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Short communication

Chronic resistance training enhances the spinal excitability of the biceps brachii in the non-dominant arm at moderate contraction intensities

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HIGHLIGHTS

- Supraspinal excitability of the biceps brachii in the non-dominant arm was not different between chronic resistance trained and non-resistance trained individuals.
- Chronic resistance trained individuals had greater spinal excitability of the biceps brachii in the non-dominant arm.
- Increased strength in the non-dominant limb in chronic resistance-individuals is, in part, spinally mediated.

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ABSTRACT

The purpose of the study was to assess corticospinal excitability of the biceps brachii in the non-dominant arm of chronic resistance-trained (RT) and non-RT individuals. Seven chronic-RT and six non-RT male participants performed 4 sets of 5 s pseudo-randomized contractions of the non-dominant elbow flexors at 25, 50, 75, 90, and 100% of maximum voluntary contraction (MVC). During each contraction, transcranial magnetic stimulation, transmastoid electrical stimulation, and Erb's point electrical stimulation were administered to assess the amplitudes of motor evoked potentials (MEPs), cervicomedullary evoked potentials (CMEPs), and maximal muscle compound potentials (M_{max}), respectively, in the biceps brachii. MEP and CMEP amplitudes were normalized to M_{max}. Training did not affect ($p > 0.14$) MEP amplitudes across any contraction intensity. CMEP amplitudes were significantly ($p < 0.05$) higher in the chronic-RT group at 50% and 75% of MVC by 38% and 27%, respectively, and there was a trend for higher amplitudes at 25%, 90%, and 100% MVC by 25% ($p = 0.055$), 36% ($p = 0.077$), and 35% ($p = 0.078$), respectively, compared to the non-RT group. Corticospinal excitability of the non-dominant biceps brachii was increased in chronic-RT individuals mainly due to changes in spinal excitability.

1. Introduction

Changes in corticospinal excitability (CE) accompany the strength increases with chronic resistance training. Recently, Pearcey et al. [22] showed that motor evoked potential (MEPs, *i.e.*, supraspinal excitability) amplitudes recorded in the biceps brachii during dominant arm elbow flexion contractions at intensities above 50% MVC were lower in the chronic resistance trained (RT) group than the non-RT; whereas, cervicomedullary evoked potentials (CMEPs, *i.e.*, spinal excitability) were similar. They suggested that the decrease in the MEP amplitudes in the chronic-RT group might have been due to an increased firing rate of the spinal motoneurons (*i.e.*, increased spinal and/or spinal motoneuron excitability). Since resistance training increases motor unit maximal firing rates [32,34], the increase in strength from chronic resistance training may be due, in part, to enhanced motoneuron firing frequency, especially at the higher force outputs. Two other studies found no effect of chronic resistance training on corticospinal excitability of the biceps brachii [11] and tibialis anterior [27]. However, in these studies spinal excitability was not

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examined [11,27]. Findings from acute resistance training studies have illustrated concomitant changes in CE (utilizing similar stimulation techniques as employed in [22]) of the first dorsal interosseous [8] and extensor carpi radialis [7] and strength. The authors [7,8] also suggested that the changes in CE following acute resistance training were due to either an increased spinal excitability or increased firing rate of the spinal motoneuron. Thus, the resistance training-induced changes in CE of muscles located in the dominant limb appear to be mainly of spinal origin. Interestingly, all of the aforementioned studies focused on changes in CE of a muscle in the dominant limb. To our knowledge, no studies to date have determined how chronic resistance training alters CE of a muscle located in a non-dominant limb. Differences in CE have been shown between dominant and non-dominant fine motor control muscles of the hand [26], potentially due to use-dependence; however, an increased usage of the non-dominant limb due to chronic resistance training may alter CE of a given muscle compared to non-RT individuals.

The purpose of the current study was to determine if CE of the biceps brachii in the non-dominant arm was different between chronic-RT and non-RT individuals. In order to compare CE of the biceps brachii in the non-dominant arm to the changes in CE of the biceps brachii in the dominant arm [as shown in [22]], we sought to determine how CE of the biceps brachii in the non-dominant arm changes over elbow flexion contractions from low to maximum intensity. Based on work by Pearcey at al. [22] as described earlier, it was hypothesized that chronic-RT individuals would produce more non-dominant elbow flexor force than non-RT individuals. The increased force would be, in part, due to differences in CE that were mainly of spinal origin. Specifically, the changes in CE may be due to enhanced excitability of spinal motoneurons.

