Effect of Lengthening Contraction Velocity on Muscle Damage of the Elbow Flexors

DALE WILSON CHAPMAN1,2, MICHAEL NEWTON1, MICHAEL MCGUIGAN1, and KAZUNORI NOSAKA1

1School of Exercise, Biomedical and Health Sciences, Edith Cowan University, Joondalup, AUSTRALIA; and 2Physiology Department, Australian Institute of Sport, Canberra, AUSTRALIA

ABSTRACT

CHAPMAN, D. W., M. NEWTON, M. MCGUIGAN, and K. NOSAKA. Effect of Lengthening Contraction Velocity on Muscle Damage of the Elbow Flexors. Med. Sci. Sports Exerc., Vol. 40, No. 5, pp. 926–933, 2008. Purpose: This study investigated the effect of lengthening contraction velocity on exercise-induced muscle damage. Methods: Sixteen men were placed into two groups performing either 30 (N = 8) or 210 (N = 8) maximal lengthening contractions of the elbow flexors on an isokinetic dynamometer. Dominant and nondominant arms were randomly assigned for a slow-velocity (S: 30°·s−1) or a fast-velocity (F: 210°·s−1) exercise separated by 14 d. Maximal voluntary strength of isometric contractions (iMVC) and isokinetic concentric contractions (cMVC), range of motion (ROM), upper-arm circumference, muscle soreness, and serum creatine kinase (CK) activity were measured before, immediately after, and 1–120 h after exercise. Changes in these measures over time were compared by a two-way repeated-measures ANOVA to examine the effect of velocity in the same number of contractions (S30 vs F30; S210 vs F210) or the effect of contraction number at the same velocity (S30 vs S210; F30 vs F210). Results: A significant (P < 0.05) interaction effect was evident only for iMVC between S30 and F30, but it was evident for iMVC, cMVC, ROM, and CK between S210 and F210. Changes in most of the measures were significantly (P < 0.05) smaller after 30 contractions (S30 and F30) than after 210 contractions (S210 and F210). Conclusion: These results suggest that the effect of contraction velocity on the magnitude of muscle damage after 30 contractions is minor; however, when 210 lengthening contractions were performed, the effect of contraction velocity became conspicuous. It is concluded that fast-velocity lengthening contractions are likely to induce greater muscle damage than slow-velocity contractions; however, muscle fatigue seems to be a confounding factor for the velocity effect. Key Words: ECCENTRIC EXERCISE, MUSCLE STRENGTH, RANGE OF MOTION, DELAYED ONSET MUSCLE SORENESS, CREATINE KINASE

Eccentric exercise consisting of repeated lengthening contractions results in disruption of muscle ultrastructure and decreases in muscle function (24). It has been shown that the magnitude of change in muscle structure and function after eccentric exercise is affected by range of movement or muscle length (13,30), torque produced (12,28,36), number of contractions performed (10,17), and contraction velocity (8,31,33). Among these factors influencing muscle damage, this study focused on contraction velocity, because controversy exists concerning the effect of lengthening contraction velocity on muscle damage.

Several animal studies have investigated the effect of contraction velocity on muscle histopathology and loss of muscle function using single (5,19) or repeated stretches (22,36,38–40) of stimulated muscles. Some of these studies have demonstrated an effect of velocity on magnitude of muscle damage (5,22,36,38), but others have found no significant effect (19,39,40). Some human studies (8,31,33) have been conducted to examine the effect of lengthening contraction velocity on markers of muscle damage, and these studies have reported conflicting findings. For example, Paddon-Jones et al. (31) show that recovery of isokinetic muscle strength was quicker after fast-velocity (180°·s−1) lengthening contractions of the elbow flexors than slow-velocity (30°·s−1) contractions, and increases in upper-arm girth after exercise were significantly smaller for the fast exercise than for the slow exercise. However, no significant differences between conditions were found for isometric muscle strength and serum creatine kinase (CK) activity, whereas significantly greater muscle tenderness was observed after the fast exercise compared with the slow exercise. In contrast, Shepstone et al. (33) report that fast-velocity (210°·s−1) lengthening contractions (N = 30) resulted in greater ultrastructural disruptions in elbow flexors compared with slow-velocity (20°·s−1) contractions, but this study did not investigate any other indicator of muscle damage.

