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Neuromuscular fatigue following high versus low-intensity eccentric exercise of biceps brachii muscle

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ABSTRACT

Purpose: This study investigated neuromuscular fatigue following high versus low-intensity eccentric exercise corresponding to the same amount of work.
Methods: Ten volunteers performed two eccentric exercises of the elbow flexors: a high-intensity versus a low-intensity exercise. Maximal voluntary contraction torque and surface electromyography of the biceps brachii muscle were recorded before, immediately and 48 h after exercises. Maximal voluntary activation level, neural (*M*-wave) and contractile (muscular twitch) properties of the biceps brachii muscle were analysed using electrical stimulation techniques.
Results: Maximal voluntary contraction torque was significantly ($P < 0.01$) reduced immediately and 48 h after exercise but the reduction was not different between the two conditions. Electromyography associated with maximal voluntary contraction significantly decreased ($P < 0.05$) immediately and 48 h after exercise for both conditions while maximal voluntary activation level was only significantly reduced immediately after the high-intensity exercise. Peak twitch alterations were observed immediately and 48 h after exercise for both conditions while *M*-wave did not change.
Conclusion: High and low-intensity eccentric exercises with the same amount of work induced the same reduction in maximal strength capacities of the biceps brachii muscles. The magnitude of peripheral and central fatigue was very similar in both conditions.

1. Introduction

A succession of eccentric muscular contractions induces systematically a transient reduction in maximal voluntary contraction (MVC) force commonly named muscular fatigue (Friden et al., 1983; Clarkson et al., 1986). For example, there is evidence for a reduction in elbow flexion MVC following eccentric contractions (Hortobàgyi and Katch, 1990; Michaut et al., 2002). This MVC decrease resulted from changes in central and peripheral mechanisms such as decrease of neural input and alterations of the maximal compound action potential (*M*-wave) and isometric muscular twitch. Warren et al. (1999) suggested that measures of muscle function provide the most effective means of evaluating the magnitude of damage resulting from eccentric muscle actions.

The fatigue level can considerably change according to the characteristics of eccentric exercise, suggesting the concept of "*task dependency*" (Enoka and Stuart, 1992). There is widespread agreement that damage increases with the length of the stretch (Lieber and Friden, 1993). However, Hunter and Faulkner (1997) observed that the isometric force deficit measured at the original length depends mainly on the work volume applied. Moreover, the results showed that muscular damage would increase with the exercise duration. According to Talbot and Morgan (1996) with repeated eccentric contractions, the number of permanently weakened or overstretched sarcomeres gradually increases. Many studies have found a positive correlation between the degree of damage and the number of eccentric contractions (McCully and Faulkner, 1985; Warren et al., 1993a). For a maximal intensity of exercise, the maximum force reduction seems to be more significant when the number of repetition is high (Nosaka and Sakamoto, 2001; Nosaka and Newton, 2002). Previous studies also showed that the magnitude of force reduction was positively correlated with the level of tension development (Hunter and Faulkner, 1997; Gosselin and Burton, 2002). Warren et al. (1993a) reported that muscular damages are initiated by mechanical factors, where muscular tension constitutes the principal element. Nosaka and Newton (2002) have shown that muscular tissue damage was appreciably lower after three sets of ten submaximal contractions (50% of maximal voluntary contraction) than three sets of ten maximal contractions (100% of maximal voluntary contraction).

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A reduced efficiency of excitation–contraction (E–C) coupling process has been demonstrated after eccentric exercise in humans through the use of the muscular tension developed and activation relationship (Jones, 1996). Furthermore, these investigators estimated that at least 75% of the reduction in the maximal force evoked by a tetanic stimulation was due to E–C coupling failure immediately post-exercise, and although the contribution declined with recovery, they estimated that E-C coupling failure accounted for at least 57% of the reduction in titanic force at 5 days post-exercise (Edwards et al. 1977; Jones 1981). Consequently, failure of E–C coupling will impair maximal and submaximal force generation. Paschalis et al. (2005) indicated that matching volumes of maximal intensity (100% of peak torque) and submaximal intensity (50% of peak torque) eccentric exercise have similar effects on muscle damage, but maximal intensity has a more prominent effect on muscle performance. This difference in peak torque reduction could be explained by a more significant central fatigue for the maximal intensity compared to the submaximal intensity. Previous studies have shown that eccentric muscle actions of the biceps brachii induced a decrease in neural input during MVC evidenced by a reduction in maximal myoelectrical activity of this muscle or a decrease in maximal voluntary activation (Gibala et al., 1995; Michaut et al., 2002). To our knowledge, Paschalis et al. (2005) investigation is the only study that examined the difference in muscle damage and muscle performance perturbations in relation to maximal and submaximal intensity eccentric exercise corresponding to the same amount of work. However, this study has not investigated the components of neuromuscular fatigue. Therefore, the purpose of the present study was to examine the effects of high versus low-intensity eccentric exercise on peripheral and central component of muscular fatigue. According to Paschalis et al. (2005) results, we hypothesised that a high-intensity eccentric exercise may induce greater MVC decrease and central fatigue than low-intensity eccentric exercise, corresponding to the same amount of work. To test this hypothesis, neural and contractile properties of the biceps brachii muscles were examined before, immediately after and 48 h after a series of eccentric contractions performed at two different intensities (high versus low).

