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Symptomatic and Functional Responses to Concentric-Eccentric Isokinetic Versus Eccentric-Only Isotonic Exercise

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Context: Rehabilitation protocols involving eccentric resistance exercise performed with loading more than 100% concentric 1-repetition maximum are effective in increasing muscle function in both healthy and injured populations. The mode of eccentric exercise (isokinetic versus isotonic) may be an important factor in limiting symptoms of delayed-onset muscle soreness and in improving muscle function after training.

Objective: To compare functional and symptomatic responses after an eccentric-only (ECC) isotonic exercise protocol and after a combined concentric-eccentric (CON-ECC) isokinetic exercise protocol matched for total exercise volume.

Design: Observational study.

Setting: Controlled research laboratory.

Patients or Other Participants: Twenty-four healthy, untrained, college-aged men (n = 12) and women (n = 12).

Intervention(s): Participants were randomly assigned to the ECC isotonic or CON-ECC isokinetic exercise group and performed a single bout of resistance exercise involving the elbow flexors.

Main Outcome Measure(s): Measurements of elbow flexion and extension, isometric strength, and muscle point tenderness were obtained before exercise (baseline) and during follow-up sessions (days 2, 4, 7, and 14). Separate 1-way analyses of variance and repeated-measures analyses of variance were used to determine outcome differences. Tukey post hoc testing was performed when indicated.

Results: At baseline, no differences were present between groups for any measure. The ECC isotonic exercise protocol resulted in a 30% to 36% deficit in muscle strength, a 5% to 7% reduction in elbow flexion, and a 6% to 8% reduction in elbow extension at follow-up days 2 and 4 ($P < .01$). The CON-ECC isokinetic exercise protocol did not alter muscle strength or range of motion at any time when compared with baseline. Muscle point tenderness increased from baseline on days 2 and 4 in both groups ($P < .05$) but was not different between groups throughout the recovery period.

Conclusions: Our results indicated more pronounced functional deficits occurred after a single bout of ECC isotonic exercise than with a CON-ECC isokinetic exercise protocol matched for training volume.

Key Words: muscle soreness, enhanced eccentric exercises, rehabilitation

Key Points

- The eccentric-only isotonic exercise protocol created greater functional (muscle strength and range-of-motion) deficits compared with the concentric-eccentric isokinetic protocol.
- Strength deficits were present 2 to 7 days after the eccentric-only isotonic exercise protocol and returned to baseline by day 14, but the concentric-eccentric isokinetic exercise protocol did not create strength deficits at any time throughout the recovery phase.
- Elevations in muscle point tenderness were nearly identical for both exercise protocols.

Determining the symptomatic and functional responses to various resistance-training protocols may enable clinicians to prescribe safer and more effective exercise protocols for both healthy and injured individuals. A primary goal of postinjury rehabilitation is to recover, and possibly to increase, muscle strength after injury.[1–3] When prescribing resistance training protocols for healthy or injured populations, resistance exercises that combine concentric and eccentric muscle actions are typically implemented. Both types of muscle actions are generally performed with similar absolute intensities; however, a 40% to 50% greater load can be performed during maximal eccentric muscle actions than during maximal concentric actions.[4,5] This indicates that the eccentric phase of exercise is underloaded throughout typical resistance exercise. Additionally, researchers[6] have shown that when the same amount of torque is produced by a muscle during concentric and eccentric contractions, fewer motor units are recruited during the eccentric contraction. Several authors[1,2,7] have indicated that, when compared with concentric actions of equal absolute exercise intensities, eccentric-only (ECC) actions promote greater neural activation,[1,3,7,8] skeletal muscle hypertrophy,[1,3,7,8] and muscle-tendon and ligament stiffness, indicating that eccentric exercise may be a superior resistance-training method and may also be beneficial during postinjury rehabilitation. Further, Kaminski et al[2] suggested that enhanced eccentric exercise may reduce the risk of musculotendinous injury or reinjury during high-intensity activities by improving the muscle-tendon's ability to withstand force and strain without failing. However, eccentric exercise may also elevate the magnitude of exercise-induced myofiber damage,[2,6,9,10] which may delay or limit full structural and functional recovery during physical rehabilitation and training. Thus, systematic evaluations of the safety and efficacy of exercise protocols that involve overloaded eccentric muscle actions appear necessary before these protocols can be implemented in recreation or rehabilitation settings.