Our recent study (8) has demonstrated that a fast-velocity (210°·s−1) lengthening contraction exercise of the elbow flexors resulted in significantly greater decrements and slower recovery of both isometric and isokinetic muscle
strength, a 450% greater peak in serum CK activity, larger increases in upper-arm circumference, and delayed-onset muscle soreness compared with a slow-velocity (30°·s⁻¹) lengthening contraction exercise. In this investigation, the time that the muscle was under lengthening contractions (120 s) was matched between the exercises, resulting in a large difference in the number of lengthening contractions performed between the slow- (30 contractions) and fast-velocity (210 contractions) exercises. It is possible that the greater number of muscle contractions performed in the fast-velocity exercise was the reason for the greater changes in the measures compared with the slow-velocity exercise.

To confirm the results of our previous study, it is necessary to compare the fast- and slow-velocity eccentric exercises by matching the number of lengthening contractions.

Therefore, the present study was designed to test the hypothesis that the magnitude of exercise-induced muscle damage would still be greater for the fast- than slow-velocity eccentric exercise when the same number of lengthening contractions were performed in both conditions. The number of contractions was set to 30 for one group and 210 for another group of subjects, and the subjects in both groups performed the slow-velocity exercise (30°·s⁻¹) with one arm and the fast-velocity exercise (210°·s⁻¹) with the other arm.

METHODS

Subjects and Study Design

Sixteen men with no upper-limb resistance training experience in the prior 6 months volunteered for this study. Their mean (± SD) age, body weight, and height were 26.3 ± 5.1 yr, 77.5 ± 10.0 kg, and 1.80 ± 0.07 m, respectively. All subjects were right-hand dominant and performed a slow-velocity (S: 30°·s⁻¹) eccentric exercise with one arm and fast-velocity (F: 210°·s⁻¹) eccentric exercise with the other arm, separated by 14 d. The order of the exercise and the arm used first were counterbalanced among subjects. Approval for this investigation was granted from the institutional human ethics committee. The study conformed to the Declaration of Helsinki for medical research involving human subjects, and the subjects provided written informed consent before participating. Subjects were informed not to take any nutritional supplements or anti-inflammatory drugs, not to change their regular dietary intake, and not to engage in strenuous physical activity during the experimental period.

Subjects were randomly assigned to either a group that performed 30 lengthening contractions (N = 8) or to one that performed 210 lengthening contractions (N = 8). No significant (P = 0.08–0.71) differences between the groups were evident for age, height, body mass, or preexercise muscle strength of the elbow flexors. The number of subjects was determined using the difference in the changes in maximal voluntary isometric strength between the fast- and slow-velocity exercises in our previous study (8), with an alpha level of 0.05 and a power (1 − β) of 0.80.

Exercise Protocol

Subjects were positioned on an isokinetic dynamometer (Cybex 6000, Ronkonkoma, NY), with their arm supported at 45° of shoulder flexion, using an arm curl bench. The range of motion (ROM) was from 60° of elbow flexion to 180° (full extension). The exercise consisted of five sets of six repetitions for the 30 contractions, and 35 sets of six repetitions for the 210 contractions, with a 90-s rest period between sets, as in the previous study (8). The rest between contractions was 12 s, during which the elbow joint was moved passively from the extended position to the start position at 10°·s⁻¹. Subjects were encouraged by the investigator throughout the exercise to apply maximal resistance against the lever arm of the isokinetic dynamometer that forcibly extended the elbow joint, and visual feedback of the torque generated during each contraction was given.

