Original Article

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Delayed-onset muscle soreness and motor performance of the upper extremity

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Abstract The purpose of this study was to examine the effects of delayed-onset muscle soreness after a strength-training session on the motor performance of the upper extremities, including the reaction time, speed of movement, tapping speed and coordination. In addition, muscle strength, electromyographic (EMG) activity, creatine kinase (CK) and soreness responses were measured. The study was a randomised cross-over intervention study, where 30 subjects (divided into two groups, A and B) performed a 1-h muscle strength-training session of the upper extremities, and the responses were measured 48 h after that. All of the subjects experienced muscle soreness, which was evaluated on a visual analogue scale. The mean value of CK activity was 115 IU·l⁻¹ before training and 1259 IU·l⁻¹ after training (P < 0.001). There were no statistically significant differences in wrist flexion/extension muscle strength or EMG tests in either group. Isometric elbow extension strength decreased by 4% (P < 0.01) in group A, and elbow flexion strength decreased by 6% (P < 0.05) in group B. There were no statistically significant changes in simple reaction time, choice reaction time, or speed of movement or coordination in either group. However, tapping speed decreased by 2% (P < 0.05) in group A and by 6% (P < 0.001) in group B. Based on the results of this study, it seems that the feeling of incompetence to perform fast and accurate movements with sore muscles is mainly a subjective feeling, and it may be that the real effect of muscle soreness on motor performance is quite small, and presumably less than generally assumed.

Key words Muscle strength · EMG · Creatine kinase · Coordination

Introduction

An intensive muscle strength-training session performed by untrained subjects may cause muscle soreness in the strained muscles. This soreness is especially noticeable after exercises consisting of maximal eccentric muscle actions (Nosaka and Clarkson 1996; Hyatt and Clarkson 1998). Generally, the soreness peaks at about 24–48 h after the exercise (Gleeson et al. 1998). This delayed sensation of muscle soreness has been associated with muscle damage, and it causes a decrease in muscle performance, including the range of motion (Vincent and Vincent 1997), muscle strength and electromyographic (EMG) activity (Hortobágyi et al. 1998), and increases serum creatine kinase (CK) activity (Vincent and Vincent 1997) and muscle circumference (Ebbeling and Clarkson 1989). These changes are temporary, and although the values usually return to normal within 10 days (Vincent and Vincent 1997), some may normalise within a few hours (Kroon and Naeije 1991).

A visual analogue scale (VAS; Scott and Huskinson 1976) has frequently been used to determine the level of the perceived muscle soreness (Vincent and Vincent 1997; Gleeson et al. 1998), and an elevated CK level to demonstrate muscle damage after exercise (Nosaka and Clarkson 1996; Lund et al. 1998). After exercise, the amounts of CK released into the circulation (the normal values are < 220 IU·l⁻¹ for women and < 280 IU·l⁻¹ for men) remain at a higher level for 10 days (values peak at 3–5 days after the exercise), and this biochemical marker is an indirect indicator of muscle membrane damage (Vincent and Vincent 1997). However, there is notable interindividual variation in total CK activity after exercise (Nosaka et al. 1991; Nosaka and Clarkson 1996). There are three principal isoenzymes of CK, CK-MM, CK-MB and CK-BB, and about 90% of total CK in the

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skeletal muscles appears in the MM isoform (Yamashita and Yoshioka 1991; Hyatt and Clarkson 1998).

Most of the studies on delayed-onset muscle soreness have addressed the effect of soreness on muscle force, EMG and CK changes (Nosaka and Clarkson 1996; Hortobágyi et al. 1998). The authors of the previous studies have paid very little attention to the effects of muscle soreness on the other components of extremity performance, such as coordination and motor performance. Since an intensive muscle strength-training session causes delayed-onset muscle soreness in the strained muscles a few days after the training session, we hypothesised that soreness, pain, or fear of pain may affect fast movements or lead to the avoidance of painful fast movements by the sore muscles. We therefore designed a study to investigate these possible movement changes in five different motor control tasks. In addition, the study presents muscle soreness following a common exercise procedure, not a fabricated laboratory model, which is expected to make the findings more applicable to real life exercise or rehabilitation sessions than most laboratory studies. This knowledge would be useful when designing and implementing therapy or exercise during a period of muscle soreness.