Recently, investigators[11–17] have shown that rehabilitation protocols involving eccentric-resistance exercises, performed with either free weights or an isokinetic dynamometer, are effective in increasing functional capacity and decreasing muscular pain. However, care must be taken when implementing eccentric exercise, as individuals may develop exercise-induced muscle damage and its associated symptoms, including muscle soreness, loss in range of motion (ROM), and reduced muscle strength.[2,6,18] The exact mechanisms underlying delayed-onset muscle soreness (DOMS) remain unknown, but evidence now indicates that DOMS is related to the secondary cascade of tissue damage. Secondary tissue damage occurs after an injury in which damaged cells release chemical mediators, such as cytokines and proteolytic enzymes associated with the acute inflammatory response.[19,20] Studies designed to compare the magnitude of exercise-induced muscle damage and associated symptoms after different modes of eccentric exercise may lead to improvements in the design and implementation of rehabilitative exercise protocols.

Two common exercise protocols that involve overloaded eccentric muscle actions are ECC isotonic exercise, which uses constant supramaximal external resistance, and combined concentric-eccentric (CON-ECC) isokinetic exercise, which uses constant angular velocities. Researchers[11–16] have examined eccentric exercise and overall outcome goals, such as functional capacity and ability to return to activity, but the short-term muscle strength, muscle soreness, and ROM responses to different modes of eccentric exercise have not been investigated in either healthy or injured populations. Therefore, the purpose of our study was to compare functional and symptomatic responses (ie, muscle strength, ROM, and muscle point tenderness) after an ECC isotonic protocol and after a CON-ECC isokinetic exercise protocol in healthy individuals matched for total training volume.

METHODS

Participants

Twenty-four healthy individuals (12 men, 12 women; age = 21.17 ± 2.78 years, height = 171.40 ± 10.09 cm, mass = 72.85 ± 16.32 kg) volunteered for this study. To meet the inclusion criteria, participants had to be aged 18 to 35 years and untrained (ie, no resistance exercise during at least 6 weeks before the study). Untrained participants were studied to avoid the potentially confounding repeated-bout effect.[21,22] Participants were excluded if they (1) had consumed any nutritional supplement intended to enhance exercise performance during the 6 weeks before the study or (2) had any orthopaedic injury that limited exercise performance. All study participants provided written informed consent, and the study was approved by the University of Florida Institutional Review Board.

Study Design

For this randomized, matched-group study, participants reported to the Sports Medicine Research Laboratory at the University of Florida for 5 separate test sessions. A matched-group study[22–24] was performed to avoid the repeated-bout effect. During all test sessions, participants were instructed to wear appropriate clothing (short-sleeved or sleeveless shirts) so that physical measurements could be obtained. During the initial exercise bout (day 0), participants were randomized into either the ECC isotonic or CON-ECC isokinetic exercise protocol group, and measurements of isometric strength, ROM, and muscle point tenderness were obtained. Participants were randomized by having each one pull a number from a hat, and an equal number of men and women were assigned to each group. Next, participants underwent the appropriate ECC isotonic or CON-ECC isokinetic exercise protocol with the nondominant arm. Postexercise, participants were instructed to avoid (1) consuming any nonsteroidal anti-inflammatory drugs, (2) stretching, (3) applying ice or cold compresses to the arm, and (4) performing any other intervention intended to alleviate any possible exercise-induced muscle soreness. During the follow-up sessions (days 2, 4, 7, and 14), isometric strength, ROM, and muscle point tenderness were reevaluated.

Exercise Protocols

During this study, participants performed either an ECC isotonic or a CON-ECC isokinetic exercise protocol for the elbow flexors of the nondominant arm. Before exercise participation, participants were instructed on proper exercise form. Throughout all exercise testing, oral encouragement was given to elicit maximal effort. After completion of the designated exercise protocol, participants were instructed to provide a rating of perceived exertion (RPE). They were given a Borg RPE scale, which consists of an ordinal scale with values ranging from 6 to 20.[25] Written anchors that corresponded with the numbers on the RPE scale were supplied to standardize comparisons across individuals and tasks. Greater exertion was indicated with a larger number, less exertion with a smaller number.

