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Equal Volumes of High and Low Intensity of Eccentric Exercise in Relation to Muscle Damage and Performance

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ABSTRACT. Paschalis, V., Y. Koutedakis, A.Z. Jamurtas, V. Mougios, and V. Baltzopoulos. Equal volumes of high and low intensity of eccentric exercise in relation to muscle damage and performance. *J. Strength Cond. Res. 19(1):184–188. 2005.*—We examined differences in muscle damage and muscle performance perturbations in relation to the same volumes of high (HI) and low intensity (LI) of eccentric exercise. Untrained young healthy men ($n = 12$) underwent 2 isokinetic quadriceps eccentric exercise sessions, 1 on each randomly selected leg, separated by a 2-week interval. In the first session subjects performed HI exercise (i.e., 12 sets of 10 maximal voluntary efforts). In the second session, volunteers were subjected to continuous exercise of LI (50% of peak torque) until the total work done was approximately equal to that generated during HI. Muscle damage (serum creatine kinase concentration [CK], delayed onset of muscle soreness, and range of motion) and muscle performance (eccentric [EPT] and isometric peak torque [IPT]) indicators were assessed pre-exercise and 24, 48, 72, and 96 hours postexercise. Compared to baseline data, changes in muscle damage indicators were significantly different ($p < 0.05$) at almost all postexercise time points in both conditions. However, apart from the significant elevation of CK at 24 hours after HI ($p < 0.05$), no other significant differences were observed between the 2 exercise conditions ($p > 0.05$). The main finding in relation to muscle performance was that decrements following HI exercise were significantly greater ($p < 0.05$) compared to LI. Compared with baseline data, the EPT values following HI and LI exercise were as follows: 24 hours, 72.1% vs. 92%; 48 hours, 81.9% vs. 94.8%; 72 hours, 77.7% vs. 100.6%; 96 hours, 86.8% vs. 107.9%. The corresponding data for IPT were as follows: 24 hours, 86.4% vs. 102.8%; 48 hours, 84.2% vs. 107%; 72 hours, 84.8% vs. 109.2%; 96 hours, 86.8% vs. 114.4%. These results indicate that matching volumes of HI and LI eccentric exercise have similar effects on muscle damage, but HI has a more prominent effect on muscle performance.

KEY WORDS. isokinetic dynamometry, peak torque, creatine kinase, delayed onset muscle soreness, range of motion

Introduction

Eccentric exercise has been used as a means to develop strength and muscle size (7). However, both intensity and duration of eccentric exercise can affect aspects of muscle damage and muscle performance (31). Indeed, unaccustomed high-intensity (HI) eccentric exercise is associated with a decrease in selected muscle damage parameters including range of motion (ROM) (23), swelling (29), development of delayed onset of muscle soreness (DOMS) (13), and elevation of intracellular enzymes, such as creatine kinase (CK) and lactate dehydrogenase (2). HI eccentric exercise also causes decrements in muscle performance, as evident by the reduction in eccentric peak torque and peak isometric force (24). Muscle damage and muscle performance are further affected by medium-intensity eccentric exercise (10, 20).

Only 1 study has examined the magnitude of muscular damage and performance perturbations following both HI and low-intensity (LI) eccentric exercise (22). It was found that the same number of HI and LI repetitions produced greater initial muscle damage and force decrement following the HI, whereas the recovery rate was quicker after the LI eccentric exercise session. However, given that the total work done in the 2 exercise conditions was different, it could be argued that the work volume rather than the intensity of exercise confounded the reported data. The fact that arm muscles were used in the aforementioned study may have further influenced the findings.

No data are available on the effects of different intensities of eccentric exercise, characterized by the same work volume, on leg muscle damage and performance. However, such knowledge could help recreational or competitive athletes to create effective exercise programs for muscle strength and size development. Therefore, the purpose of the current investigation was to examine differences in muscle damage and muscle performance perturbations in relation to equal volumes of HI and LI quadriceps eccentric exercise.

