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Research paper

Changes in supraspinal and spinal excitability of the biceps brachii following brief, non-fatiguing submaximal contractions of the elbow flexors in resistance-trained males

Saied Jalal Aboodarda[a], David B. Copithorne[a], Gregory E.P. Pearcey[a], Duane C. Button[a,b], Kevin E. Power[a,b,*]

[a] School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John's, Newfoundland, Canada
[b] Faculty of Medicine, Memorial University of Newfoundland, St. John's, Newfoundland, Canada

HIGHLIGHTS

- Corticospinal excitability was assessed following brief non-fatiguing contractions.
- Supraspinal excitability is increased immediately post-exercise.
- Spinal excitability is decreased immediately post-exercise.

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ABSTRACT

The purpose of the current study was to assess the effects of 5 brief (2 s), intermittent, submaximal elbow flexors voluntary contractions at 50% of maximal voluntary contraction (MVC) on measures of central (*i.e.* supraspinal and spinal) excitability. Supraspinal and spinal excitability of the biceps brachii were assessed *via* transcranial magnetic stimulation (TMS) of the motor cortex and transmastoid electrical stimulation (TMES) of the corticospinal tract, respectively. TMS-induced motor-evoked potentials (MEPs), TMES-induced cervicomedullary-evoked potentials (CMEPs), Erb's point peripheral nerve stimulation and MVC were assessed prior to and following submaximal voluntary contractions at 50% of MVC. The MEP to CMEP ratio increased (584 ± 77.2%; $p = 0.011$) and CMEP amplitudes decreased (62 ± 3.0%; $p = 0.02$) immediately post-exercise. MVC force output did not change immediately post-exercise. The results suggest that brief, non-fatiguing intermittent submaximal voluntary contractions transiently enhance supraspinal excitability while decreasing spinal excitability. The impact of these changes on one's ability to generate or maintain force production remains unknown.

1. Introduction

The excitability of the neuromuscular system is history-dependent. Numerous studies have assessed changes in the excitability of central nervous system following various exercise interventions, with the vast majority focused on elucidating the mechanisms of central fatigue. A seldom reported consequence of exercise is that it is possible to increase the excitability of the corticospinal pathway following voluntary contractions, a process referred to as post-exercise facilitation (PEF). A common means to assess corticospinal excitability following an exercise intervention is to assess motor-evoked potentials (MEPs) elicited *via* transcranial magnetic stimulation (TMS) of human motor cortex. Using TMS, PEF has been shown to occur in biceps brachii [16], extensor carpi radialis (ECR) [22], soleus [16], flexor carpi radialis (FCR) [2] and thenar muscles [1] with varying intensities and durations of muscle contractions.

Samii et al. [22] demonstrated PEF of MEPs in the ECR following 10 s of wrist extension at 10–50% of MVC. Norgaard et al. [16], reported PEF of MEPs recorded from the biceps brachii following short duration isometric contractions (*i.e.* 2, 4, and 6 s) at different contraction intensities (25%, 50% and 100% of MVC). PEF was not affected by either the duration or intensity of the contractions and was transient, having dissipated by 15.2 s post-contractions.

* Corresponding author at: School of Human Kinetics and Recreation, Memorial University, 230 Elizabeth Avenue, St. John's, Newfoundland, Canada, A1C 5S7. Fax: 709 864 3979.
E-mail address: kevin.power@mun.ca (K.E. Power).

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Balbi et al. [1] indicated that a 1 s PEF of MEP occurred for different contraction durations (*i.e.* 5, 15 and 30 s) and intensities (*i.e.* 10, 25 and 50% of MVC) in the thenar muscles. Unlike Norgaard et al. [16], however, maximal PEF was present following a single, short duration (5 s), 50% MVC effort, suggesting that the intensity and duration of the preceding contraction are factors in the amount of PEF. It was not clear from these studies whether PEF of MEP amplitude was of supraspinal or spinal origin, though both Samii et al. [22] and Norgaard et al. [16] suggested that PEF was supraspinally mediated.

Interestingly, PEF can occur concurrent with decreased cervicomedullary MEP (CMEPs) amplitudes elicited *via* transmastoid electrical stimulation (TMES), indicating an increased supraspinal excitability and decreased spinal motoneurone excitability [5]. Decreased spinal motoneurone excitability occurs following strong contractions lasting 10 s to 2 min in the elbow flexors [5] and following short duration (10 s) contractions at 50% of MVC [18]. Long-lasting depression of spinal motoneurone excitability also occurs in the first dorsal interosseous [7], abductor digiti minimi (ADM) [12] and the tibialis anterior (TA) [12] muscles. However, in the TA, CMEPs can also be facilitated following 10 s MVCs suggesting increased spinal motoneurone excitability [8]. Furthermore, evidence from studies using motor unit recordings indicate that spinal motoneurone excitability can be increased with non-fatiguing, repeated submaximal contractions (<50% MVC) [9] [23]. For example, the torque recruitment threshold of a motor unit progressively decreases during repetitive isometric contractions [23]. The reduced recruitment threshold has been suggested to be due to increases in contraction-mediated synaptic input, such as post-contraction discharge of muscle spindles [23] and/or to changes in the intrinsic properties of spinal motoneurones, such as the activation of excitatory, persistent inward currents [9].