Combined CON-ECC Isokinetic Exercise Protocol. The CON-ECC isokinetic exercise protocol was performed using a Kin-Com isokinetic dynamometer (Chattanooga Group, Hixson, TN). Participants were seated on the Kin-Com, and the nondominant elbow was aligned with the axis of rotation of the dynamometer. The angular velocity was set at 30°/s for concentric actions and 60°/s for eccentric actions. Range of motion was set between 45° and 110° of elbow flexion-extension for each participant. Each participant was instructed to perform near-maximal concentric and eccentric actions consisting of 5 sets of 10 repetitions, with a 30-second recovery period between sets. Total work for this protocol is given by the Kin-Com dynamometer in joules.

Eccentric-Only Isotonic Exercise Protocol. The ECC isotonic exercise protocol was performed on the Cybex arm-curl machine (Cybex International Inc, Medway, MA). Elbow ROM was performed between 10° and 100° for this protocol. A 1-repetition maximum (1RM) for the dominant arm was determined by having participants concentrically curl a set amount of weight for a single repetition. The dominant arm was used for 1RM testing to avoid the possibility of soreness and fatigue and to avoid the potentially confounding effects of repeated bouts on muscular function and soreness.[21,22] The load was progressively increased in 5-lb (2.27-kg) increments until participants were unable to successfully complete a full repetition. The last complete repetition was recorded as the dominant-arm concentric 1RM value. A 1-minute rest interval was given between attempts. After the 1RM assessment, participants used their nondominant arm to perform 3 sets of 10 repetitions at 140% of their concentric dominant-arm 1RM value.[4] During the exercise intervention, participants were instructed to slowly lower the weight over an orally cued 6-second duration or until they could no longer resist the weight. After each eccentric action, the researcher (C.M.G.) returned the weight to the starting position. Participants rested for 1 minute between sets. Total work was determined for this protocol by measuring the distance in feet that the weight stack moved over the set ROM used. This distance of 1.17 ft (0.351 m) was multiplied by total volume of weight lifted (repetitions × weight) to give us a measurement in foot-pounds. This measurement was converted to joules by multiplying by a factor of 1.3558.

DEPENDENT MEASUREMENTS

Maximal voluntary isometric force (MVIF), ROM, and muscle point tenderness of the biceps brachii were evaluated during each test session (baseline pre-exercise injury and follow-up postexercise injury). The MVIF was measured using the Kin-Com dynamometer. Participants were seated, with their nondominant arms placed at their sides in 90° of elbow flexion, neutral rotation of the humerus, and supination of the forearm. Each participant performed 3 separate 2.5-second maximal voluntary isometric contractions of the nondominant arm. A 30-second recovery was provided between contractions.[26,27] The average of the 3 values was recorded as MVIF in newtons.

Both pain-free and total active elbow flexion and elbow extension ROM were evaluated with a standard plastic goniometer. The goniometer approximated the axis of rotation for the humeroulnar joint, and the goniometer arms were aligned with the humerus and forearm.[26,27] Total ROM was evaluated with the participant flexing or extending the elbow as far as possible. Pain-free ROM was evaluated with the participant flexing or extending the elbow only through the ROM that caused no pain or discomfort.

Muscle point tenderness was assessed using a Fischer algometer (Pain Diagnostics & Thermography, Great Neck, NY) and a visual analog scale (VAS).[20,26–28] The algometer administered focal pressure using a 1-cm^2 blunted tip to the most tender point on the biceps brachii muscle. The instrument was held perpendicular to the muscle belly of the biceps, and a force of 4 kg was applied to the selected point. The tester (J.J.P.) determined the most tender point by palpating the biceps muscle. The accuracy of the dial is ±0.05 kg. The pressure is applied manually perpendicular to the surface of the skin at a constant rate. The Fischer algometer is a valid and reliable tool for assessing pain threshold in human participants.[20,26–28]

Table 1. Baseline Characteristics Between Groups (Mean ± SD)