Torque and work data of each contraction were displayed on a screen and recorded by an IBM desktop computer operating AMLAB (version II, Lewisham, Australia) data acquisition software. The torque and lever arm position data of the dynamometer were sampled at 200 Hz via a 16-bit data-acquisition card of the AMLAB system (Minirack, AMLAB II, Lewisham, Australia) and were analyzed using AMLAB software (AMLAB II, Lewisham, Australia).

Muscle strength. Isometric maximal voluntary contraction (iMVC) was performed at joint angles of 70° (iMVC-70), 90° (iMVC-90), 110° (iMVC-110), 130° (iMVC-130), and 150° (iMVC-150) on the isokinetic dynamometer in the same position as that used in the exercise protocol. For each angle, subjects were verbally encouraged to perform two maximal contractions, holding each contraction for 4 s, and allowed 30 s of rest between each effort and 60 s between different joint angles from 150° to 70°. Using the average peak torque produced from the two efforts at each angle, a polynomial fourth-order curve was fitted via custom Labview software program (Software version 8.2; National Instruments, Sydney, Australia), and an optimum angle for maximal peak torque (aMPT) production was determined.

An isokinetic concentric maximal voluntary contraction (cMVC) was performed at angular velocities of 30°·s⁻¹ (cMVC-30), 150°·s⁻¹ (cMVC-150), and 210°·s⁻¹ (cMVC-210). Subjects performed two contractions at each velocity, and the order of contractions was slow to fast, with a 60-s rest between velocities. The ROM for the cMVC measures was from the full-extension position (considered 180°) to 60° of elbow flexion. The peak torque of the two contractions at each velocity was averaged and used for further analysis.

ROM. Measurements of the elbow joint angle were taken when the subjects attempted to fully extend their elbow.
joint for an extended angle and when they fully flexed their elbow joint in an attempt to touch their shoulder with the palm for a flexed angle. These measurements were obtained using a plastic goniometer, with the subjects in a standing position. Landmarks used to measure the elbow joint angles were the lateral epicondyle of the humerus, the palpated distal end of the deltoid muscle, the midpoint of between the styloid processes of the ulna and radius, and the styloid process of the radius. These sites were marked on the skin with a semipermanent ink marker to obtain consistent measures, and the landmarks were renewed each day. The ROM was determined by deducting the flexed arm angle from the extended angle, and the change from the preexercise value (in degrees) was used in further analysis.

**Upper-arm circumference.** Circumference of the upper arm was assessed using a constant-tension tape, with the arm relaxed and hanging by the subject’s side. Measurements were taken from the sites at 3, 5, 7, 9, and 11 cm above the crease line of the elbow of the exercised arm. Each site was marked with a semipermanent ink marker to obtain consistent measures. The average of the five sites was recorded as the arm circumference and was used for analysis.

**Muscle soreness.** Muscle soreness was assessed using a 100-mm visual analogue scale; each subject was instructed that 0 indicated no pain, whereas 100 was an indication of “unbearable” pain. Subjects were instructed to rate the soreness experienced during each palpation by marking on the line. Soreness of the upper arm and forearm was rated as the arm was palpated in four marked positions: 3–5 cm and 9–11 cm above the elbow crease, and laterally at sites associated with the brachialis and brachioradialis. Palpation was performed by the same investigator for all subjects, and the pressure and the protocol (a circular motion over the site) were standardized. A sum of the four palpation measures was used for further analysis.

**Serum CK activity.** An 8.5-mL blood sample was drawn from the antecubital vein, using a standard venipuncture technique into a serum-separating tube (SST II Advance, BD Vacutainer). The sample was allowed to clot at room temperature for 30 min before being centrifuged at 4°C for 10 min at 3000 rpm. The serum was stored at −80°C for later analysis for serum CK activity. The analysis was conducted using a Hitachi Modular PT (Mannheim, Germany) automated clinical chemistry analysis machine with Roche Diagnostics Reagents (Mannheim, Germany). The normal reference range provided by the manufacturer for serum CK activity with this method is < 200 U·L⁻¹.

