LOCOMOTOR APPARATUS IN EXERCISE AND SPORTS

Effect of the Number and the Intensity of Eccentric Muscle Actions on Muscle Damage Markers

Original Article

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ABSTRACT

A single bout of resistance training, especially those comprising the performance of eccentric actions, induces damage to the muscle structure. Some characteristics of the eccentric exercise bout (i.e. the number and the intensity of contractions) may increase muscle damage. Thus, the aim of this study was to investigate if the number and the intensity of the eccentric muscle actions significantly increase muscle damage (as evaluated through alterations in indirect markers of muscle damage). Twenty-four young male adults were randomly placed into three groups. One of the groups performed 30 eccentric actions of the elbow flexors at 70% of 1RM (ECC30-70, n = 8). Another group performed the same number of repetitions, but at 110% of 1RM (ECC30-110, n = 8). A third group performed a higher number of repetitions (60) at 70% of 1RM (ECC60-70, n = 8). Range of motion, limb girth, maximal dynamic strength (1RM) and muscle soreness were assessed before, immediately after, 48h and 96h post exercise. Results were analyzed by a 2-way ANOVA and showed that alterations were significantly greater in ECC30-110 when compared with ECC30-70 and ECC60-70. These data suggest that the intensity of the eccentric actions significantly affects the magnitude of muscle damage in a more pronounced way than the number of contractions.

Keywords: muscle strength, range of motion, resistance training.

INTRODUCTION

The performance of a single bout of resistance training, especially those comprising eccentric muscle actions, causes damage to the structure of the skeletal muscle. This damage causes an inflammatory response which induces delayed onset of muscle soreness, edema, increased blood creatine kinase concentration (CK), decreased range of motion and muscle strength[(1)] and altered muscle`s force-length relationship[(2)], which causes maximal strength to be attained at a longer muscle length. These alterations may persist for up to 14 days[(3)].

The mechanical overload imposed to the muscle is a well-accepted mechanism for explaining the exercise-induced muscle damage. In this regard, it is proposed that during eccentric actions, the sarcomeres are stretched while generating tension. Some of the active sarcomeres are weaker than others and hence, they are stretched to a greater extent. This event causes a decrease in the overlap of actin and myosin filaments, and, often, these myofilaments may not overlap again[(4,5)]. Repeting eccentric actions causes the tension, which should be supported by the myofilaments, to be imposed on the elastic elements of these sarcomeres, causing their disruption[(14)] and increasing the extent of the muscle damage.

The magnitude of muscle damage seems to be associated to the degree of muscle tension developed[(6)], which suggests that the intensity of the eccentric action plays an important role in this process[(7)]. Besides intensity, the number of repetitions performed seems to influence on the magnitude of the muscle damage[(8-11)]. However, distinct results have been found from the combination of these factors.

Thus, the aim of this study was to compare the effect of different numbers of repetitions and intensity on the indirect markers of muscle damage (delayed onset muscle soreness, range of motion, arm circumference and muscle strength performance) in the elbow flexor muscles.

MATERIALS AND METHODS

Sample

Twenty-four male physically active subjects (20.1 ± 2.4 years, 73.2 ± 9.4kg, 175.4 ± 5.1cm), with no history of articular injuries on the wrists, elbows and shoulders, who had not been engaged in strength training for six months prior to the study, took part in this study. All of the subjects were informed about the aims, risks and benefits associated with the study and signed an informed consent form before the participation. The subjects were randomly divided into three groups. One group performed 30 eccentric actions at 70% of 1RM (ECC30-70, n = 8); a second group performed the same number of repetitions, but at 110% of 1RM (ECC30-110, n = 8); and the third group performed 60 repetitions at 70% of 1RM (ECC60-70, n = 8).

Experimental procedures

The individuals reported to the laboratory for a total of two sessions, 14 days apart from one another. In one of the experimental sessions, subjects performed a unilateral maximal dynamic strength test (1RM test) of the elbow flexors using the non-dominant arm. After the 1RM test, the subjects performed familiarization with the damage protocol with the contralateral arm. This familiarization consisted of three sets of five repetitions at 70% of 1RM obtained on the ipsilateral arm with an interval of two minutes between sets.

On the second experimental session, the participants performed the muscle damage-inducing protocol. After the warm-up period, subjects performed one of the following protocols (ECC30-70, ECC30-110 or ECC60-70). With exception of muscle strength (baseline values were assessed during the first experimental session), all of the indirect markers of muscle damage were measured before, immediately after, 48 and 96 hours after the muscle damage-inducing protocols.