	Group			
	Isotonic	Isokinetic	t_{22}	*P*
Mass, kg	73.0 ± 18.5	72.7 ± 14.7	0.03	.98
Height, cm	169.5 ± 11.1	173.2 ± 9.1	0.90	.38
Maximal voluntary isometric force, N	149.0 ± 58.4	153.9 ± 50.0	0.223	.83
Elbow flexion, °	145.2 ± 6.1	144.4 ± 2.9	0.39	.70
Elbow extension, °	−1.4 ± 3.3	−1.3 ± 3.2	0.06	.95
Muscle point tenderness				
Site 1	2.1 ± 1.5	2.2 ± 1.9	0.15	.89
Site 2	2.8 ± 2.2	2.9 ± 2.0	0.10	.92
Site 3	3.1 ± 2.4	2.8 ± 2.6	0.31	.76

The VAS consisted of a 10-cm–long horizontal line, with 0 cm at the extreme left representing *no pain* and 10 cm at the extreme right representing *unbearable pain*. Point tenderness was assessed at the biceps tendon as it crossed the anterior elbow (site 1), in the biceps muscle belly at its widest point (site 2), and in the long head of the biceps tendon as it passed through the bicipital groove (site 3). Each participant was instructed to draw a single vertical line at the point that most accurately represented his or her perceived level of pain when the algometer force was applied.

DATA ANALYSIS

Separate 2 (group) × 5 (time) repeated-measures analyses of variance (ANOVAs) were calculated to determine differences in the outcome measures (MVIF, ROM, muscle point tenderness) between groups. All ANOVA values were reported as means ± standard errors. Tukey post hoc analyses were performed when necessary. Separate 1-way ANOVAs were calculated to determine differences between groups at specific times. Additionally, a 2-tailed independent *t* test was used to compare RPE and total work performed between groups, with values represented as means ± SDs. The α level was set a priori at ≤.05. All data analyses were performed using SPSS (version 15.0 for Windows; SPSS Inc, Chicago, IL).

RESULTS

Baseline Physical Characteristics, Rating of Perceived Exertion, and Total Work

Baseline physical characteristic data from all participants are presented in Table 1. At baseline, we found no differences between groups for any measure of muscle strength, ROM, or muscle point tenderness. Additionally, we found no differences between groups for either RPE or for total work performed during the exercise intervention (Table 2).

Maximal Voluntary Isometric Force

Within-Groups Differences Among Days. The ECC isotonic exercise group experienced a 36% deficit in MVIF on day 2 ($F_{4,88}$ = 7.44, *P* = .001), and MVIF remained 31.8% below baseline on day 4 ($F_{4,88}$ = 6.58, *P* = .003) and 13.7% below baseline on day 7 ($F_{4,88}$ = 2.83, *P* = .07)

Table 2. Group Characteristics of Ratings of Perceived Exertion and Total Work (Mean ± SD)

	Group			
	Isotonic	Isokinetic	t_{22}	*P*
Rating of perceived exertion (Borg scale: 6–20)	16.9 ± 2.3	16.3 ± 1.4	0.75	.46
Total work, J	2698 ± 1497	2475 ± 1014	0.43	.68

before returning to baseline at day 14 ($F_{4,88}$ = 0.21, *P* = .87) (Figure 1). The CON-ECC isokinetic exercise group did not experience a reduction in maximal strength at any time during the recovery phase (Figure 1).

Between-Groups Differences Over Time. A between-groups difference in MVIF was found on days 2 ($F_{4,88}$ = 2.22, *P* = .04) and 4 ($F_{4,88}$ = 2.96, *P* = .007) postexercise. Muscle strength was diminished in the ECC isotonic group compared with the CON-ECC isokinetic group during recovery days 2 ($F_{4,88}$ = 2.22, *P* = .04) and 4 ($F_{4,88}$ = 2.96, *P* = .007). The MVIF was still diminished on day 7 ($F_{22,23}$ = 1.48, *P* = .15) for the ECC isotonic group; however, this finding was not different from the finding for the CON-ECC isokinetic group, and MVIF gradually returned to baseline by day 14 ($F_{22,23}$ = 0.90, *P* = .38).

ROM

No difference in baseline total ROM was observed between the CON-ECC isokinetic and ECC isotonic groups (145.8° ± 3.9° and 146.6° ± 8.0°, respectively; $F_{22,23}$ = 0.11, *P* = .75).