2. Methods

2.1. Approach to the problem and experimental design

This experiment was conducted to examine the effect of the intensity of eccentric exercise of the biceps brachii muscle on neuromuscular function. To examine central and peripheral components of fatigue, transcutaneous stimulation of the musculocutaneous nerve was performed to evaluate maximal voluntary activation level (VA), muscular twitch and *M*-wave of the biceps brachii muscle.

2.2. Subjects

Ten right handed healthy untrained volunteers (6 males and 4 females) (mean ± SD: age 27.3 ± 3.9 y; weight 68.2 ± 8.3 kg; height 173.2 ± 7.8 cm) took part in this study after they were fully informed of the procedure. Subjects were requested to avoid any vigorous physical activities or unaccustomed exercises during the experimental periods, other than that required for the study. None of the subjects had a history of neuromuscular or vascular disease. The written informed consent was obtained from the subjects, and the study was conducted according to the Declaration of Helsinki and in respect to the agreement of an ethics committee for protecting people.

2.3. Experimental protocol

During an initial session that took place during the month before the experiment, each of the 10 subjects was familiarised with the eccentric and isometric contractions, the neuromuscular tests and the visual feedback monitor. The preliminary session and the eccentric exercise were performed on an isokinetic ergometer (Biodex System 3, Biodex Corporation, Shirley, NY, USA). The dynamometer was calibrated weekly according to the instructions provided by the manufacturer. The position of the seat was adjusted to suit the subjects′ anthropometric characteristics and to align the elbow joint flexion–extension axis with that of the dynamometer lever arm. The arm was positioned in front of the body on a padded support adjusted to 45° of shoulder flexion, the forearm was supinated and the wrist was placed against the level arm. Velcro straps were used to stabilize the subjects.

2.3.1. Randomisation to the sessions

The two sessions were randomly assigned to either high-intensity (HI) or low-intensity (LI), and either left arm or right arm. For all subjects, testing was thus conducted twice, once on the right arm, HI or LI, and once on the left arm, LI or HI (Fig. 1). In order to avoid any experimental bias, randomization was made so that each HI and LI was performed on the same number of right and left arms for each gender.

2.3.2. Preliminary session

The preliminary session was performed immediately before each HI and LI eccentric exercises. During this session, each of the ten subjects was instructed to perform a standardised warm-up composed of ten submaximal elbow flexions. Then, at the angular velocity of 60°/s, they performed three maximal eccentric contractions (ME_{60}) of the biceps brachii muscle on the assigned arm. The eighty and forty-percent of the highest ME_{60} torque were used to determine, respectively the high-intensity (HI) and the low-intensity (LI) of the eccentric exercises.

2.3.3. Eccentric exercise

The HI and LI sessions corresponded to 15 and 30 eccentric actions of the biceps brachii muscle at 80% ME_{60} and 40% ME_{60}, respectively. Thus, the subjects performed an equivalent relative total work. The eccentric exercise was performed at the angular velocity of 60°/s. During all eccentric exercise, a visual feedback was presented to the subjects to allow them to visualise their elbow flexion torque. This visual feedback allowed the subjects to

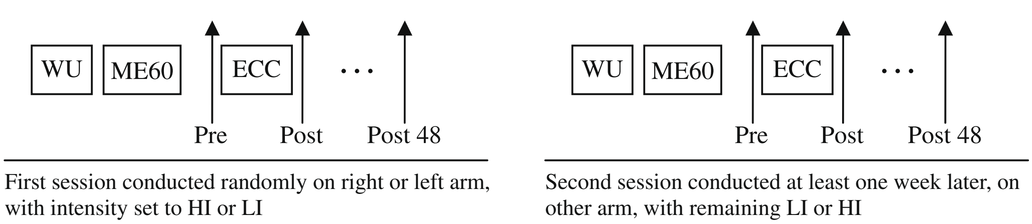

Fig. 1. Graphic representation of the experimental protocol. WU: warm-up, ME60: 3 maximal eccentric contractions at 60°/s, ECC: eccentric exercise with HI (high-intensity eccentric exercise) or LI (low-intensity eccentric exercise). Up arrows indicate neuromuscular tests consisting of 3 evoked twitches and 3 MVCs with superimposed twitch.