Protocols of muscle damage

Prior to the completion of the protocols, the subjects performed a specific warm-up to the elbow flexors. The warm-up consisted of two bouts of 10 repetitions at 40-50% of 1RM. The interval between bouts was set at 90 seconds. Three minutes after the warm-up, participants performed the muscle damage-inducing protocol. Range of motion was set at 120º for all of the protocols, starting with the elbow flexed at approximately 60º and ending with elbow at a complete extension (180º). At the end of each eccentric contraction, the researcher returned the weight to the initial position. The eccentric actions should be performed in three seconds, and a metronome was used to control the rhythm. A two-minute interval was respected between each set for all of the protocols.

Protocol of muscle damage ECC30-70

The subjects were asked to perform five sets of six eccentric actions at 70% of 1RM.

Protocol of muscle damage ECC60-70

The subjects were asked to perform 10 sets of six eccentric actions at 70% of 1RM.

Protocol of muscle damage ECC30-110

The subjects were asked to perform five sets of six eccentric actions at 110% of 1RM.

MEASUREMENTS

Maximal dynamic strength (1RM) of the elbow flexors

The 1RM test consisted of the assessment of the maximal amount of load which could be lifted in a complete repetition of the elbow flexion exercise. The test was performed one week before the muscle damage-inducing protocol and was preceded by a specific warm-up of one set of eight repetitions with approximately 50% of the estimated 1RM and one set of three repetitions with 70% of estimated 1RM. The interval between warm-up sets was set at 90 seconds. After the warm-up, subjects rested for three minutes, and then they had up to five attempts to achieve their maximal load. In case the number of repetitions was insufficient, the test was repeated in another occasion, at least five days apart. A three-minute interval was given between each attempt and the subjects were not informed about the amount of load they were lifting. The test was performed on a *Scott* bench. This test was performed 14 days before, immediately after, 48 and 96 hours after the end of the protocols.

Range of motion (ROM)

The range of motion of the elbow joint was assessed with a goniometer, at the beginning, immediately after, 48 and 96 hours after the completion of the experimental session. Range of motion was assessed by measuring both the maximum flexion and the relaxed elbow angles with a clear plastic goniometer. Reference points (midpoint between ulnar and radial styloid processes, lateral epicondyle of the humerus and deltoid insertion) were determined by palpating the tested arm[12]. They were marked with permanent ink to ensure consistency on subsequent testing days. The relaxed angle was measured by asking the subject to stand with his arm relaxed and with the goniometer placed over the reference points. Maximum flexion angle followed the same procedure but the subject was asked to touch his ipsilateral shoulder with the palm of his hand. ROM was calculated by subtracting flexion angle from relaxed angle.

Arm circumference

The arm circumference served as an indirect marker of muscular edema[13]. This measurement was performed in four distinct points: 1 (CIR1), 5 (CIR5) and 7cm (CIR7) above and 1cm (CIR-1) below the lateral epicondyle at the beginning, immediately after, 48 and 96 hours after the performance of the experimental session. The measurement points were marked with permanent ink for consistency, and were reproduced during the entire study. The measurements were performed using a measuring tape and with the arm at neutral and relaxed position along the body.

Delayed onset of muscle soreness (DOMS)

The subjects were asked to indicate their subjective perception of DOMS at the beginning, immediately after, 48 and 96 hours after the experimental session performance. A visual analogue scale (VAS) that consisted of a 10cm line with "no soreness" at one end and "extremely painful" at the other was used to determine muscle soreness. The subjects indicated by marking on the line the point which represented the pain that they were feeling on the exercised muscles. The distance in centimeters from the zero extremity to the mark made by the subject was considered as the pain measurement.

STATISTICAL ANALYSIS

The data were analyzed according to descriptive analysis. Analysis of variance (two-way ANOVA) for repeated measurements (group and time) was used for data analysis. Whenever a significant F value was found, a Tukey *post hoc* was used for multiple comparison purposes. The significance level was set at p 0.05.

RESULTS

There were no significant differences between groups in the 1RM test performance before the muscle damage-inducing protocols. The 1RM values decreased significantly immediately after the exercise only in the ECC30-110. Forty-eight hours after the protocol, strength returned to pre-intervention values. Further, there was a group main effect. Alterations in muscle damage markers were greater in ECC30-110 compared to the other two groups, but there was no difference between ECC30-70 and ECC60-70 (figure 1).

DOMS significantly increased in the ECC30-110 and ECC60-70 groups immediately after and 48h after the exercise. Additionally, a group main effect was found. Ninety-six hours after the exercise, DOMS returned to the initial values both in the ECC60-70 and the ECC30-110 groups (figure 2).