Elbow Flexion Within-Groups Differences Among Days. Total elbow flexion for the ECC isotonic exercise group was reduced by 6.6% on day 2 postexercise ($F_{4,88}$ = 8.48, *P* = .002), and it remained 5.3% below baseline on day 4 ($F_{4,88}$ = 6.88, *P* = .004) (Figure 2). Although not different from baseline, total elbow flexion remained 3.0% below baseline on day 7 ($F_{4,88}$ = 3.81, *P* = .06) and gradually returned to baseline by day 14. Similarly, pain-free elbow flexion for the ECC group was reduced by 13.1% on day 2 ($F_{4,88}$ = 11.20, *P* = .001) and 9.1% on day 4 ($F_{4,88}$ = 7.80, *P* = .004) (Figure 3). Although not different from baseline, it was still diminished by 3.1% at day 7 ($F_{4,88}$ = 2.63, *P* = .12) and returned to baseline by day 14. Conversely, total and pain-free elbow flexion did not change on any follow-up day for the CON-ECC isokinetic exercise group (*P* > .05) (Figures 2 and 3).

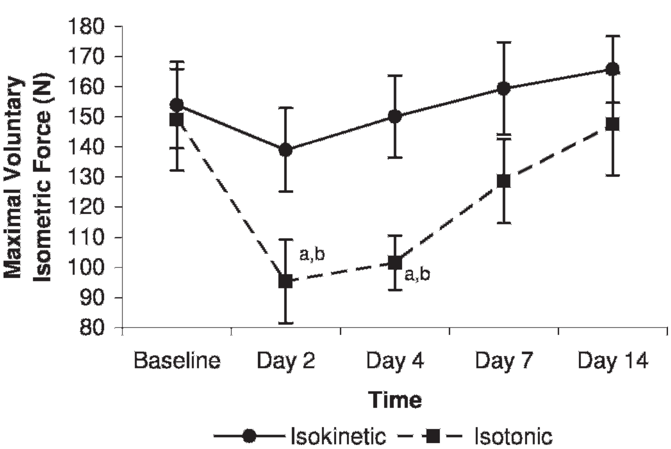

Figure 1. Comparison of maximal voluntary isometric force. ᵃ Indicates difference from baseline (*P* < .01). ᵇ Indicates difference between groups (*P* < .05).

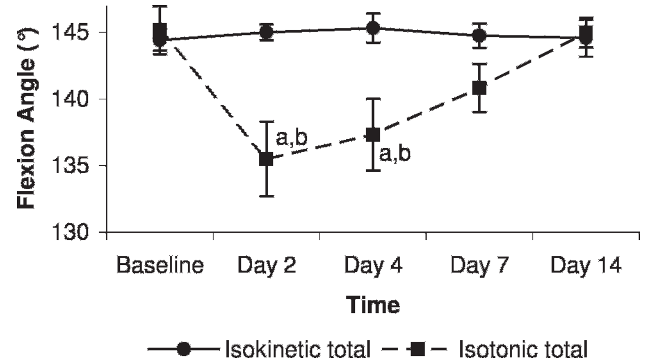

Figure 2. Change in total elbow flexion. ᵃ Indicates difference from baseline (*P* < .01). ᵇ Indicates difference between groups (*P* < .01).

Elbow Flexion Between-Groups Differences Over Time. The ECC isotonic exercise group experienced greater reductions in total and pain-free elbow flexion ROM on days 2 (*P* < .01) and 4 (*P* < .01) postexercise when compared with the CON-ECC isokinetic group (Figures 2 and 3).

Elbow Extension Within-Group Differences Among Days. Total elbow extension for the ECC isotonic group was reduced by 7.5% on day 2 ($F_{4,88}$ = 7.86, *P* = .003) (Figure 4). It remained 6.6% below baseline on day 4 ($F_{4,88}$ = 6.91, *P* = .014) and returned to baseline by day 14. Similarly, pain-free elbow extension for the ECC group was reduced by 15% on day 2 ($F_{4,88}$ = 8.59, *P* < .001) and 13% on day 4 ($F_{4,88}$ = 7.46, *P* = .001), before returning to baseline by day 14 (Figure 5). Total and pain-free elbow extension did not change on any follow-up day for the CON-ECC isokinetic group (Figures 4 and 5).

Elbow Extension Between-Groups Differences Over Time. We did not find a between-groups difference in pain-free elbow extension on day 2 ($F_{22,23}$ = 2.44, *P* = .13), but we did find a between-groups difference on day 2 for total elbow extension ($F_{22,23}$ = 10.45, *P* = .004). Both total and pain-free elbow extension were different between groups on day 4 (*P* < .05), with the ECC isotonic exercise group showing elbow extension deficits compared with the CON-ECC isokinetic exercise group (Figures 4 and 5).

