Full Range of Motion Induces Greater Muscle Damage Than Partial Range of Motion in Elbow Flexion Exercise With Free Weights

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Abstract

Baroni, BM, Pompermayer, MG, Cini, A, Peruzzolo, AS, Radaelli, R, Brusco, CM, and Pinto, RS. Full range of motion induces greater muscle damage than partial range of motion in elbow flexion exercise with free weights. *J Strength Cond Res* 31(8): 2223–2230, 2017—Load and range of motion (ROM) applied in resistance training (RT) affect the muscle damage magnitude and the recovery time-course. Because exercises performed with partial ROM allow a higher load compared with those with full ROM, this study investigated the acute effect of a traditional RT exercise using full ROM or partial ROM on muscle damage markers. Fourteen healthy men performed 4 sets of 10 concentric-eccentric repetitions of unilateral elbow flexion on the Scott bench. Arms were randomly assigned to partial-ROM (50–100°) and full-ROM (0–130°) conditions, and load was determined as 80% of 1 repetition maximum (1RM) in the full- and partial-ROM tests. Muscle damage markers were assessed preexercise, immediately, and 24, 48, and 72 hours after exercise. Primary outcomes were peak torque, muscle soreness during palpation and elbow extension, arm circumference, and joint ROM. The load lifted in the partial-ROM condition (1RM = 19.1 ± 3.0 kg) was 40 ± 18% higher compared with the full-ROM condition (1RM = 13.7 ± 2.2 kg). Seventy-two hours after exercise, the full-ROM condition led to significant higher soreness sensation during elbow extension (1.3–4.1 cm vs. 1.0–1.9 cm) and smaller ROM values (97.5–106.1° vs. 103.6–115.7°). Peak torque, soreness from palpation, and arm circumference were statistically similar between conditions, although mean values in all time points of these outcomes have suggested more expressive muscle damage for the full-ROM condition. In conclusion, elbow flexion exercise with full ROM seems to induce greater muscle damage than partial-ROM exercises, even though higher absolute load was achieved with partial ROM.

Key Words strength training, exercise-induced muscle damage, Scott bench

Introduction

Resistance training (RT) is often reported as the most effective method for long-term increases in strength and muscle mass (31). However, acute effects of RT should be considered for prescription and periodization, because individuals participating in RT experience exercise-induced muscle damage, which impairs muscle function and limits performance for some days after exercise (7). Therefore, sufficient recovery time should be implemented between training sessions, which could be achieved in a gym environment through assessment of indirect markers of muscle damage, such as muscle strength capacity, delayed-onset muscle soreness (DOMS), joint range of motion (ROM), and limb circumference (CIR) (7,34).

Mechanical factors seem to initiate the injury process, and a cascade of metabolic events and inflammation increase muscle damage in the following days after exercise (24). Exercise intensity (i.e., load) and volume (i.e., number of sets and repetitions) are the most commonly manipulated variables in RT programs, which affect mechanical stress over the muscle and, consequently, the magnitude of exercise-induced muscle damage (5,20). However, other intervenient factors on mechanical stress applied over the muscle tissue should be considered, such as muscle group (3), type of exercise (30), type of muscle action (12), and movement velocity (2). Additionally, evidence suggests that joint ROM used during resistance exercise may also affect the muscle damage response (11,17,23).

Previous studies (11,17,23) showed greater muscle damage (or a trend to) in elbow flexor muscles exercised at long– compared with short–muscle lengths. However, these studies have exclusively used maximal eccentric contractions, performed in isokinetic conditions and with a fixed ROM starting at short– or long–muscle lengths. Importantly, these