**Time course of measurements.** With the exception of blood sampling, all other criterion measures were taken from the exercised arm. Strength measures, ROM, upper-arm circumference, and muscle soreness were measured during one familiarization session, immediately before exercise, immediately after exercise, and at 1, 24, 48, 72, 96, and 120 h after exercise. Blood samples were drawn from the nonexercised arm before one familiarization session, at 30 min before exercise, and at 24, 48, 72, 96, and 120 h after exercise. The measurements were taken in the following order: blood sample, muscle soreness, stretched and flexed elbow joint angle, arm circumference, and then the muscle strength measures.

**Statistical Analysis**

There were two groups in this study; one group performed 30 slow (S30) and 30 fast lengthening contractions (F30), and another group performed 210 slow (S210) and 210 fast lengthening contractions (F210). Comparisons were made not only within each group to examine the effect of

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**FIGURE 1**—Changes in work for 30 slow (S30), 30 fast (F30), 210 slow (S210), and 210 fast (F210) lengthening contractions. Mean (SD) values are shown. The inset depicts the total work performed during exercise for the four exercise bouts. Mean (SD) values are shown. *Significantly different between slow and fast velocities after the same number of contractions; # significantly different between the number of contractions performed at the same contraction velocity.

**FIGURE 2**—Comparison between slow (S) and fast (F) exercise for normalized changes in maximal voluntary isometric torque from baseline (100%) at 150° elbow flexion immediately after (post) and 1 h after exercise, and 24–120 h after 30 (A) and 210 lengthening contractions (B). Mean (SD) values are shown. *Significant difference between exercise velocities after the same number of contractions.
figure 3—Comparison between slow (S) and fast (F) exercise for changes in maximal ROM from baseline (0) immediately after (post) and 1 h after exercise, and 24–120 h after 30 (A) and 210 lengthening contractions (B). Mean (SD) values are shown. * Significant difference between exercise velocities after the same number of contractions.

contraction velocity in the same number of contractions (S30 vs F30 and S210 vs F210) but also between groups to investigate the effect of number of contractions at the same velocity (S30 vs S210 and F30 vs F210). A third comparison was made between S30 vs F210 to examine the velocity effect on the same amount of muscle contraction time as we have previously reported (8). The total work performed during exercise was compared between slow- and fast-velocity conditions for each group by a one-way ANOVA, and a Tukey’s post hoc test was used to determine the changes from the baseline. Changes in the criterion measures over time were compared by a two-way repeated measures ANOVA (group x time) for velocity effect (S30 vs F30, S210 vs F210), contraction number effect (S30 vs S210, F30 vs F210), or combination effect (S30 vs F210). If a significant interaction effect was shown by the ANOVA, a Tukey’s post hoc test was performed to identify the time points where a significant difference occurred. Data were analyzed using the statistical software package SPSS (version 13.0), and significance was set at P < 0.05. All data are presented as means ± SD unless otherwise stated.

RESULTS

None of the criterion measures before exercise were significantly different between arms in each group or between groups. All criterion measures changed significantly after 210 lengthening contractions (S210 and F210), regardless of the exercise velocity; however, this was not

FIGURE 4—Comparison between slow (S) and fast (F) exercise for changes in upper-arm circumference from baseline (0) immediately after (post) and 1 h after exercise, and 24–120 h after 30 (A) and 210 lengthening contractions (B). Mean (SD) values are shown.