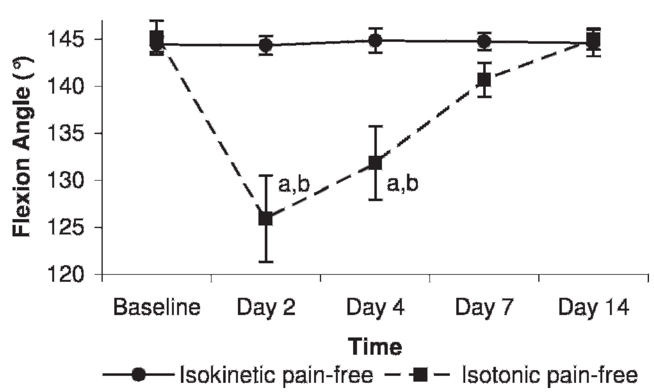

Figure 3. Change in pain-free elbow flexion. ᵃ Indicates difference from baseline (*P* < .01). ᵇ Indicates difference between groups (*P* < .01).

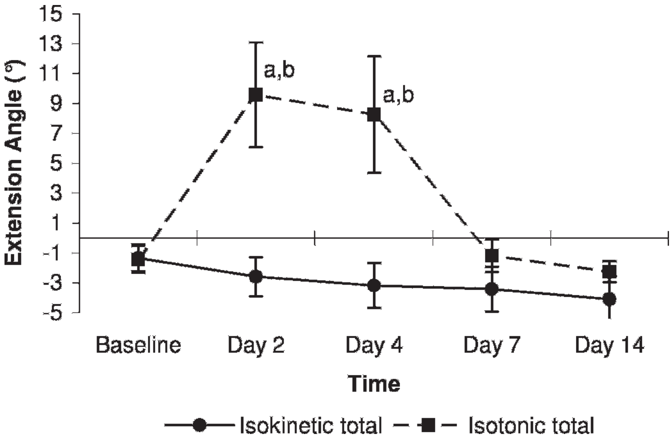

Figure 4. Change in total elbow extension. [a] Indicates difference from baseline ($P < .01$). [b] Indicates difference between groups ($P < .01$).

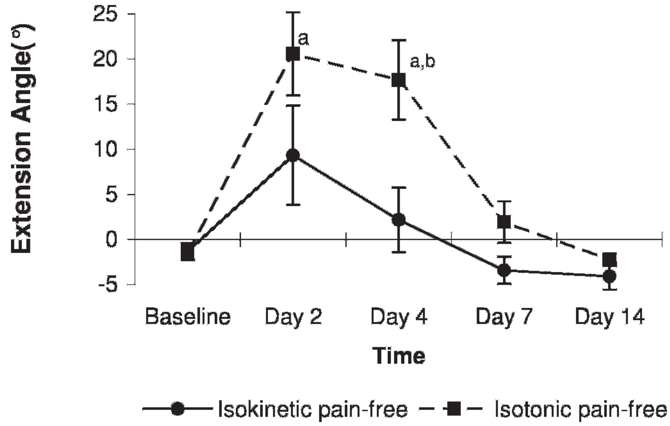

Figure 5. Change in pain-free elbow extension. [a] Indicates difference from baseline ($P < .01$). [b] Indicates difference between groups ($P < .05$).

MUSCLE POINT TENDERNESS

A main effect was present for all 3 muscle point tenderness sites on days 2 and 4 ($P < .05$), indicating that both groups experienced postexercise muscle soreness; however, no differences were present between groups throughout the 14-day recovery period.