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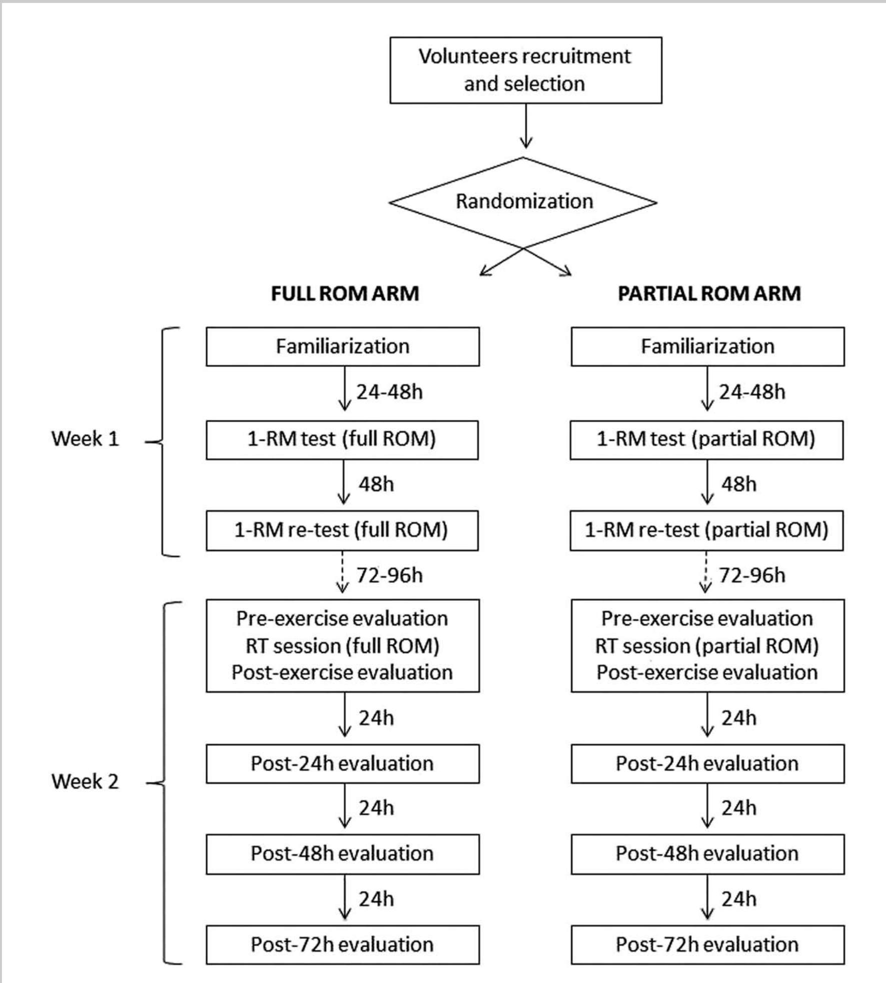

Figure 1. Simplified experimental design.

conditions are dissimilar from those observed during a traditional RT program (i.e., using free weights or gym machines). Exercises with full ROM have been recommended in traditional RT, despite a partial ROM (when long– and short–muscle lengths are avoided) allowing an exercise to be accomplished with a higher load (13,14,25). In fact, weightlifters and RT practitioners commonly perform exercises with partial ROM to displace superior amounts of load or even to complete a target number of repetitions during a set. However, there is a lack in the literature regarding the acute effects of ROM on muscle damage induced by traditional RT exercises.

In summary, it remains unknown whether the higher load lifted in the partial-ROM condition or the larger angular amplitude during the full-ROM exercise is the preponderant factor for muscle damage magnitude and recovery time-course in traditional RT exercise. Therefore, the purpose of this study was to investigate the acute effect of a traditional RT exercise using full ROM or partial ROM on muscle damage markers of healthy young men. Taking into consideration previous findings that full ROM seemed to promote higher strength gains compared with partial ROM after a systematized RT program (13,25) and assuming a close relationship between muscle damage generated in RT sessions and muscular adaptation (29), we hypothesized that muscle damage would be more expressive for the full-ROM condition.