FIGURE 6—Comparison between slow (S) and fast (F) exercise for changes in serum CK activity before (0) and 24–120 h after 30 (A) and 210 lengthening contractions (B). Mean (SD) values are shown. * Significant difference between exercise velocities after the same number of contractions.
the case for 30 lengthening contractions. No significant changes in CK were evident after 30 lengthening contractions for both slow (S30) and fast (F30) exercise bouts. The work performed during each set decreased significantly for the first five sets for all conditions, and further decrease was observed in the additional 30 sets for 210 contractions (Fig. 1). The magnitude of decrease in work was significantly greater for S210 compared with F210. As shown in Figure 1 (inset), the total work performed during the exercise was significantly greater for the fast- than for the slow-velocity exercise, and the differences between the S30 and F30, and between S210 and F210, were 13% and 44%, respectively. A significant difference in the total work performed was also evident between groups at the same contraction velocity but with a different number of contractions (S30 vs S210 and F30 vs F210); however, the magnitude of difference was less than sevenfold.

Comparison between S30 and F30, and between S210 and F210. Changes in muscle strength were similar among isometric contractions at the five different angles and isokinetic concentric contractions. Figure 2 shows changes in iMVC-150 after 30 lengthening contractions at slow and fast velocities (a) and after 210 lengthening contractions at slow and fast velocities (b). A significant interaction effect between S30 and F30 was evident; however, no differences were identified with the post hoc test. A significant difference between S210 and F210 was shown by the ANOVA, with the post hoc test showing significant differences at 72–120 h postexercise. After exercise, the angle for maximal torque shifted to a longer length for all groups; however, no significant difference in the changes in optimum angle was evident between S30 and F30, or between S210 and F210.

As shown in Figure 3, no significant difference between S30 and F30 was seen for changes in ROM, but a significant difference between S210 and F210 was evident, with significantly greater values being observed at 72 h after exercise. No significant difference in the changes in upper-arm circumference was evident between S30 and F30, or between S210 and F210 (Fig. 4).

Figure 5 shows changes in the sum of the four palpation soreness measures before and after exercise. No significant difference was found between S30 and F30, or between S210 and F210. Changes in serum CK activity are shown in Figure 6. No significant interaction effect was evident for the changes in CK activity after S30 and F30; however, changes in CK activity were significantly greater after F210 than after S210, with a significant difference at 72–120 h after exercise.

Comparison between S30 and S210, F30 and F210, and S30 and F30. Table 1 shows the results from a series of two-way repeated-measures ANOVA between arms in each group (S30 vs F30, S210 vs F210), which were explained in the previous sections, and between groups (S30 vs S210, F30 vs F210, S30 vs F30). The results of isometric muscle strength are limited to iMVC-90 and iMVC150, because they are representative of the results from the other angles. Comparisons between S30 and S210 show a significant interaction effect for all variables except for optimum angle and muscle soreness; the loss of muscle strength and ROM, the increase in upper-arm circumference, and serum CK activity were significantly greater for S210 than for S30. For the comparisons between F30 and F210 and between S30 and F210, a significant interaction effect was not evident for optimum angle, ROM, or muscle soreness, but the loss of muscle strength, the increase in upper-arm circumference, and serum CK activity were significantly greater for F210 compared with F30. Comparison between S30 and F210 showed significantly greater decreases in muscle strength and significantly greater increases in upper-arm circumference and muscle soreness for F210.

**DISCUSSION**

The main aim of the present study was to compare between slow (30°·s⁻¹) and fast-velocity (210°·s⁻¹) contractions for changes in indirect markers of muscle damage after 30 or 210 lengthening contractions of the elbow flexors. A significant interaction effect between the velocities was evident only for iMVC when 30 contractions were performed, but one was found for iMVC at all angles, cMVC-150, ROM, and CK when 210 contractions were performed (Table 1). These results suggest that the effect of velocity on muscle damage increases when the number of contractions increases.

In the comparison between 30 slow- and 210 fast-velocity
contractions where the time that the muscle was under tension is the same between conditions, the difference between the two velocities for the changes in the markers of muscle damage increased further (Figs. 2–6), confirming the findings of our previous study (8). However, the present study did not resolve the issue of the effect of lengthening contraction velocity on the magnitude of muscle damage, because the influence of contraction velocity was not clear in the 30-contraction group.

