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# Low-intensity elbow flexion eccentric contractions attenuate maximal eccentric exercise-induced muscle damage of the contralateral arm

Trevor C. Chen[a,*], Ming-Ju Lin[b], Jian-Han Lai[a], Hsin-Lian Chen[b], Hui-I Yu[c], Kazunori Nosaka[d]

[a] Department of Physical Education, National Taiwan Normal University, Taiwan
[b] Department of Physical Education, Health and Recreation, National Chiayi University, Taiwan
[c] Endocrinology, Metabolism and Diabetes Division, Chiayi Christian Hospital, Taiwan
[d] Centre for Exercise and Sports Science Research, School of Medical and Health Sciences, Edith Cowan University, Australia

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ABSTRACT

*Objectives:* The magnitude of muscle damage induced by maximal eccentric contractions (MaxEC) of the elbow flexors (EF) is reduced when it is preceded by low-intensity (10% of maximal voluntary isometric contraction strength) eccentric contractions (10%EC) of the same muscle, or by MaxEC of the opposite EF. This study investigated whether 10%EC would reduce the magnitude of muscle damage after MaxEC performed by the opposite arm.
*Design:* Comparison among 6 groups for changes in indirect markers of muscle damage.
*Method:* Young (21.0 ± 1.8 years) untrained men were assigned to five experimental groups (n = 13/group) that performed 30, 10%EC followed by 30 MaxEC of the other arm performed at either 1 (1d), 2 (2d), 7 (1wk), 14 (2wk) or 21 days (3wk) later, and one control group that performed 30 MaxEC without 10%EC (n = 13). Changes in several indirect markers of muscle damage after MaxEC were compared among the groups by mixed-design two-way ANOVAs.
*Results:* No significant changes in maximal voluntary concentric contraction torque, plasma creatine kinase activity and muscle soreness were evident after 10%EC. Changes in these variables after MaxEC were smaller ($p < 0.05$) for the 1d, 2d and 1wk groups than control group, without significant differences between the 1d, 2d and 1wk groups. No significance differences in the changes were evident among the 2wk, 3wk and control groups, except for muscle soreness showing smaller ($p < 0.05$) increases for the 2wk and 3wk groups than control group.
*Conclusions:* These results showed that 10%EC conferred muscle damage protection to the contralateral arm that performed MaxEC.


## 1. Introduction

Unaccustomed eccentric exercise results in muscle damage represented by prolonged decreases in muscle function and delayed onset muscle soreness (DOMS), but produces a protective effect against muscle damage to the same muscle in subsequent bouts of the same or a similar eccentric exercise.[1–3] This protective effect is referred to as repeated bout effect (RBE), which is typically characterised by smaller decreases in and faster recovery of muscle function and less development of DOMS, and smaller increases in plasma creatine kinase (CK) activity following the second than the first eccentric exercise bout.[4–6]

It has been shown that performing low-intensity eccentric contractions that do not induce muscle damage attenuates the magnitude of muscle damage induced by “maximal” eccentric contractions (MaxEC).[7–9] For example, Chen et al.[7] reported that 30 low-intensity eccentric contractions with a light dumbbell set at 10% of maximal voluntary isometric contraction strength (10%EC) provided approximately 40% protection (e.g., 39% smaller peak DOMS) against a subsequent bout of MaxEC performed 2 weeks later for the elbow flexors (EF).

Several studies have shown that the magnitude of muscle damage induced by MaxEC is reduced when the second MaxEC is

* Corresponding author.
*E-mail addresses:* tcchen@ntnu.edu.tw (T.C. Chen), mjlin@mail.ncyu.edu.tw (M.-J. Lin), cityqaz0922@gmail.com (J.-H. Lai), csl357087@yahoo.com.tw (H.-L. Chen), cych04490@gmail.com (H.-I. Yu), k.nosaka@ecu.edu.au (K. Nosaka).

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performed by the homologous muscle of the contralateral limb, which is referred to as the contralateral RBE (CL-RBE).[2,10,11] For instance, Chen et al.[10] have recently reported that CL-RBE is evident when the right and left EF MaxEC bouts were separated by 1 day (changes in muscle damage markers were attenuated by 51% in average), 1 week (48%) or 4 weeks (26%), but not within 12 h or at 8 weeks.

If the protective effect is transferred from one arm to the other, it is possible that 10%EC performed by one arm could provide a protective effect against muscle damage induced by MaxEC of the contralateral arm. If this occurs, it is also interesting to examine whether such an effect lasts for 2–3 weeks as shown in the ipsilateral condition.[7] Therefore, the present study investigated whether 10%EC would confer protective effect against MaxEC of the opposite EF that were performed either 1, 2, 7, 14 or 21 days later. It was hypothesised that 10%EC would reduce the magnitude of muscle damage after MaxEC performed by the opposite arm within 7 days, but not 14 or 21 days.

## 2. Methods

Sedentary young men (n = 78) who had no musculoskeletal injuries of the upper extremities were recruited for this study from university students. They provided informed consent to participate in this study that had been approved by the Institutional Review Board. The study was conducted in conformity with the Declaration of Helsinki. Their mean (±SD) age, height, body mass, and maximal voluntary concentric contraction torque (MVC-CON) of the EF were 21.0 ± 1.8 year, 171.6 ± 5.6 cm, 65.5 ± 7.2 kg, and 32.3 ± 3.0 Nm, respectively.