DISCUSSION

Eccentric-only isotonic exercise results in myofiber microtrauma[2,26] and DOMS, which results in symptoms of reduced muscle strength,[2,18,19,26] reduced ROM,[19,26] and elevated muscle point tenderness.[2,6,18,19,26] Eccentric muscle actions are primarily responsible for DOMS; however, the acute functional responses after different modes of eccentric resistance exercise (ie, ECC versus CON-ECC) have not been previously reported. Therefore, we attempted to identify the acute musculotendinous responses resulting from 2 different overloaded eccentric resistance exercise protocols by comparing the functional (ie, muscle strength and ROM) and symptomatic (ie, muscle point tenderness) responses to ECC isotonic and CON-ECC isokinetic exercise protocols matched for training volume. The ECC protocol was performed with constant external resistance (140% dominant-arm 1RM), whereas the CON-ECC protocol involved constant angular velocity (30°/s for concentric and 60°/s for eccentric). Our primary finding was that the ECC isotonic protocol created greater functional (strength and ROM) deficits when compared with the CON-ECC isokinetic protocol, and it took approximately 14 days to fully recover from these functional deficits after the ECC isotonic protocol. The strength deficits after ECC isotonic exercise were present 2 to 7 days postexercise and returned to baseline by day 14, but CON-ECC isokinetic exercise did not create strength deficits at any time throughout the recovery phase. In part, our results corroborated previous reports[7,19,28–30] indicating that muscle strength is reduced for up to 7 days after ECC exercise. Conversely, the results from our CON-ECC isokinetic protocol appeared to contradict reports of other authors[2,26–28] who indicated that the CON-ECC isokinetic exercise protocol results in strength deficits lasting up to 4 days. The differing strength responses after the ECC isotonic and CON-ECC isokinetic protocols may be explained by inherent differences in the mode of resistance (ie, constant external resistance [isotonic] versus constant angular velocity [isokinetic]); however, investigators[26,27] have observed strength deficits lasting 96 hours after an identical isokinetic exercise protocol. Alternatively, the strength deficits after ECC isotonic exercise may have resulted from the greater eccentric-specific training volume completed in this group compared with the CON-ECC isokinetic group.[2,3,10,29] We successfully matched total training volume between groups, but the voluntary nature of the concentric and eccentric actions in the CON-ECC isokinetic exercise protocol precluded direct matching of both total and eccentric-specific training volumes between groups. Regardless of the underlying mechanism or mechanisms, the ECC isotonic protocol produced greater strength deficits during the short-term recovery phase after resistance exercise than were produced by the CON-ECC isokinetic exercise protocol.

Similarly, our results indicated that the ECC isotonic exercise protocol produced greater ROM deficits than the CON-ECC isokinetic exercise protocol. We observed reductions in total and pain-free ROM for both elbow flexion and extension after the ECC protocol, but both exercise groups displayed nearly identical elevations in muscle point tenderness. Although both types of exercise produced similar levels of symptomatic muscle point tenderness, the ECC isotonic protocol may have produced a higher level of muscle damage and inflammation than the CON-ECC isokinetic protocol. Although we did not measure cellular markers of inflammation, it is well documented[19,20,29,31] that high-intensity eccentric exercise produces a secondary cascade involving the release of proinflammatory cytokines (eg, interleukin-6 and tumor necrosis factor–α), proteolytic enzymes (eg, creatine kinase), and oxygen free radicals (eg, isoprostanes). In addition, researchers have reported that the secondary cascade produces localized muscle point tenderness, stiffness, and weakness; however, the exact physiologic mechanism (or mechanisms) underlying the development of DOMS remains elusive. Future studies designed to compare the cellular inflammatory responses after different modes of eccentric-enhanced resistance exercise may contribute to an improved understanding of the mechanism or mechanisms underlying DOMS.

Both ECC[20,29] and CON-ECC exercise[18,31] protocols have been used to systematically track the acute inflammatory responses resulting from musculotendinous injury. Investigators[6,9,18,19,31,32] have demonstrated that the inflammatory responses and functional deficits that occur after eccentric resistance exercise mimic the acute musculotendinous strain-injury response; however, the magnitude of inflammation and functional deficit typically can be greater after the acute strain injury. In our study, the ECC isotonic exercise protocol resulted in muscle soreness and concomitantly greater strength and ROM deficits than did the CON-ECC isokinetic exercise protocol, indicating that greater myofibril inflammation occurred after the ECC isotonic protocol compared with the CON-ECC isokinetic protocol. As such, ECC isotonic exercise may be an improved model for evaluating the mechanical and/or chemical alterations resulting from musculotendinous injury, but this remains speculative.

