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Force recovery after eccentric exercise in males and females

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Abstract In this study we investigated force loss and recovery after eccentric exercise, and further characterized profound losses in muscle function (n = 192 subjects – 98 males, 94 females; population A). Maximal voluntary contractile force (MVC) was assessed before, immediately after, and at 36 and 132 h after eccentric exercise. Two groups were then established (A1 and A2). Group A1 demonstrated a > 70% reduction in MVC immediately after exercise, but were recovering at 132 h after exercise. These subjects performed a follow-up MVC 26 days later (n = 32). Group A2 demonstrated a > 70% reduction in MVC immediately post-exercise, but still exhibited a > 65% reduction in force at 132 h post-exercise; these subjects also performed a follow-up MVC every 7 days until full recovery was established (n = 9). In population A, there was a 57% reduction in MVC immediately post-exercise and a 67% recovery by 132 h post-exercise (P < 0.01), with no significant gender differences (P > 0.05). In group A1, although more females (two-thirds) showed large force losses after exercise, these females demonstrated greater %MVC recovery at 132 h post-exercise (59% vs 44%) and at 26 days post-exercise (93% vs 81%) compared to the males. In group A2, MVC recovery occurred between 33 and 47 days post-exercise. In conclusion, 21% of all subjects showed a delayed recovery in MVC after high-force eccentric exercise. Although there were no significant gender differences in force loss, a disproportionately larger number of females demonstrated force reductions of > 70%. However, their recovery of force was more rapid than that observed for the males who also demonstrated a > 70% force loss.

Key words Maximal isometric force · Strength loss · Muscle damage · Gender differences

Introduction

Several types of eccentric exercise protocols are being used in research to induce and study mild forms of muscle damage in humans. In the past 2 years alone over 130 human studies have been published, attesting to the popularity and relative safety of this form of exercise. These different protocols share the common outcome of inducing mild and repairable forms of muscle damage. Recovery for the various indices of muscle damage (force reduction, muscle soreness, changes in range of motion, swelling) has generally been reported to be resolved between 10 days and 2 weeks after eccentric exercise (Clarkson et al. 1992).

One way that damage to the muscle is manifested after eccentric exercise is in the reduction in a subject’s maximal voluntary contractile force (MVC) immediately post-exercise and in the days following eccentric exercise. Reduction in MVC is most likely due to an initial damaging event such as mechanical disruption to the muscle fiber, as well as a secondary event occurring in the days following eccentric exercise (Faulkner and Brooks 1997; Faulkner et al. 1993). This secondary response, which exacerbates the initial damage to the muscle, may be due to the disruptions in calcium homeostasis or the inflammatory response (Clarkson and Sayers 1999). The typical response to high-force eccentric exercise protocols is a 50–60% reduction in force immediately post-exercise, followed by gradual recovery. By day 10, the muscle has recovered approximately 85% of its baseline MVC, and by 2 weeks the muscle is usually fully recovered (Clarkson et al. 1992). Force reduction is reported to be one of the best indicators that muscle damage has occurred following eccentric exercise (Warren et al. 1999).

A recent case report from our laboratory demonstrated exaggerated reductions in MVC immediately after eccentric exercise, and prolonged reductions in MVC recovery in two male subjects after eccentric exercise (Sayers et al. 1999). In both subjects, recovery of
force was not complete even after 47 days. Although prolonged recovery of force has been reported in the literature (Howell et al. 1993), little research has focused on this adverse response to eccentric exercise.

The purpose of this study was to examine force loss and recovery in a large group of male and female subjects and to characterize individuals who suffer prolonged consequences upon participation in eccentric exercise protocols.

**Methods**

**Study design**

The study involved four visits to our laboratory for the purpose of observing the force response to eccentric exercise. On visit 1, subjects reported to the Exercise Science laboratory, read and signed an informed consent document consistent with the guidelines of the University of Massachusetts Human Subjects Review Committee, and were given a brief physical and medical history questionnaire by a physician. On visit 2, subjects reported to the laboratory in the evening for an eccentric exercise session involving 50 maximal contractions of the elbow flexors of the non-dominant arm. MVC of the elbow flexors was taken prior to and immediately following eccentric exercise. Subjects returned to the laboratory approximately 36 h later (on the morning of visit 3) for a third measure of MVC. On visit 4, subjects returned 4 days after visit 3 (152 h after eccentric exercise) for their final MVC measure.