Methods

Experimental Approach to the Problem

In order to address the primary hypothesis presented herein, we selected healthy men with no experience in any form of structured resistance training. Prior to and during their participation in the study, subjects maintained their usual nutritional and lifestyle habits but avoided any involvement in strenuous exercise activities. All subjects were assessed for muscle damage and muscle performance pre-exercise and 24, 48, 72, and 96 hours postexercise.

The within-subject design of our study has been based on a model previously used in investigations of similar nature (4, 22). Specifically, subjects underwent 2 isokinetic quadriceps eccentric exercise sessions, 1 on each randomly selected leg, separated by a 2-week resting interval, which has been previously shown to be adequate for the return of selected muscle damage characteristics to baseline levels (21). Eccentric exercise was either HI or LI in nature, with the former always preceding the latter, using the same angular velocity (1.05 radians per second). During HI sessions, subjects performed 12 sets of 10 maximal eccentric voluntary efforts with 2 minutes rest between sets. LI sessions consisted of continuous eccentric exercise at 50% of the individual subject's eccentric peak torque (EPT). Feedback on the exercise intensity was automatically provided by an isokinetic dynamometer. LI exercise ceased when the total work done was approximately equal to that generated during HI exercise (defined as "work volume", and expressed in watts), which was also automatically calculated by an isokinetic dynamometer. By controlling the work performed in each exercise condition, we were able to make comparisons in relation to muscle damage and muscle performance.

Subjects

Twelve healthy men (age, 21.0 ± 1.0 year; body mass, 78.6 ± 2.1 kg; and height, 179.5 ± 1.4 cm) volunteered to participate in this study. Subjects read and signed an informed consent form according to the standards of the Thessaly University Ethics Committee and the statement of protection of human subjects in the Declaration of Helsinki. Exclusion criteria included experience with scheduled eccentric exercise training, any form of resistance training for at least 6 months prior to this investigation, and use of anti-inflammatory drugs.

Testing Procedures

For each subject, 2 familiarization laboratory visits were followed by the 2 knee-extensor eccentric exercise sessions. Muscle damage (serum creatine kinase concentration [CK], delayed onset muscle soreness [DOMS], and ROM)and muscle performance (EPT and isometric peak torque [IPT]) indicators were assessed prior to and 24, 48, 72, and 96 hours post–eccentric muscle exercise. Preceding each exercise session, subjects performed a warm-up consisting of 8 minutes of cycling on a Monark cycle ergometer (Vansbro, Sweden) at 70 rpm and 50 W, followed by 5 minutes of stretching exercises.

Except for CK and DOMS, all studied parameters were assessed on an isokinetic dynamometer (Cybex Norm Lumex, Ronkonkoma, NY), which has been used in similar studies (24, 25). The dynamometer was calibrated weekly according to the instructions provided by the manufacturer, and the details of the assessment protocol appear elsewhere (16). The position of the seat was adjusted to suit the subjects' anthropometric characteristics and to align the knee joint flexion-extension axis with that of the dynamometer lever arm.

Muscle Damage Indicators

Creatine Kinase. Because serum CK is an intracellular enzyme and its release indicates muscle membrane damage, it has been extensively used in muscle damage assessments (5, 23). Blood samples were obtained prior to exercise and 24, 48, 72, and 96 hours postexercise, in line with previously published protocols (6, 13). Blood samples were drawn from an antecubital vein into plain evacuated test tubes. The blood was allowed to coagulate at room temperature for 30 minutes and was then centrifuged at 1,500*g* for 10 minutes. The serum layer was removed and frozen at −20° C until analyzed. CK was determined in duplicate using a commercial kit (Megalab, Athens, Greece). The normal reference range of CK concentration for men using this method is 45–130 U/L.

Delayed Onset of Muscle Soreness. Each subject determined soreness by palpation of the muscle belly and the distal region of the vastus medialis, vastus lateralis, and rectus femoris while in a seated position with muscles relaxed. Perceived soreness was then rated on a scale ranging from 1 (normal) to 10 (very, very sore), as previously documented (5, 13).