2. Material and methods

2.1. Participants

Seven chronic-RT (>2 years at ≥3 times per week of resistance training experience) (height 176.9 ± 4.7 cm, weight 79.2 ± 6.3 kg, age 22.9 ± 3.5 years) and six non-RT (height 182.1 ± 9.3 cm, weight 91.4 ± 18.0 kg, age 22.0 ± 2.2 years) males participated in the study. Participants were verbally informed of all procedures, and read and signed a written consent form. Participants completed the magnetic stimulation safety checklist [25] and Edinburg handedness inventory: short form to determine participants' arm dominance [33] prior to the start of the experiment. All participants were strongly right-handed or left-handed (laterality quotient (LQ); right-handed LQ = 93 ± 11.5; left-handed LQ = 93 ± 10.0). The Memorial University of Newfoundland Interdisciplinary Committee on Ethics in Human Research approved this study (ICEHR #20140710-HK).

2.2. Experimental protocol

Participants performed a voluntary isometric contraction protocol which included four sets of 5 s contractions of the non-dominant elbow flexors at 5 target forces (25, 50, 75, 90, 100% MVC) for a total of 20 contractions (4 contractions at each target force). Once the participant reached the prescribed force they received TMS, TMES, and Erb's point stimulation at 1, 2.5, and 4 s, respectively. At the start of each set, participants performed a MVC and all subsequent target forces with stimulation protocol (25–90% of MVC) in that set were randomized. During all contraction intensities in one set the MEP, CMEP, and muscle compound action potential (M-wave) responses were recorded from the bicep brachii. To minimize the effect of fatigue, there was 2 min of rest following 90% and 100% MVC, 1 min of rest following 75 and 50% MVCs and 30 s of rest following all forces at 25% MVC [4,22,23] (see Fig. 1A and B for experimental set-up and stimulation protocol).

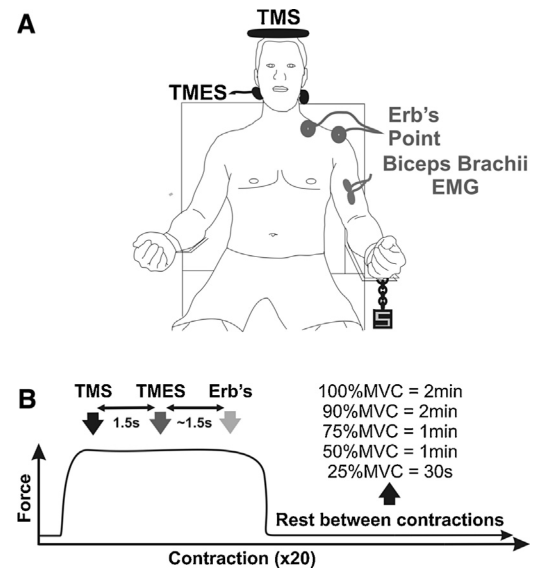

Fig. 1. (A) Diagram of experimental apparatus for elbow flexion contractions and time and type of stimulation. (B) Subjects performed 4 sets of 25, 50, 75, 90, and 100% MVCs (20 contractions in total) and received TMS (black arrow, at 1.0 s), TMES (white arrow, at 2.5 s) and Erb's point stimulation (grey arrow, at 4.0 s) during each muscle contraction. Rest periods between contractions varied based on the intensity.

2.3. Elbow flexor force

Participants sat in an upright position with hips, knees, and elbows flexed at 90° with forearms in a neutral position and resting on padded support. The upper torso was rested against the backrest and secured with straps around the waist and shoulders. The wrist of the non-dominant arm was inserted into a non-compliant padded strap, attached by a high-tension wire that measured force using a load cell (Omegadyne Inc., Sunbury, OHIO). Forces were detected by the load cell, amplified (×1000) (CED 1902) and displayed on a computer screen.

Electromyography activity was recorded from the biceps brachii muscle. Surface EMG recording electrodes (Meditrace Pellet Ag/AgCl electrodes, disc shape, and 10 mm in diameter, Graphic Controls Ltd., Buffalo, NY) were placed 2 cm apart over the mid-muscle belly of the biceps brachii. A ground electrode was secured on the lateral epicondyle. EMG signals were analog-digitally converted at a sampling rate of 5 kHz using a CED 1401 interface and signal 4 software (Cambridge Electronic Design Ltd., Cambridge, UK).

2.4. Stimulation conditions

All stimulation conditions and methods utilized in the current study were similar to that previously reported from our laboratory that compared the corticospinal excitability of the biceps brachii in the dominant arm of chronic-RT and non-RT individuals [22].

2.4.1. Brachial plexus (Erb's point) electrical stimulation

Erb's point was electrically stimulated *via* adhesive Ag–AgCl electrodes (diameter 10 mm) fixed to the skin over the supraclavicular fossa (cathode) and the acromion process (anode). Current pulses (200 μs duration) were delivered *via* a constant current stimulator (DS7AH, Digitimer Ltd., Welwyn Garden City, UK). The stimulator setting (chronic-RT = 207.1 ± 45.0 mA and

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