Methods

Experimental Approach to the Problem

After recruitment, the subjects visited the laboratory for data collection on 7 occasions (Figure 1). In the first visit, they were familiarized to the procedures and tests. In the second visit, 1 repetition maximum (1RM) test was performed; one arm performed the elbow flexion 1RM test with a partial ROM, whereas the contralateral arm performed the elbow flexion 1RM test with a full ROM, according to the randomization protocol. Although evidence suggests similar responses of preferred and nonpreferred arms to a muscle damage protocol (19), an equal number of volunteers performed each experimental condition at the preferred side. After 48 hours, both arms repeated the 1RM test for reliability purposes. After at least 72 hours, subjects returned to the laboratory to perform the respective RT protocol determined for each arm. The indirect markers of damage were assessed before and immediately after exercise and 24, 48, and 72 hours after exercise in both arms.

Subjects

Fourteen untrained male undergraduate subjects, aged between 18 and 25 years, volunteered for the study. As a part of the inclusion criteria, subjects were not to be involved in any systematized training programs for at least 3 months before they started the study. All subjects were informed about the purpose, procedures, benefits, and risks that might result from this study and agreed to participate through a signed informed consent. Subjects <18 years old

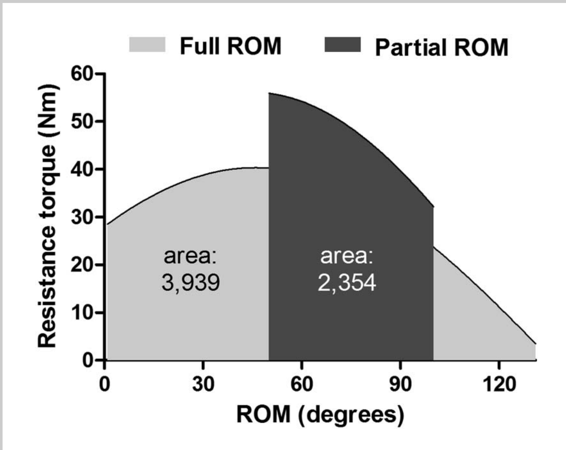

Figure 2. Resistance torque (calculated through mean values of forearm length and load) along the range of motion and estimated work (area under curve) performed in each condition.

were not included in this study. The study was conducted according to the declaration of Helsinki, and all procedures were approved by the local research ethics committee. Physical characteristics (mean ± *SD*) for age, weight, and height were 21.1 ± 1.9 years, 77.1 ± 13.6 kg, and 178.9 ± 5.6 cm, respectively. Participants were instructed to perform no vigorous physical activity during the study and not to take any medication, dietary supplement, or alcoholic beverages.

One Repetition Maximum Test

To determine the 1RM load, subjects visited the laboratory 2 times with at least 48 hours between each session. The same procedures were maintained on both occasions. Subjects warmed-up with a light to moderate load for 10 repetitions of unilateral elbow flexion using a dumbbell resistance on a Scott bench (preacher curl; Sculptor, Porto Alegre, RS, Brazil). According to the randomization protocol, one arm was tested at partial ROM (50–100°) and the other at full ROM (0–130°), considering 0° as full elbow extension. To control ROM, 2 metallic bars were used to regulate dumbbell displacement (25). Adjustments to determine 1RM load were made through trial and error, as previously described (27). No more than 5 attempts with a 3-minute rest interval between trials were necessary to determine 1RM. A metronome controlled the cadence: 1 second for each phase (concentric and eccentric) for the partial-ROM condition and 2 seconds for each phase for the full-ROM condition. The 1RM test was ceased if the subject was unable to move the dumbbell in the target cadence.