Range of Motion. The subjects lay prone on the isokinetic dynamometer with their knee joint against the lever arm. A passive flexion was performed by one of the investigators at a very low angular velocity (0.35 radians per second), and the position where the subject felt any discomfort was taken to indicate the end of the pain-free ROM.

Muscle Performance Indicators

For the purpose of this study, the previously used muscle performance indicators of EPT (24) and IPT (4) were adopted. Specifically, the best of 3 maximal voluntary efforts was recorded for both parameters using the isokinetic dynamometer described in the testing procedures above. EPT was conducted at 1.05 radians per second, while the thigh-shin angle of 110° was used for IPT assessments.

Statistical Analyses

The Kolmogorov-Smirnov test of normality revealed that none of the variables studied required logarithmic transformation. However, due to lack of homogeneity in variance, nonparametric analyses were applied for CK and DOMS as previously suggested (30). A 2 × 5 (intensity × time) repeated measures analysis of variance (ANOVA) and contrast test through simple main effects were used to analyze the remaining of the parameters studied. The significance level was set at $p \leq 0.05$. Data are reported as means ± *SEM*.

RESULTS

The total work for the quadriceps muscles during HI and LI sessions was 31,002 ± 1,764 W and 30,957 ± 1,768 W, respectively. These values were not statistically different ($p > 0.05$). Subjects were exercising at 83.3 ± 1.8 % and 50.0 ± 0.7 % of their pre-exercise EPT for HI and LI, respectively. The number of repetitions performed during LI sessions was 202 ± 7. No significant differences were found at baseline levels between HI and LI in any of the studied parameters.

Muscle Damage Indicators

Plasma CK (Figure 1) and DOMS (Figure 2) increased significantly ($p < 0.05$) at all time points after both exercise sessions. It is worth noticing that both of these parameters remained significantly above pre-exercise levels for the entire duration of the study, indicating sustained muscle damage. ROM (Figure 3) declined significantly ($p < 0.05$) at 24 hours after HI and LI eccentric exercise and at 48 hours after HI. However, apart from the significant elevation of CK at 24 hours after HI ($p < 0.05$), no other significant differences were observed between the 2 exercise conditions ($p > 0.05$).

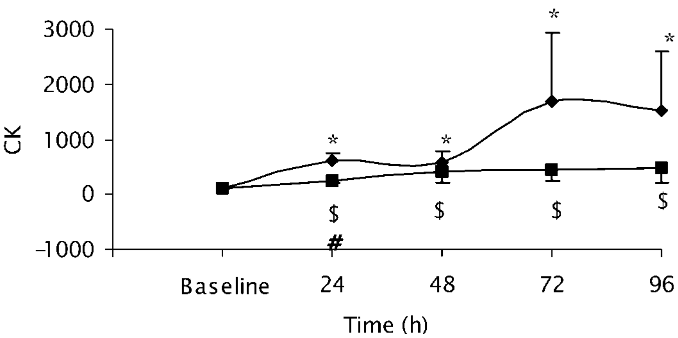

FIGURE 1. Percent (%) change of serum creatine kinase (CK) measured 24, 48, 72, and 96 hours after high-intensity (HI; ♦) and low-intensity (LI; ■) eccentric exercise training. Error bars denote *SEM*. * indicates significant change compared to baseline values after HI eccentric training; $ indicates significant change compared to baseline values after LI eccentric training; # indicates significant change between the 2 bouts.

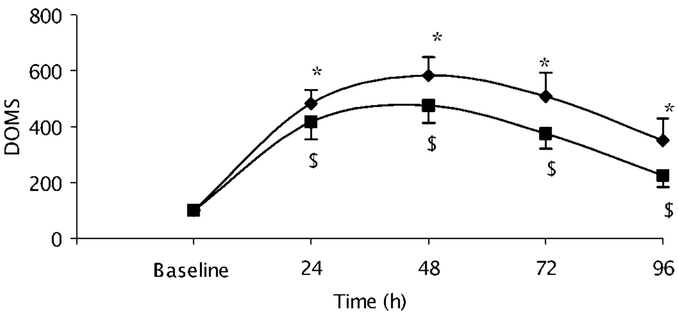

FIGURE 2. Percent (%) change of delayed onset muscle soreness (DOMS) measured 24, 48, 72, and 96 hours after high-intensity (HI; ♦) and low-intensity (LI; ■) eccentric exercise training. Error bars denote *SEM*. * indicates significant change compared to baseline values after HI eccentric training; $ indicates significant change compared to baseline values after LI eccentric training.