While it is clear that nervous system excitability can be modulated following exercise, it is not clear whether or how brief (2 s), non-fatiguing, intermittent submaximal contractions (50% MVC) modulates supraspinal and/or spinal excitability. Thus, the objective of this study was to assess the effects of brief, non-fatiguing, intermittent submaximal contractions of the elbow flexors on supraspinal and spinal excitability of the biceps brachii.

2. Materials and methods

2.1. Participants

Eight physically active, resistance-trained males (height 173 ± 8.2 cm, weight 77.63 ± 12.8 kg, age 28.3 ± 7.1 years) from the university population volunteered for the study. The participants were informed verbally of the possible risks and discomforts of the study and they gave informed, written consent. Prior to the experiments, all participants completed a magnetic stimulation safety checklist designed to screen for potential contraindications with magnetic stimulation procedures [21]. Participants were asked to refrain from drinking coffee and participating in vigorous physical activity at least 1 day before attending each experimental session. The study was approved by the Interdisciplinary Committee on Ethics in Human Research (#20130807-HK) at Memorial University of Newfoundland and was accordance with the Tri-Council guideline in Canada with full disclosure of potential risks to subjects.

2.2. Experimental protocol

Participants were required to come to the laboratory to complete two experimental sessions.

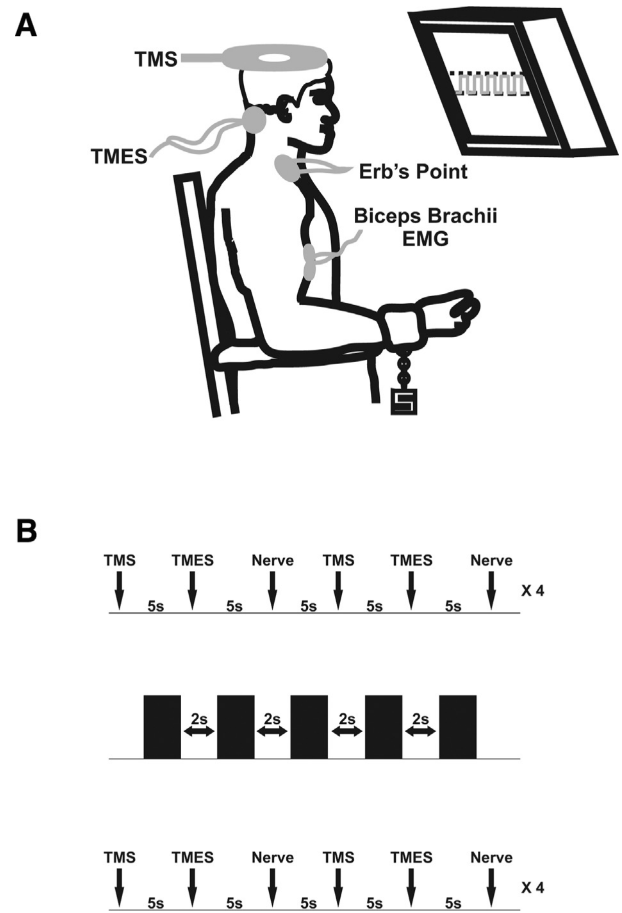

Fig. 1. Experimental set-up and general procedure.
(A) Participants were comfortably seated in a custom built chair with the wrist of the dominant arm inserted into a padded strap. Transcranial magnetic stimulation (TMS) was applied over vertex to activate the motor cortex of the contralateral hemisphere. Transmastoid electrical stimulation (TMES) was applied between the mastoid processes and nerve stimulation at Erb's point. Evoked potentials were recorded from the biceps brachii. (B) The protocol consisted of TMS, TMES and nerve stimulation at 5 s intervals over a 30 s duration frame. The frame was then repeated 4 times pre-exercise and beginning immediately post-exercise protocol and again 5 min post-exercise (top and bottom panels). The exercise protocol itself consisted of 5, 2 s contractions at 50% MVC with 2 s rest between contractions (bottom panel).

2.2.1. Experimental Session 1

Participants performed two 5 s MVCs of the dominant elbow flexors with the highest possible rate of force production separated by 2 min of rest. If the difference between the two MVCs was more than 5%, a third MVC was performed. The highest MVC force output was defined as maximal. Verbal encouragement was provided during the contraction. The MVC was performed first to allow 50% of MVC to be determined (see Fig. 1A,B for experimental set-up) for the exercise protocol. After ∼10 min of rest, MEP and CMEP responses were matched (see below) and M_{max} was determined. After five more minutes of rest, pre- and post-exercise measurements consisting of four sets of 30 s duration trials, with each 30 s trial consisting of a twice repeated sequence of stimulations in the same order (TMS, TMES and nerve) were taken. Each stimulus was separated by 5 s (Fig. 1B). Thus, pre- and post-exercise testing lasted 120 s and included 8 transcranial, 8 transmastoid and 8 nerve stimulations. This sequence was performed once before, immediately post- and beginning at 5 min post-exercise.

The exercise protocol consisted of 5 submaximal contractions at 50% of elbow flexion MVC. The contractions were intermittent with 2 s 'on' and 2 s 'off' (Fig. 1B, bottom panel). The 50% MVC target force was displayed on a computer screen and participants were