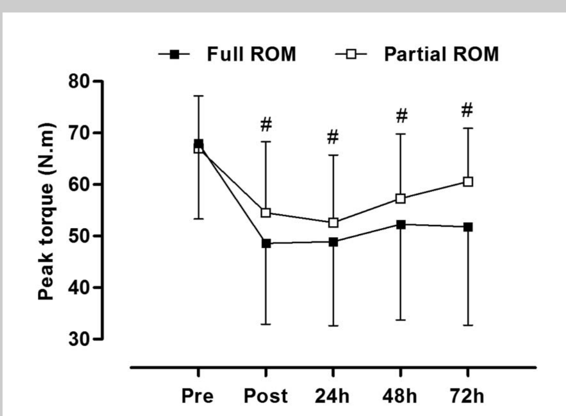

Figure 3. Peak torque (PT) throughout testing sessions for both conditions. #Significantly lower than preexercise for both conditions.

Resistance Training Session

The RT protocol consisted of 4 sets of 10 concentric-eccentric repetitions on unilateral elbow flexion using a dumbbell resistance equal to 80% of full or partial ROM 1RM on the same Scott bench used for 1RM tests. Cadence was controlled through a metronome: 1 second for each phase for the partial-ROM condition and 2 seconds for each phase for the full-ROM condition. A 2-minute rest interval was used between sets. According to previous randomization and 1RM tests, one arm performed the elbow flexion exercise at partial ROM (50–100°), whereas the contralateral arm performed the exercise at full ROM (0–130°). Importantly, some volunteers were not able to perform 130° of ROM because of limited elbow flexion by the muscle mass and/or to limited elbow extension by the reduced stretching or fatigue and swelling during exercise; however, all participants in the full-ROM condition performed at least 2-fold more range of motion than those in the partial-ROM condition.

Estimated Work

Trigonometric functions were used to calculate the resistance torque for each joint position (resolution = 1°) in the exercise in the full- and partial-ROM conditions. The mean value of subjects' forearm length (30 cm), the forearm position in relation to the ground, the mean load supported in 1RM for each experimental condition and the gravity effect were considered for resistance torque calculations. Movement acceleration effects were not considered in the calculations. Torque-angle curves were plotted, and the areas under curves were considered the estimated work performed in the full-ROM and partial-ROM conditions.

Peak Torque

Elbow flexion peak torque (PT) was assessed using a Cybex NORM dynamometer (Cybex, Ronkonkoma, NY, USA) attached to a Scott bench, as described elsewhere (8). Briefly, subjects were positioned in the Scott bench and the dynamometer rotation center was aligned to the elbow rotation center. The test consisted of 3 maximum isometric voluntary contractions of the elbow flexors. Elbow was kept in at 90°, each contraction lasted 5 seconds, and a 2-minute rest interval was maintained between tests. Subjects were verbally

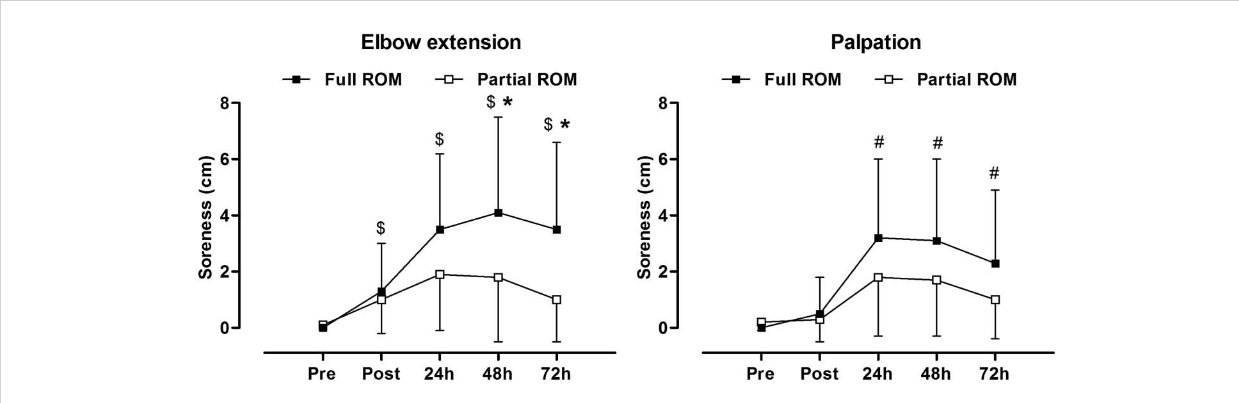

Figure 4. Muscle soreness during elbow extension (left) and palpation (right) throughout the testing sessions for both conditions. $Significantly higher than preexercise for full ROM. #Significantly higher than preexercise for both conditions. *Full ROM significantly higher than partial ROM.

encouraged to maximal effort during all tests. The greatest PT among 3 trials was used for further analysis.