It has been documented that the number of lengthening contractions is a factor affecting the magnitude of muscle damage (6,10,17). Chen and Nosaka (10) compared 30, 50, and 70 lengthening contractions of the elbow flexors using a dumbbell, and they report significantly smaller decreases in isometric strength and ROM and smaller increases in arm circumference after 30 contractions compared with 50 or 70 contractions; however, no significant difference was evident for muscle soreness, serum CK activity, or myoglobin concentration among the conditions. The number of contractions was much greater in one of the conditions (210) in the current study, which may have contributed to the significant difference in serum CK activity between the 30- and 210-contraction groups. No significant difference between 30 and 210 contractions was evident for aMPT and muscle soreness (Table 1). Several studies have shown a shift of optimum angle to a longer muscle length after eccentric exercise of the elbow flexors (32), knee extensors (3), or knee flexors (4). It seems that the shift of optimum angle is a result of fatigue and damage to sarcomeres (25); however, it has been shown that the magnitude of the shift is not necessarily associated with the magnitude of muscle damage (11). The discrepancy between the magnitude of muscle soreness and the magnitude of changes in other markers of muscle damage has been reported (29).

The number of contractions performed was not proportional to the total work performed or the magnitude of strength loss. As shown in Figure 1, the difference in the total work performed between 30 and 210 lengthening contractions was less than fivefold, and the difference in the magnitude of decrease in iMVC after exercise between the contractions was less than twofold (Fig. 2). This is probably attributable to fatigue occurring during the repetitive contractions. We have recently reported that total work, change in work, torque developed, and change in torque developed during maximal lengthening contractions do not correlate with the magnitude of changes in common indirect markers of muscle damage (9). It is possible that mechanical stress to muscle fibers decreases with increases in the number of contractions, because of an inability to continue to produce high forces (10). It is proposed that the greater work performed in the fast- than in the slow-velocity lengthening contractions (Fig. 1) was associated with greater forces generated at longer lengths during the fast contractions, firstly because of the reduced contraction time in the fast-velocity exercise, and secondly because length dependence of fatigue and the rate of fatigue are greater at shorter muscle lengths (20). It has been shown that greater force at longer muscle lengths results in greater muscle damage (27,30). This may be one of the reasons why the changes in some criterion measures were greater after the fast- than after slow-velocity contractions.

No significant difference was found between S30 and F30 for the changes in most criterion measures; however, when the number of contractions increased to 210, the difference between slow- and fast-velocity exercises became apparent (Figs. 2–6 and Table 1). This suggests that contraction velocity is not a dominant factor in influencing the magnitude of muscle damage, but factors relating to both contraction velocity and the number of contractions affect the magnitude of muscle damage. Thus, the findings of our previous study (8) showing that 210 fast-velocity contractions resulted in significantly greater changes in indirect markers of muscle damage compared with 30 slow-velocity contractions were clearly attributable to the differences in velocity and number of contractions.

The mechanisms responsible for the greater damage induced by fast-velocity lengthening contractions could be related to the percent contribution of individual muscle fibers to force production. It has been reported that muscle fibers are not fully activated during lengthening contractions (2,37). For example, Beltman et al. (2) report that the voluntary activation level during attempted maximal lengthening contractions (79%) was significantly lower than during isometric (93%) or shortening contractions (92%) in the case of the knee extensors. It is not known whether this is also the case for the elbow flexors, but it seems likely that fewer muscle fibers of the elbow flexors are activated during lengthening contractions compared with isometric or shortening contractions. Considering that there is no significant difference in the voluntary torque production among varying velocities (30, 90, 150, and 210°·s⁻¹) of lengthening contractions (7), it seems reasonable to assume that the levels of mechanical stress to active muscle fibers are similar between the fast- and slow-velocity lengthening contractions, if lengthening contraction velocity does not affect the voluntary activation level. It is possible that the number of cross-bridges capable of generating force was smaller in the fast-velocity than the slow, and this might induce greater mechanical stress per active cross-bridge during the fast-velocity lengthening contractions. Because fast twitch muscle fibers are more susceptible to fatigue, it is possible to speculate that the number of fast-twitch muscle fibers actually generating force decreases with an increasing number of contractions. This could explain why the effect of velocity became more conspicuous with 210 contractions than with 30 contractions.