Additionally, researchers[21,22] have shown that performing a single bout of eccentric exercise may reduce the susceptibility of skeletal muscle to microtraumatic injury after subsequent bouts of resistance exercise in a load-dependent manner and that this protective effect lasts for several days to weeks after the initial exercise bout. Although we did not evaluate repeated training bouts, a single eccentric bout of exercise, such as our CON-ECC isokinetic protocol, may provide acute protection against the microtraumatic muscle damage that results from overtraining, or perhaps it will provide protection against injury. Thus, periodic use of eccentric loading protocols that do not induce DOMS may help the participant to avoid the detrimental symptomatic and functional deficits that are associated with overtraining and may reduce musculoskeletal injury potential, especially considering that several exercise or rehabilitation bouts are typically performed per week. However, this remains to be determined.

Clinical Implications

The primary goals of musculotendinous postinjury rehabilitation are (1) to reduce inflammation and pain in the injured area and (2) to restore muscle function to preinjury levels. Thus, resistance exercises that increase muscle strength while minimizing myofiber damage may enhance recovery after injury. Eccentric exercise may augment muscle strength adaptations, as other researchers[7,19,28,32,33] have suggested; however, an elevated risk of musculotendinous soreness also exists when using overloaded eccentric exercise.[30] In our study, the CON-ECC isokinetic exercise protocol induced muscle soreness but did not alter ROM, indicating limited muscle damage and a blunted inflammatory response after the use of the isokinetic exercise device. Conversely, the ECC isotonic exercise protocol incited muscle soreness and reduced arm function (biceps strength and elbow flexion and extension ROM). The combination of these results appears to indicate that, when performed with this protocol, CON-ECC isokinetic exercise resulted in less musculotendinous damage and inflammation than did ECC isotonic exercise, at least in healthy, uninjured muscle. Thus, CON-ECC isokinetic exercise protocols may be advantageous during early-phase injury rehabilitation, as a greater total training load can be performed when using isokinetic exercise without inducing functional deficits that may delay injury recovery. In addition, periodic use of CON-ECC isokinetic protocols may protect against training-induced muscle microtrauma or perhaps musculotendinous injury without inducing long-duration symptomatic or functional deficits.

Limitations

Several limitations in our study design may restrict the generalization of our findings, including group differences in (1) velocity of eccentric contraction (isokinetic at 60°/s versus isotonic at 6 seconds per eccentric repletion),[19] (2) contraction type (CON-ECC versus ECC),[2] and (3) eccentric-specific workload.[2] In particular, altering the variables involved in the ECC isotonic and CON-ECC isokinetic exercise protocols may result in outcomes that are different from those we found, as authors[19] of at least one study have reported greater muscle damage after fast-velocity versus slow-velocity isokinetic muscle actions; however, isotonic exercise does not appear to be affected by the speed of the eccentric contraction.[34] Additionally, the inclusion of concentric muscle actions in the CON-ECC isokinetic group directly limits our findings, as the concentric action represented 46% of the total CON-ECC training volume. As previously discussed, we matched total workload between groups but were not able to match eccentric-specific workloads between the 2 protocols because of the voluntary nature of eccentric isokinetic exercise. Future research that directly controls contraction types, total and eccentric-specific training loads, time under tension, and speed of contraction may assist in delineating the causes of DOMS and related impairments and may ultimately improve exercise prescription for both healthy and at-risk populations.

The selection of the biceps brachii may also limit our findings to muscles comprising similar mixed-muscle fiber origins.[35] Jamurtas et al[31] reported that eccentric exercise involving the upper extremities induces larger deficits and slower recovery of strength and greater increases in blood markers of muscle damage than does lower extremity eccentric exercise. Therefore, generalization of our findings to muscles predominantly comprising fast-twitch type IIA or IIX muscle fibers or to lower body musculature should be done with caution.

CONCLUSIONS

We demonstrated that an ECC isotonic exercise protocol involving constant external resistance produced greater functional deficits than did a CON-ECC isokinetic exercise protocol matched for training volume. Specifically, the ECC isotonic protocol resulted in a larger muscle strength deficit and a greater reduction in ROM compared with the CON-ECC isokinetic protocol. Thus, CON-ECC isokinetic protocols may be more appropriate during early-stage rehabilitation because of a potentially lower level of myofiber damage and inflammation, but this remains to be determined. Future research examining the functional and symptomatic responses between ECC and CON-ECC exercise protocols matched for total eccentric workload appears warranted and may elaborate on the mechanical initiators of DOMS.

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