Muscle Soreness

Muscle soreness was evaluated using a visual analog scale, which consisted of a line with 100 mm without any numbers or markers. The left end of the line denoted "no pain," and the right end represented "extremely painful." Subjects were instructed to draw a mark on the line according to their sensation during 2 situations: elbow extension movement; and palpation performed by a researcher at the middle point of muscle belly of the biceps brachii. Soreness was quantified by measuring the distance between the initial point line ("no pain") and the point marked by the subject (1).

Arm Circumference

Subjects remained standing with the arms relaxed beside their body for CIR measurement. The CIR of the upper arm was determined by placing a tape measure at 60% of the distance between lateral epicondyle and acromion. The CIR measurement sites were marked with a semipermanent ink pen to ensure reliability in subsequent assessments (3).

Range of Motion

A plastic goniometer (Carci, SP, Brazil) was used to assess ROM. Subjects remained in the standing position with the arms relaxed for goniometer positioning, and the goniometer was placed on the elbow joint on the lateral epicondyle of the humerus. Then, subjects were asked to maximally flex the elbow. Range of motion consisted of the total angular amplitude starting from the elbow in the relaxed position until maximal voluntary elbow flexion (3).

Statistical Analyses

A paired-sample *t* test was used to compare 1RM load between conditions. A 2-way analysis of variance (condition × time) was used to compare PT, soreness, ROM, and CIR. A priori sphericity was tested through Mauchly's test, and Greenhouse-Geisser correction was used when necessary. Statistical significance was set at an alpha level of 0.05. Results are expressed as mean ± *SD*. All analyses were performed using SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA).

Results

All subjects were able to complete the number of sets and repetitions determined in both experimental conditions during the RT session. Significantly, higher loads (40 ± 18%; $p < 0.01$) were lifted in the partial-ROM condition (1RM = 19.07 ± 3.02 kg) compared with the full-ROM condition (1RM = 13.71 ± 2.16 kg). Considering these mean load values for each exercise condition, the full-ROM condition led to a larger estimated work compared with the partial-ROM condition (Figure 2).

Peak torque presented no time-condition interaction ($p = 0.204$), and just a significant time effect was observed ($p < 0.001$). Peak torque decreased over all time points and remained significantly lower than baseline up to 72 hours after exercise ($p < 0.001$). The lowest PT values occurred at 24 hours for both conditions. Peak torque fall ranged between 23 and 29% for the full-ROM condition and between 9 and 22% for the partial-ROM condition throughout the study (Figure 3).

Muscle soreness during elbow extension presented a significant time-condition interaction ($p = 0.031$). This soreness test showed significantly higher values for full ROM compared with partial ROM at 48 hours ($p = 0.048$) and 72 hours ($p = 0.012$). In addition, soreness in the full-ROM arm remained higher than baseline values until 72 hours ($p < 0.001$), whereas no significant changes occurred in the partial-ROM arm along time ($p > 0.05$ for all time point comparisons). Peak soreness levels were found at 24 hours for the partial-ROM condition and at 48 hours for the full-ROM condition. Mean soreness values for the full-ROM arm were 31–248% higher than the partial-ROM arm between 24 and 72 hours after exercise (Figure 4, left graph).