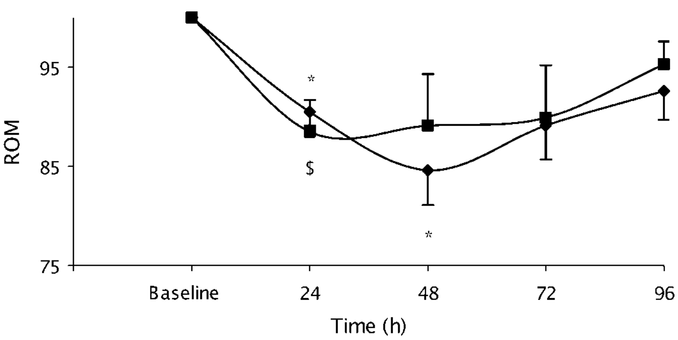

FIGURE 3. Percent (%) change of range of motion (ROM) measured 24, 48, 72, and 96 hours after high-intensity (HI; ♦) and low-intensity (LI; ■) eccentric exercise training. Error bars denote *SEM*. * indicates significant change compared to baseline values after HI eccentric training; $ indicates significant change compared to baseline values after LI eccentric training.

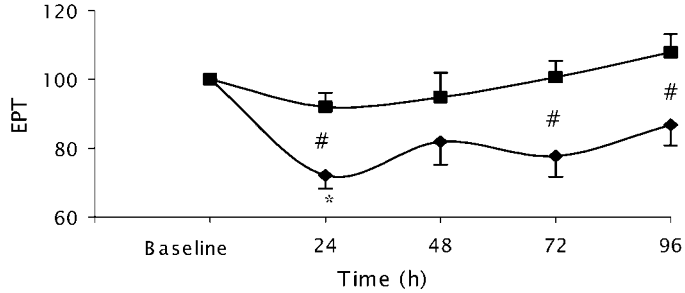

FIGURE 4. Percent (%) change of eccentric peak torque (EPT) measured 24, 48, 72, and 96 hours after high-intensity (HI; ♦) and low-intensity (LI; ■) eccentric exercise training. Error bars denote *SEM*. * indicates significant change compared to baseline values after HI eccentric training; # indicates significant change between the 2 bouts.

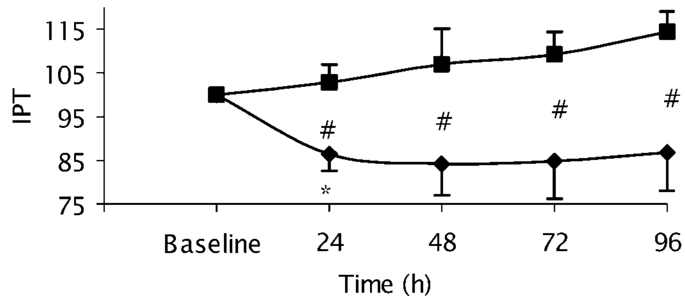

FIGURE 5. Percent (%) change of isometric peak torque (IPT) measured 24, 48, 72, and 96 hours after high-intensity (HI; ♦) and low-intensity (LI; ■) eccentric exercise training. Error bars denote *SEM*. * indicates significant change compared to baseline values after HI eccentric training; # indicates significant change between the 2 bouts.

Muscle Performance Indicators

Muscle performance parameters were significantly affected only by HI at 24 hours postexercise (Figures 4–5). However, unlike muscle damage, which revealed no differences between the 2 exercise bouts, HI resulted in greater declines in muscle performance compared to LI ($p < 0.05$) in almost all time points of assessment. It is worth mentioning that at 96 hours after HI eccentric training muscle performance parameters revealed declines by 14% in relation to baseline data (Figures 4–5). In contrast, at the same point of time following LI eccentric exercise these parameters recovered and eventually exceeded the baseline data by 8–15%.