Furthermore, it has been proposed that skeletal muscle undergoing lengthening contractions becomes fatigued, entering a state of rigor, leading to an increase in strain imposed on the active fiber, and, ultimately, “popping” of the sarcomere structures (23). A greater number of fibers may enter a state of rigor with an increase in the number of
lengthening contractions. Stephenson et al. (34) have stated that the excitation–contraction–relaxation cycle was less likely to be compromised during repeated contractions of slow-twitch muscle fibers. Thus, it seems possible that fast-twitch muscle fibers would reach a state of rigor first. Unique activation strategies for lengthening contractions have been proposed (16), with some researchers demonstrating that fast motor units are preferentially activated during lengthening contractions (18,26); however, others have reported no difference in activation patterns between shortening and lengthening contractions (1,35). It seems that the order of muscle fiber recruitment in maximal lengthening contractions is not different from that in shortening or isometric contractions (2). Crameri et al. (14) recently have reported that the magnitude of muscle damage was greater for the forced lengthening of a muscle under percutaneous electrical stimulation than for the forced lengthening of a muscle during voluntary contractions, suggesting that the pattern of muscle fiber recruitment affects the magnitude of muscle damage. It is not known whether the pattern of recruitment is different between slow and fast lengthening contractions. Further study is necessary to investigate whether damage occurs to fast-twitch fibers more extensively during fast-velocity lengthening contractions with an increasing number of contractions.

It is important to note that no significant differences between the contraction velocities were found for some of the criterion measures (i.e., aMPT, cMVC-30, cMVC-210, upper-arm circumference, muscle soreness), regardless of the number of lengthening contractions performed. As discussed earlier, the discrepancy between the magnitude of muscle damage and the magnitude of perceived muscle soreness has been documented (14,29). It has been proposed that a breakdown and subsequent inflammation of the extracellular matrix (ECM), rather than muscle fibers, influences the development of muscle soreness and inflammation after eccentric exercise (15,21). It may be that muscle soreness is more associated with damage to ECM and that the velocity does not affect the magnitude of ECM damage. This may also explain the absence of a difference between velocities for changes in upper-arm circumference, which is indicative of swelling. It is difficult to explain why no significant difference between S210 and F210 existed for cMVC-30 and cMVC-210, although a significant difference between velocities was observed for other muscle strength measures, including cMVC-150 (Table 1). It is interesting to note that the velocities of the isokinetic strength measures were the same as the velocities used in the lengthening contractions; however, the significance of this is difficult to explain. Even if the isokinetic torque measures at different velocities can reflect muscle fiber types affected by exercise, the lack of any significant difference between the fast- and slow-velocity contractions for the changes in these measures suggests that muscle fibers were damaged similarly in the slow- and fast-velocity exercises.

Our current and previous investigation (8) demonstrate that fast-velocity lengthening contractions are likely to induce greater muscle damage than slow-velocity lengthening contractions. The results of the present study support the common belief among athletes and coaches that moderate- to high-velocity eccentric exercise results in greater levels of muscle damage than slow-velocity eccentric exercise. Although the findings thus far have been demonstrated only in an untrained population, if replicated in a trained population, the results would have significant implications for athletes participating in sports incorporating repetitive lengthening contractions at high angular velocities in training programs before competition.

The results and conclusions of the present study do not constitute endorsement by American College of Sports Medicine.

REFERENCES


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