominant limb was firmly strapped into the dynamometer and joint angles of the hip, knee and ankle were set as 90°, 120° and 90°, respectively. To prevent any extraneous movement, the leg under assessment was fixed into a thigh stabiliser. Participants performed dorsiflexion by resisting or assisting (depending on contraction type) as the ankle moved through a range of 30°. Shortening and lengthening contractions were set at 75° and 105°, respectively at an angular velocity of 15°/s. All values were recorded as the ankle passed anatomical zero (90°); such that the dynamometer angle was used to trigger the TMS pulse. Instantaneous torque data was displayed on the dynamometer's monitor for the participant. Clear instructions were given to focus on activation of the TA and minimise activation in other muscles.

2.4. Maximal voluntary contraction (MVC)

MVC of the dorsiflexors was assessed prior to assessment. Participants performed three maximal contractions of each contraction type (shortening, lengthening and isometric) with the highest being accepted as MVC. If the third contraction produced the highest torque additional maximal contractions were performed until there was no further increase in maximal torque. Torque was recorded as the ankle passed anatomical zero (90°).

2.5. Surface electromyography (EMG)

EMG was recorded on the belly of the TA. Specifically, electrodes (22 mm diameter, model; Kendall, Tyco Healthcare Group, Mansfield, MA, USA) were placed 2 cm apart and one third of the way between the head of the fibula and the medial malleolus (Hermens et al., 2000). EMG was recorded over the TA with the reference electrode positioned on the medial malleolus. The site was shaved and abraded with preparation gel and finally cleansing with an alcohol wipe. EMG was amplified (1000×) and band pass filtered 10–1000 Hz (D360, Digitimer, Hertfordshire, UK) and sampled at 5000 Hz (CED Power 1401, Cambridge Electronic Design, Cambridge, UK).

2.6. TMS protocol

A concave double coned coil (110 mm) and a magnetic stimulator (Magstim 200^2, Magstim Company Ltd., Carmarthenshire, UK) were used to evoke MEPs. The coil was placed over the primary motor cortex (M1) of contralateral hemisphere at an area relating to the area of the dominant leg. MEPs were induced with a posterior to anterior intracranial current. Once optimal coil placement, or hot spot, was determined over M1, the scalp was marked with semi-permanent ink to ensure consistent placement of subsequent stimulations, which has been previously shown to demonstrate very good reliability (Tallent et al., 2012). Resting motor threshold (rMT) was established as an MEP of >50 μV in 5 out of 10 consecutive pulses (Rossini et al., 1994) and reported as a percentage of stimulator output. All corticospinal responses were averaged from 8 stimuli at a stimulator output of 120% rMT. Participants performed eight shortening and eight lengthening contractions at 80%, 50%, 25% and 15% of the task specific MVC. Each block of eight contractions was conducted in a randomised order however, the order during the familiarisation session and main trial remained consistent for each participant. During TMS, all contractions were separated by a minimum of 20 s to ensure MEPs had returned to resting values (Tallent et al., 2012b). Approximately 110 pulses were discharged during each trial, which included during rest, contractions and determining the hotspot and resting motor threshold.