The purposes of the study were to inflict exercise-induced muscle damage to the muscles of the upper extremities during a 1-h muscle strength-training session and to examine the effects of delayed-onset muscle soreness on the muscle strength, EMG and motor performance of the upper extremities in healthy volunteers, including parameters such as simple reaction time, choice reaction time, speed of movement, tapping speed and coordination.

Methods

Subjects

The participants were 30 healthy students (12 men, 18 women) at the Oulu College of Social and Health Care (23 subjects) and the Oulu University (7 subjects). The subjects were physically quite active during their leisure time, but none was involved in regular exercise or muscle strength-training programmes. The subjects were divided randomly into two groups (A and B). Both groups consisted of 15 subjects (6 men, 9 women), and the characteristics of the groups are shown in Table 1. Handedness was reported by the subjects, and all were right-hand dominant by the criterion of the preferred hand for writing. To be included in the study, the subjects were to have no history of previous injuries of the upper extremities or heart disease, hypertension or neurological diseases. Each subject signed an informed consent document to participate voluntarily in the study.

Test procedure

The aim of the study was to inflict exercise-induced muscle damage to the muscles of the upper extremities during a 1-h muscle strength-training session, and to study the effects of delayed-onset muscle soreness on the motor performance of the upper extremities. We used the VAS and the serum CK response to show and quantify muscle damage and soreness, and muscle strength measurements, EMG records and the Human Performance Measurements/Basic Elements Performance (HPM/BEP) system to assess the effects of muscle soreness on the motor performance of the upper extremities.

The study was a randomised cross-over intervention study, where the 30 participants were divided randomly into 2 groups (group A and Group B; n = 15 for both groups), and all subjects were measured on 5 different occasions. At first, both groups performed isometric muscle strength tests on wrist and elbow flexion/extension (EMG data were recorded during the elbow isometric tests) and motor performance tests (simple reaction time, choice reaction time, speed of movement, tapping speed and coordination) of the right hand on three consecutive days (days 1–3, baseline measurements). The subjects performed the same tests at the same time of the day on each day.

On the 3rd day, the subjects of group A carried out a 1-h muscle strength-training session of the upper extremities after the measurements. On the 5th day (i.e. 48 h after the training session), when the peak soreness of the strained muscles was assumed to be reached, the same measurements were repeated. On the 5th day, group B did the tests as a control group. After that, the schedules of the groups were exchanged, and group B carried out the 1-h muscle strength-training session on the 8th day. On the 10th day (i.e. 48 h after the training session), the same measurements were repeated. Group A then did the tests as a control group. The study protocol and the measurement times are presented in more detail in Fig. 1. The scheme of the study was accepted by the Oulu University Ethics Committee.

Instrumentation

Motor control of the upper extremities

The HPM/BEP system (Basic Elements of Performance, Human Performance Measurement, Arlington, Tex., USA) was used for the collection of data. In this study, the module for hands (BEP 1) was used. The module for hands is a multifunctional system designed to measure different aspects of the upper extremity, including reaction times, movement speed, tapping speed and the coordination of upper extremity motor control. The BEP 1 (Fig. 2) consists of 8 red lights for visual stimuli and 15 touch-sensitive plates divided into 4 regions on top of the module. Different tests are performed on the four regions of the module. Although the reliability of the HPM/BEP tests has been described previously in detail by Kauranen and Vanharaanta (1996), we carried out our own reliability analysis for our sample.

The subjects performed the following tests during each measurement session: (1) Simple reaction time (five trials), (2) two-choice reaction time plus speed of movement (six trials), (3) index-finger tapping (two trials), and (4) coordination test (two trials). The number of trials was set by the Human Performance Measurement software (HPM/BEP, version 4.2).

Table 1 Characteristics of the groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group A (n = 15)</th>
<th>Group B (n = 15)</th>
<th>All (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>24.3 (6.9)</td>
<td>19–47</td>
<td>21.4 (1.9)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.7 (10.5)</td>
<td>156–190</td>
<td>171.1 (9.4)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>66.3 (11.7)</td>
<td>52–85</td>
<td>67.5 (16.3)</td>
</tr>
</tbody>
</table>