**Subjects**

One hundred ninety-two subjects (98 males, 94 females) participated in the study (population A). Population A was originally recruited to participate in a large clinical trial to assess the efficacy of an anti-inflammatory drug on muscle pain. However, independent from the muscle soreness aspect of the clinical trial, we assessed force in order to acquire data on force loss and recovery in a large group of subjects. Since the drug treatment was only one over-the-counter dose given after the force assessment on visit 3, we did not expect the treatment to affect the force response to eccentric exercise on the measure taken 4 days later and beyond. Moreover, analysis of the force measures from all groups in population A (drug treated, non-dosed, and placebo) showed that there were no significant effects of the treatment at any time point (132 h or 26 days). The one-dose drug treatment had no effect on recovery of force and, thus, we were very confident that the assessment of force among the groups in this study up to and beyond 26 days was free from any treatment bias. Subjects were assigned to one of two groups, A1 and A2, based on their immediate force response to eccentric exercise and their response at 132 h post-exercise.

Group A1 consisted of subjects who demonstrated large initial reductions in MVC immediately after eccentric exercise (>70% reduction in MVC) coupled with a demonstrated force recovery at 132 h post-exercise. Of the 192 subjects in population A, 32 (17%) exhibited this response. Of these 32 subjects, 20 agreed to return for one follow-up visit after they had completed their final scheduled appointment (visit 4). This follow-up visit occurred approximately 4 weeks after the eccentric exercise (day 26).

Group A2 consisted of subjects who demonstrated a large initial reduction in MVC immediately after eccentric exercise (>70% reduction in MVC), similar to Group A1, but who also showed a prolonged recovery in MVC, such that by 132 h after eccentric exercise (visit 4), there was still a >65% reduction in MVC. Out of the 192 subjects in population A, 9 (5%) demonstrated this response. All nine subjects in group A2 agreed to return to the laboratory every 7 days after visit 4, until they had achieved full recovery of MVC or until they could no longer participate in the study. Table 1 describes the physical characteristics of the subjects in each of the three groups in this study.

**Exercise protocol**

The exercise regimen was designed to induce muscle damage through eccentric contractions using a modified preacher curl apparatus. The regimen consisted of 50 maximal eccentric contractions of the elbow flexors of the non-dominant arm. While the subject applied maximal resistance against a firm pad located at the distal forearm, the investigator pulled down on a lever causing forced elbow extension. Because of the mechanical advantage offered by the lever system, the investigator was able to exceed the maximum resistance exerted by the subject throughout the entire range of motion. The subject was instructed to maximally resist against the action of the investigator, with special emphasis on the end-range of motion, at which subjects typically yield to the external resistance. Each subject performed 2 sets of 25 maximal contractions, the 2 sets separated by a 5-min rest period. Each action lasted approximately 3 s, with 12 s of rest between actions.

**Maximal voluntary contractile force**

Isometric force was assessed at 90° elbow flexion (full extension = 180°) using a strain gauge attached to a preacher curl machine. Subjects were seated on the preacher curl machine, with both feet on the floor and the upper arm supported at 45° of shoulder flexion by the padded bench, with the elbow flexed at 90° during the contraction. Three maximal isometric contractions were performed with 60 s of rest between trials. Each contraction was held for 3 s, and the mean of the three isometric force measurements was used as the criterion measure. The isometric force measurement used in this study has shown excellent reliability (r = 0.97) in previous research from our laboratory (Sayers et al. 2000).

**Statistical analysis**

To assess baseline differences in MVC between males and females in population A, t-tests for independent samples were used. Be-

<table>
<thead>
<tr>
<th>Population</th>
<th>Measurement time</th>
<th>Characteristic</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Initial</td>
<td>192 [98:94]</td>
<td>25 (0.4)</td>
<td>170.3 (0.7)</td>
<td>15210 (21.5)</td>
</tr>
<tr>
<td>A1</td>
<td>Initial</td>
<td>32 [8:24]</td>
<td>24.8 (0.9)</td>
<td>167.8 (1.5)</td>
<td>14249.9 (58.3)</td>
</tr>
<tr>
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<td>Follow-up</td>
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<td>24.9 (1.0)</td>
<td>166.9 (1.9)</td>
<td>14265.6 (60.0)</td>
</tr>
<tr>
<td>A2</td>
<td>Initial</td>
<td>9 [4:5]</td>
<td>24.0 (1.5)</td>
<td>166.6 (3.4)</td>
<td>14053.7 (75.6)</td>
</tr>
<tr>
<td></td>
<td>Follow-up</td>
<td>9 [4:5]</td>
<td>24.0 (1.5)</td>
<td>166.6 (3.4)</td>
<td>14053.7 (75.6)</td>
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