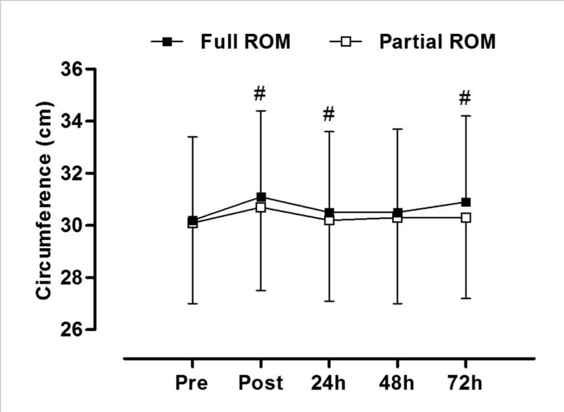

Figure 5. Arm circumference (CIR) throughout the testing sessions for both conditions. #Significantly higher than preexercise for both conditions.

Muscle soreness during palpation had no time-condition interaction ($p = 0.148$), and just a significant time effect was observed ($p < 0.001$). A significant increase in all time points compared with baseline ($p < 0.01$) was found, except for immediately after exercise ($p = 0.670$). Peak values occurred at 24 hours postexercise in both conditions. Mean soreness values in the full-ROM arm were 76–129% higher than the partial-ROM condition between 24 and 72 hours after exercise (Figure 4, right graph).

Circumference also had no time-condition interaction ($p = 0.279$), but a significant time effect ($p < 0.001$). Circumference demonstrated significant increment in all time points compared with baseline ($p \leq 0.05$), except for 48 hours postexercise ($p = 0.322$). The highest values were seen immediately after exercise for both conditions, and CIR increased 1–3% throughout the data collection (Figure 5).

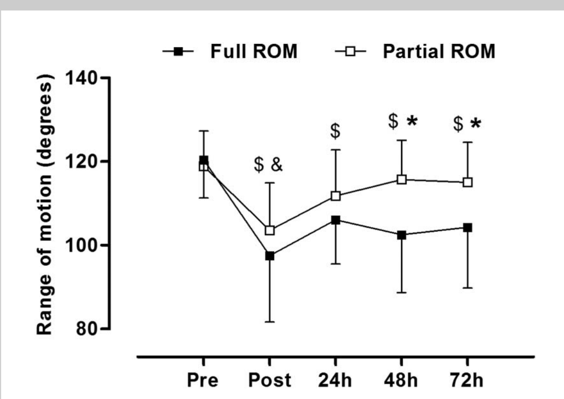

Figure 6. Range of motion (ROM) throughout the testing sessions for both conditions. $Significantly lower than preexercise for full ROM. &Significantly lower than preexercise for partial ROM. *Full ROM significantly lower than partial ROM.

Range of motion presented a significant time-condition interaction ($p = 0.029$). This outcome was significantly lower in the full-ROM condition compared with the partial-ROM condition at 48 hours ($p = 0.007$) and 72 hours ($p = 0.029$). Values in the full-ROM condition were significantly reduced compared with baseline up to 72 hours ($p < 0.01$), whereas partial ROM showed a significant decrease only immediately after exercise ($p = 0.003$). The lowest ROM values were found immediately after exercise for both conditions. Range of motion decreased between 3 and 13% and between 12 and 19% for the partial- and full-ROM conditions, respectively (Figure 6).

Discussion

To the best of our knowledge, this is the first study designed to compare muscle damage in elbow flexors after a traditional RT session with different angular amplitudes (full ROM and partial ROM) and, consequently, different loads. In summary, our findings suggest that ROM during RT of elbow flexors seems to be as or even more important than load itself for muscle damage magnitude, because the higher loads in the partial-ROM condition did not lead to greater levels of muscle damage compared with the full-ROM condition in any outcome.