Range of motion significantly decreased in ECC30-110 immediately and 48h after the exercise. Once again there was a group main effect, demonstrating that alterations in ECC30-110 were greater than in the other two groups (figure 3).

The arm circumference in the four sites did not significantly change in any of the groups at any time point evaluated (figure 4).

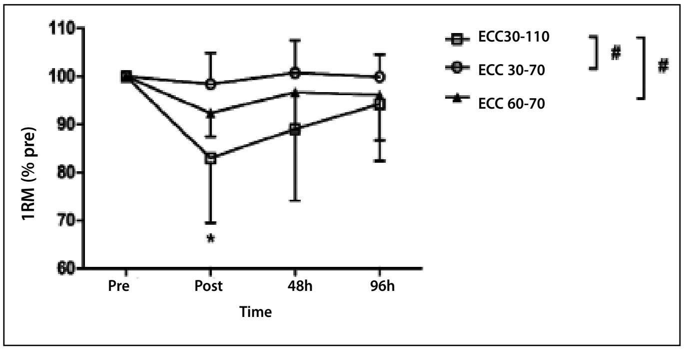

Figure 1. Percentage variations of 1RM immediately (Post), 48h and 96h post concerning the pre-intervention values.
* – $p < 0.05$ concerning the pre only in the ECC30-110 group.
# – $p < 0.05$ main group effect.

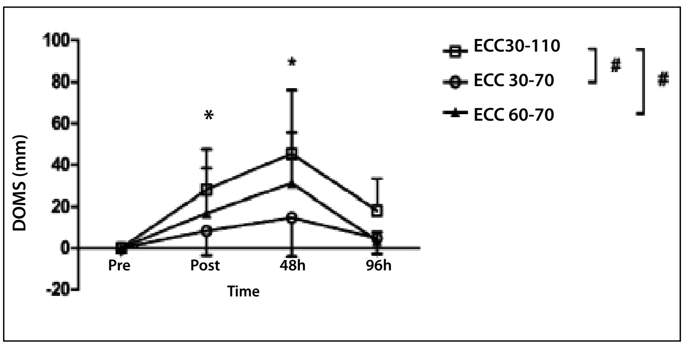

Figure 2. Delayed onset muscle soreness (DOMS) pre, immediately (post), 48h and 96h post- intervention.
* – $p < 0.05$ concerning the pre only in ECC30-110 and ECC60-70 groups.
# – $p < 0.05$ main group effect.

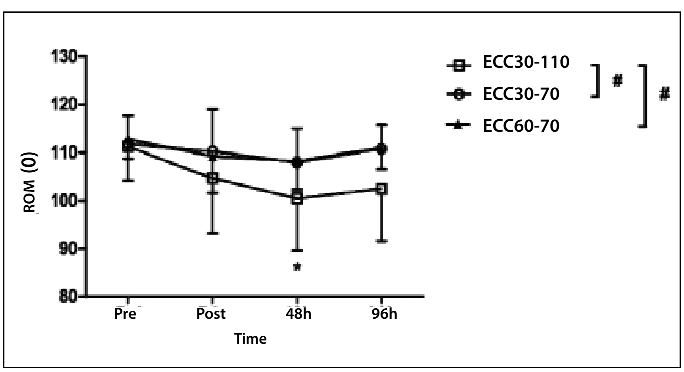

Figure 3. Range of motion (ROM) pre, immediately (post), 48h and 96h post-intervention.
* – $p < 0.05$ concerning pre only in ECC30-110 group.
# – $p < 0.05$ main group effect..

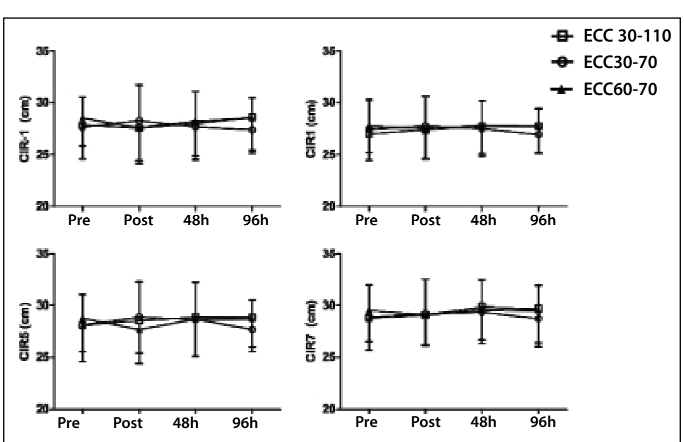

Figure 4. Arm circumference (CIR) pre, immediately (post), 48h and 96h post-intervention in the four evaluated sites.