The participants were placed into one of the six groups (n = 13/group) by matching the baseline peak MVC-CON among the groups; one control group (CON) and five experimental groups. The experimental groups performed a bout of low-intensity eccentric contractions of the EF (10%EC) with one arm either 1 day (1d), 2 days (2d), 7 days (1wk), 14 days (2wk) or 21 days (3wk) prior to a bout of MaxEC of the EF of the opposite arm. The choice of the dominant and non-dominant arm was counter-balanced among participants. The participants in the CON group performed MaxEC by their non-dominant arm without 10%EC. No significant differences in age, height, body mass, and baseline MVC-CON were observed among the groups.

The sample size was estimated using the data from our previous study[7] in which the protective effect of 10%EC on MaxEC was investigated for the same arm. Based on the possible effect size of 1 for the difference in some variables between the CON and experimental groups, alpha level of 0.05, and a power $(1-\beta)$ of 0.80,[13] it was estimated that at least 12 participants were necessary per group.

A familiarisation session was set 3 days prior to the first eccentric exercise bout, in which the participants experienced the measurements of muscle soreness (SOR), and MVC-CON. The investigator demonstrated the MaxEC and 10%EC, but no eccentric contractions of the EF were performed by the participants, since a few MaxEC could confer some protective effect.[14]

To determine the dumbbell weight for the 10%EC, maximal voluntary isometric contraction (MVIC) of the EF at the elbow joint of 90° was measured by a loadcell (model DFG51, Omega Engineering, Stamford, CT) that was attached to a cuff surrounding the wrist of the exercise arm, while each participant was seated on a custom-made preacher curl bench, placing his elbow joint angle at 90° and shoulder joint angle at 45° flexion and 0° abduction.[7] The participant was asked to flex the elbow joint maximally for 3-s, and this was repeated three times with a 45-s rest between attempts. The peak value during the 3-s contraction was recorded, and the highest value of the three peak values was used to determine the dumbbell weight. The 10%EC consisted of 5 sets of 6 eccentric contractions, in which the participants were instructed to lower a dumbbell from an elbow flexed (90°) to an elbow in a fully extended position (0°) in 3-s, and the investigator removed the dumbbell at the extended position, and the arm was returned to the start position without load.[7] The interval was 10-s between contractions, and 2-min between sets.

All participants performed a bout of MaxEC on an isokinetic dynamometer (Biodex System 3 Pro; Biodex Medical Systems, Shirley, NY, USA). The MaxEC consisted of 5 sets of 6 MaxECs of the EF at the angular velocity of $30^\circ\,s^{-1}$, and the elbow joint of the exercise arm was forcibly extended from 90° to a fully extended position by the dynamometer, while each participant was asked to maximally resist against the elbow extending motion.[7] Each contraction lasted for 3-s was repeated every 10-s, and a 2-min rest was given between sets. After each contraction, the isokinetic dynamometer passively brought the participant's arm back to the elbow flexed position at the angular velocity of $9^\circ\,s^{-1}$, which provided a 10-s rest between contractions. The peak torque and work of each contraction were calculated using a software of the Biodex Medical Systems, and their average values of each set were used for further analysis.

The dependent variables consisted of MVC-CON, plasma CK activity and SOR. MVC-CON and SOR measures were taken from the exercised arm, and blood samples were taken from the non-exercised arm. MVC-CON measures were taken 2 days and immediately before, immediately after, and 1–5 days following MaxEC for all groups. Plasma CK activity and SOR were measured at all time points shown above except immediately post-exercise. The 1d and 2d groups had the MVC-CON, CK and SOR measurements up to 1 and 2 days after 10%EC, respectively, but other experimental groups had the measures immediately before, immediately after (MVC-CON only), and 1–5 days after 10%EC. The test–retest reliability based on intraclass correlation coefficient (R) and coefficient of variation (CV) were 0.95 and 8.0% for MVC-CON torque, 1.00 and 0.0% for SOR, and 0.87 and 7.8% for plasma CK activity.

MVC-CON was measured at the angular velocity of $60^\circ\,s^{-1}$ for the range of motion of 140° for the EF (0°–140°) and elbow extensors (EE; 140°–0°) for three continuous contractions in both directions by the isokinetic dynamometer.[7] Verbal encouragement was provided during the tests. The highest value of the three trials for the EF and EE MVC-CON torque were used for further analysis.[7,15]

Approximately 5-mL of venous blood was withdrawn by a standard venipuncture technique from the cubital fossa region of the dominant arm and centrifuged for 10-min to extract plasma, and plasma samples were stored at −80 °C until analyses. Plasma CK activity was assayed spectrophotometrically by an automated clinical chemistry analyser (Model 7080, Hitachi, Co. Ltd., Tokyo, Japan) using a commercially available test kit. Each sample was analysed in duplicate, and the average value of two measures was used for further analysis.

SOR of the EF was quantified using a visual analog scale (VAS) that had a 100-mm continuous line with "not sore at all" on one side (0-mm) and "very, very sore" on the other side (100-mm). The investigator asked the participant to rate his perceived SOR on the VAS when the muscles were passively extended for the ROM that used for the MVC-CON measures.[7,16]

Data were assessed by a Shapiro–Wilk test for the normality and a Levene test for the homogeneity of variance assumption. All dependent variables before each exercise bout were compared among the groups by a one-way analysis of variance (ANOVA). Changes in the dependent variables were compared among the groups following 10%EC (five experimental groups) or MaxEC (all groups) by a mixed-design of two-way ANOVA. Changes in peak