Subjects' characteristics, such as gender (10), age (28), and conditioning status (18) and the exercised muscle group (lower vs. upper limb) (3), type of exercise (e.g., single joint vs. multijoint exercises) (30), type of muscle action (e.g., concentric vs. eccentric) (12), contraction velocity (2), exercise intensity or load (20), and number of repetitions (4) are variables that notably affect the muscle damage magnitude. In our study, each subject performed a similar exercise (Scott bench) for the elbow flexor muscles, with a controlled angular velocity (about 50–65°$\cdot s^{-1}$) and a standard training volume (4 sets of 10 repetitions). As expected, participants endured a 40% higher load in the partial ROM as compared with the full ROM, further supporting findings involving the elbow flexion (25) and bench press (13,14) exercises. Nonetheless, Figure 2 of our study makes it clear that the superior load in the partial-ROM condition is insufficient to match the amount of work performed for the full-ROM exercise. This is the practical condition that we had intention to test, i.e., the sum of both intervenient factors (joint ROM and exercise load), as commonly experienced by RT practitioners.

Nosaka and Sakamoto (23) compared isokinetic eccentric exercise bouts performed at different starting joint angles but with a similar ROM (80°) and found that longer muscle lengths induced greater muscle damage responses. Although a similar PT among conditions was achieved, the arm performed a higher total amount of work while at a shorter muscle length (23). Therefore, although the higher estimated work performed by our volunteers in the full-ROM compared with the partial-ROM condition, the postexercise response observed here seems to be mainly attributed to the longer muscle length achieved with full ROM. This relationship between fiber length and muscle damage seems very reasonable and has been supported by experimental studies since the "popping-sarcomere hypothesis," proposed by Morgan (15), according to which the sarcomeres are more susceptible to injury when exercised on the descending limb of the force-length relationship.

Previous studies focused in the ROM effect on muscle damage were restricted to isokinetic eccentric contractions (11,17,23), which is not the usual approach for traditional RT. Therefore, until now, it was unknown whether the higher loads used in the partial-ROM condition would be sufficient to compensate the larger muscle damage induced by exercises performed at longer muscle lengths in the full-ROM condition. According to our findings, full-ROM exercise seems to promote higher muscle damage levels, even though with a smaller absolute load compared with the partial-ROM exercise. However, this conclusion is not statistically supported by all outcomes of this study (i.e., PT, DOMS at palpation, and CIR). This specific magnitude and time-course response of each muscle damage marker has already been discussed elsewhere (7), and that is the reason why studies involving exercise-induced muscle damage usually use 3 or more outcomes in their experimental approaches.

In fact, isometric PT is referred to in the literature as the most reliable marker of muscle damage (34), because maximal strength capacity is commonly used as representative of muscle function. We could not observe significant differences in PT values between our 2 experimental conditions, suggesting a similar level of exercise-induced muscle damage. However, it is interesting to note that the full-ROM arm displayed strength falls around 23–29% throughout postexercise days, whereas the partial-ROM arm presented falls ranging between 9 and 22% in the same period. So, we believe the large data dispersion impaired our PT results, and it is possible that a larger sample size would enable the rejection of the null hypothesis (16).

Delayed-onset muscle soreness is one of the most used markers of muscle damage (34), although it does not fully reflect the magnitude of microscopic injury to muscle cells (21). Because this is a completely subjective outcome and characterized by high dispersion between subjects (1), we chose 2 ways to assess muscle soreness: elbow extension and palpation. The results reported here are in agreement with those of Nosaka and Sakamoto (23), who reported that elbow extension triggers greater muscle soreness than local palpation, and soreness response is more pronounced for muscles exercised in longer lengths. Although our statistical approach indicated no time-condition interaction for DOMS during palpation, the full-ROM arm presented mean values 76–129% higher than the contralateral arm. It should be highlighted that a 30% difference in pain scores is considered enough to be a clinically important response (35), thereby further supporting the higher DOMS induced by the full-ROM condition in our study.

Delayed-onset muscle soreness during elbow extension may be at least partially explained in our study by the more expressive ROM reduction observed after the full-ROM condition. Increased muscle stiffness after damaging exercises is often reported (12), and it imposes difficulty for subjects in extending the elbow joint, which may account for painful sensation. At the same time, both DOMS and ROM may be related to muscle swelling, measured here through arm CIR. However, a more precise method to assess muscle swelling may be necessary to draw conclusions about this muscle damage marker, such as ultrasound images to assess muscle thickness and echo intensity (27).