DISCUSSION

The aim of this study was to investigate the effect of the number and the intensity of the eccentric actions on indirect markers of muscular damage. Three protocols for muscular damage induction (ECC30-70, ECC30-110 and ECC60-70) were compared. The results demonstrated that increase in intensity promotes greater changes in the muscle damage markers when exercise volume (i.e. number of repetitions) was equated (ECC30-110 x ECC30-70). The protocol with higher number of repetitions (ECC60-70) and submaximal intensity did not cause significant alterations in the same parameters. These results suggest that the increase in muscle tension (e.g. intensity) greatly affects muscle damage markers than the increase in exercise volume (e.g. number of repetitions).

Morgan[14] suggested that, during the eccentric actions, the weaker sarcomeres in a muscle fiber are more stretched than others, thus decreasing the myofilaments overlapping. In some of these 'overstretched' sarcomeres, the myofilaments are not able to overlap again and disrupt during the subsequent repetitions. It is possible that the higher number of eccentric actions provides more opportunities for this rupture. Further, the initial disrpution of some sarcomeres increases the tension in the surrounding sarcomeres, causing the rupture of more sarcomeres as the number of repetitions increase[4], which would enlarge the damaged area. In accordance, following the previous suggestion by Morgan[14], Chen and Nosaka[15] observed that increasing the number of eccentric actions induced greater changes in muscle damage markers. Nevertheless, in the present study, the increase of the number of repetitions did not affect muscle damage. It is possible that these differences are due to the nature of the eccentric actions, maximal in the study by Chen and Nosaka[15]and submaximal in our investigation, which means that the higher number of submaximal contractions does not induce greater extent of muscle damage, reinforcing the role of the exercise intensity in modulating exercise-induced muscle damage.

On the other hand, Friden and Lieber[6] suggested that increasing intensity of the eccentric contractions imposes higher passive tension on the elastic elements. This increase of passive tension in association with the sarcomere strength difference may partly explain the increase in muscle damage. Nosaka and Newton[10] compared two groups of subjects who performed maximal and submaximal eccentric actions (50% of maximal isometric contraction). They observed greater changes in the muscle damage markers in the group that performed the maximal actions. These changes were observed after 24h post- exercise, since the alterations which occurred immediately after exercise were similar between the two groups. The authors suggested that the initial damage mechanism was similar between groups. However, the group which performed maximal contractions would have been submitted to greater secondary damage. Our findings are partially different from the ones by Nosaka and Newton[10], since alterations immediately after exercise were different between ECC30-70 and ECC30-110 groups, but were not different after 48h for most of the markers, indicating that recovery was similar in both groups. It is possible that in the present study, the initial damage had been different between groups, but the secondary damage was not.

In a very interesting study, Paschalis *et al.*[16] compared the effects of different intensities (100% and 50% of 1RM) of eccentric actions on muscle damage. However, the authors equated the work performed between the two intensities, which resulted in a higher number of contractions for the submaximal condition (i.e. 120 at maximal condition, and mean of 202 at submaximal condition). Thus, although the present study lacks the control of the work performed, the study desing is actually very similar to the one by Pachalis et al [16], as we compared different numbers of contractions (30 x 60) at different intensities (70% x 110% of 1RM). Nevertheless, the results of the present study slightly differ from the ones found by Paschalis *et al.*[16]. These authors reported faster strength recovery after submaximal condition, while we did not observe any difference in the decrease of muscular strength between ECC60-70 and ECC30-110 groups. It is conceivable that the difference between the experimental protocols had interfered in the different responses observed.

Indeed, it was expected larger between-group differences in the change of the muscle damage markers, as the higher number of contractions would, in theory, provide more opportunities for damage onset[4] as well as higher intensity would greatly overload the elastic elements[6]. However, it is possible that the maximal dynamic strength test (1RM test) had previously caused a small magnitude of muscle damage and, therefore, induced some protective adaptations in the muscular structure, a phenomenon known as Repeated Bout Effect[17,18]. These adaptations are initiated even by a small number of eccentric actions [19,20] and my last up to six months[21]. Thus, it is possible that this effect has protected the muscular structure against greater muscle damage in the experimental bouts, eventually decreasing the difference between groups.

Despite the possibility of this effect existence, it is also conceivable that the intensity is actually more important than the number of eccentric contractions to the onset of muscle damage, since the protective adaptations would affect the three groups in the same way.

All authors have declared there is not any potential conflict of interests concerning this article.

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