DISCUSSION

The purpose of the current investigation was to examine differences in muscle damage and muscle performance perturbations in relation to matching volumes of HI and LI quadriceps eccentric exercise. Results indicated that HI and LI have similar effects on muscle damage. However, muscle performance was affected only by HI exercise.

These findings partly agree with the only set of comparable data in which HI eccentric exercise showed greater muscle damage and muscle performance changes compared with LI (22). Discrepancies between the 2 studies relate to muscle damage, which can be explained by methodological differences. Unlike the current investigation in which the same work volume was used in both HI and LI eccentric exercise, the former study adopted different work volumes for the 2 exercise conditions.

CK has previously been used as an indicator of muscle damage (5, 23). The significant elevation of CK at all time points after both exercise sessions suggests the damaging nature of both HI and LI during eccentric exercise. However, although the concentration of CK was higher after HI, the absence of significant differences (except at 24 hours) between the 2 sessions studied was probably due to high interindividual variability in the enzyme response. This has already been confirmed in both human (19) and animal (8) studies.

DOMS (12, 25) and ROM (27) have also been used as indirect indicators of muscle damage. These parameters have been associated with, among other things, muscle inflammation (11), muscle swelling (28), and activation of intramuscular receptors (17). In the current study, DOMS and ROM were similarly affected after both exercise bouts, indicating that HI and LI eccentric exercise results in similar levels of muscle discomfort. Given that the present volunteers were subjected to similar work volumes in the 2 exercise conditions, it could be argued that it is volume rather than intensity of exercise that brings about this muscle discomfort.

Eccentric (24) and isometric (26) peak torques have been used as means to evaluate muscle performance following different exercise protocols. We found that these parameters revealed greater declines after HI compared with LI at almost all time points of assessment. These results could be attributed to the fact that HI exercise recruits mainly type II muscle fibers, which were found to be more susceptible to damage compared to type I fibers (9, 14). Because evaluation of performance after the 2 exercise conditions involved only high-intensity efforts, it may be assumed that results were affected by the integrity of type II fibers. The present subjects were untrained individuals, which, given that reduced inactivity has been linked to lower number and size of type II fibers (18), may have further contributed to the current findings.

It is noteworthy that the present results are in contrast to most of the published data, which suggest an association between muscle damage and muscle performance (3, 22, 24, 25). We found that, while significant muscle damage was measured throughout the study, muscle performance was only affected at 24 hours post-exercise. The present study does not provide a clear understanding of the factors involved. However, the tendency of muscle performance parameters to recover faster than those of muscle damage fits with the suggestion that eccentric exercise principally damages the weak muscle fibers (15) and those near the end of their life cycle (1), leaving the stronger and younger ones less affected.

The fact that we exercised lower-body as opposed to upper-body musculature may have further contributed to the present findings regarding dissociation between muscle damage and muscle performance. Available evidence suggests that leg eccentric exercise (3, 4) brings about proportionally lower strength decrements than arm muscle exercise (24, 26). The fact that lower limbs are primarily used in daily activities involving eccentric contractions may account for this.

PRACTICAL APPLICATIONS

The present data suggest that equal volumes of HI and LI eccentric exercise can cause almost the same degree of muscle damage. It could be suggested, therefore, that it is volume rather than intensity of exercise that damages the muscle. The present data also indicated that muscle performance was affected in a significantly greater degree after HI compared to LI exercise. The latter finding has a strong applied element and can be very useful to recreational athletes, as HI exercise at the beginning of a training program could affect the progress in strength or muscle size. This finding may also be useful in competitive athletes returning to training after a long absence due to injury or prolonged holiday break. Using, for instance, LI eccentric exercise at the beginning of a preparation period can bring about advantages that eccentric exercise offers with minimal effects on performance.

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