Independent of the responsible mechanism for increased DOMS and reduced ROM, one factor should be taken into account by coaches and trainers: DOMS and ROM are related to subjects' functional capacity. An uncomfortable situation promoted by a painful muscle group may lead to biomechanical changes in daily and sport tasks (6), potentially leading to decreased performance and increased injury risk. Similar consequences may be attributed to a reduced ROM capacity (33). In a simple example based in our own findings, muscles subjected to the full-ROM condition would be unable to complete a subsequent bout using the same exercise with full ROM up to 72 hours after exercise because subjects were not able to reach the last degrees of elbow extension without a certain level of discomfort.

Athletes and other RT practitioners frequently execute a training session without full muscle recovery from the previous one. Although muscle damage does not seem to be exacerbated after an RT session performed with insufficient recovery (5), it is likely that such a chronic model would lead to increased injury risk (6). To prevent the onset of maladaptation, it is important for athletes and active populations that coaches and trainers track their recovery status for proper prescription. In this way, the inexpensive and practical assessments used in this study (i.e., DOMS, ROM, and CIR) are available for these professionals.

Resistance training experts usually recommend complete ROM during exercise. Because the most common goal of RT is to enhance muscle strength capacity and considering that muscle damage level is usually considered a determinant factor for muscle hypertrophy and consequent strength improvement (29), our findings support this recommendation. However, an appropriate periodization using this condition should encompass sparse training sessions of the same muscle group into a week for a sufficient time for muscle recovery. On the other hand, a partial ROM bout seems to confer a protective effect on a subsequent full-ROM bout (22); so, partial-ROM exercises could be used before those with full ROM as a training progression in beginners or individuals who should avoid high levels of muscle damage. Furthermore, it is suggested that long-term interventions with partial-ROM exercise induce specific strength gains near the joint angles achieved in training (9), whereas the exercise executed at long–muscle lengths led to an increase in serial sarcomeres (sarcomerogenesis) (26), providing higher shortening velocity to muscle fibers (32).Therefore, specificity of the subject's activity and goals should also be taken into consideration for appropriated prescription.

A previous study from our research group investigated the effects of a 10-week RT program with partial- and full-ROM exercises on strength and muscle mass of elbow flexors (25) and demonstrated higher effect sizes for the full-ROM condition. If we simply compare these previous findings (25) with those of the present study, it could be hypothesized that the mechanism responsible for the more pronounced chronic adaptation in the full-ROM condition was the greater muscle damage. However, because these studies were conducted separately and we did not control other intervenient factors on muscle adaptation to RT, such as protein synthesis and hormonal response, it would be presumptuous to assume a causal relationship. Therefore, we encourage more studies investigating the mechanism for the responses in subjects trained with exercises encompassing full and partial ROM.

In summary, we concluded that elbow flexion exercises performed with full ROM induce greater muscle damage than partial-ROM exercises, even though the latter allow a higher absolute load compared with the first one. These results were first demonstrated by our study and should be considered to optimize RT prescription and periodization, respecting the magnitude and time-course of muscle damage and recovery after exercises with different ROM.

Practical Applications

Traditional RT using different ROM led to dissimilar muscle damage and recovery. Therefore, prescription based on different ROM should consider specific goals (i.e., increase in strength at specific angles or at the entire ROM), training schedule (i.e., number of weekly sessions and interval between sessions), and contraindication to muscle damage (e.g., individuals with increased risk for rhabdomyolysis). In addition, following the RT model tested here, coaches should consider a larger recovery period for muscle regeneration in the full-ROM compared with the partial-ROM bout. The assessment of common indirect markers of muscle damage (i.e., force, ROM, DOMS, and CIR) for tracking recovery status could be helpful for coaches to take reasonable decisions.

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