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Effect of eccentric velocity on muscle damage markers after bench press exercise in resistance-trained men

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Aim. **The purpose of this study was to determine how the execution velocity of eccentric exercises affects postexercise muscle damage in resistance-trained males using free-weight exercises.**

Methods. **Twenty young males were divided by maximum eccentric strength into two groups: slow eccentric velocity (SEV, N.=10) and fast eccentric velocity (FEV, N.=10). Both groups performed four sets of eight repetitions with 70% of their one repetition maximum eccentric in a bench press exercise with a 2-minute rest interval between sets. Each group lifted an equal total volume load. The eccentric velocity was controlled to 3 seconds for the SEV group and 0.5 seconds for the FEV group. The 1RM test, delayed onset muscle soreness (DOMS), and creatine kinase (CK) activity were evaluated before and up to 96 hours postexercise.**

Results. **A significant reduction (compared with baseline values) in 1RM test was observed up to 48 hours postexercise for the FEV group, while a significant reduction for the SEV group was only observed at 24 hours. The FEV group had a significant increase in DOMS up to 72 hours postexercise while the SEV group experienced an increase lasting up to 48 hours. The serum CK activity increased significantly only at 72 hours postexercise for both groups. There were no significant differences for any of the indirect analyses of muscle damage when the values were compared between groups.**

Conclusion. **In conclusion, a six-fold difference in eccentric velocity was not sufficient to induce a difference in muscle damage when the total volume load was equalized. However, FEV required a longer period to recover neuromuscular performance when compared with baseline values.**

KEY WORDS: Exercise - Muscles - Resistance training.

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Eccentric actions performed at high intensity/volume or by individuals unaccustomed to regular physical exercise have been shown to result in muscle damage caused mainly by mechanical factors.[1-3] From a functional point of view, muscle damage can result in a reduction of neuromuscular function; a condition can last for several days post-exercise, depending on the magnitude of the muscle damage.[4] An increase in serum creatine kinase (CK) activity and the occurrence of delayed onset muscle soreness (DOMS) are also observed. These markers have been frequently used as indirect measures of muscle damage.[5, 6]

The manipulation of acute training variables, such as execution velocity of muscle action, might influence the magnitude of muscle damage and the decline in muscular performance.[7] Previous studies have demonstrated that fast eccentric velocity promotes a greater magnitude of muscle damage.[8, 9] However, there are studies that contradict this hypothesis.[10, 11] Unfortunately, it is difficult to compare these studies because the total volume of work that was applied was not equalized. Additionally, recent evidence suggests that the magnitude of muscle damage is related to the total volume of work (in isokinetic exercise) or load that is lifted (in free weight exercise).[12-14]

In studies with free weight exercises, the eccentric exercise intensity has frequently been assigned as a percentage of the one-repetition maximum (1RM) test.[14-16] However, Hollander et al.[17] demonstrated that maximal eccentric muscle action, which is evaluated using the one-repetition maximum eccentric (1RMecc) test, induces a greater strength capacity (20-60%) than the maximum concentric muscle action, which is evaluated using the 1RM test in resistance-trained men. Therefore, it is important to individualize eccentric muscle action when designing training sessions with free weights.

Few studies have analyzed the use of free weight exercises by the trained population in resistance training programs.[7, 18] Most experimental protocols have instead used isokinetic dynamometers to evaluate the effects of eccentric velocity in untrained individuals.[8-11] Thus, the direct application of these results in the gym and for trained individuals is uncertain.

As such, the aim of this study was to evaluate the effects of fast and slow eccentric velocities on neuromuscular performance (1RM tests), DOMS, and serum CK activity after an acute bout of bench press exercise in resistance-trained men. The total volume of load lifted was equalized between groups to eliminate load effects when measuring muscle damage.

Materials and methods

Subjects

In this study, 20 young men who were experienced in resistance training, were divided into two homogeneous groups (N.=10 for each group) by their maximum eccentric strength: slow eccentric velocity (SEV: age, 26.2±1.3 years; height, 174.7±2.5 cm; body mass: 76.3±7.1 kg; body fat, 10.9±1.2%; resistance training experience, 5.9±3.1 years) and fast eccentric velocity (FEV: age, 24.1±3 years; height, 175.7±3.3 cm; body mass: 80.0±10.5 kg; body fat, 12.3±5.4%; resistance training experience, 5.6±2.3 years). The number of subjects was determined using the data of changes in maximal eccentric strength from our pilot study; eight subjects per group were shown to be necessary based on effect size (1), alpha level of 0.05 and a power (1-β) of 0.80.

All the participants completed a health questionnaire and signed an informed consent document after being informed about the research and experimental protocol. This study was approved by the Research Ethics Committee of the Methodist University of Piracicaba (Protocol nº 21/11), and is in accordance with the legal requirements of the Declaration of Helsinki.

The following criteria were used for participation in the study: (a) at least one year of continuous resistance training experience; (b) no previous injuries that might interfere with the study; (c) no use of nutritional supplements containing creatine or anabolic steroids; and (d) height between 1.70 and 1.80 meters in order to ensure the same distance between hands during the bench press. To exclude any residual effects from previous exercise on the data, the participants were instructed to refrain from any exercise outside of the study, other than the activities of daily life. Participants were also instructed not to take any medications or nutritional supplements during the study.

Procedures

In the week prior to the experimental protocol, each subject visited the laboratory on three separate occasions before the main session; each visit was separated by at least 48 hours. During the first visit, the (baseline) maximum muscle strength of each subject was determined using the

1RM test. Subjects were then familiarized with maintaining the velocity of execution in the bench press exercise using only the bar (10 kg). Next, after 48 hours, each volunteer performed the 1RMecc test; this result was used to set the exercise intensity for the experimental protocol. Briefly, the subjects performed a warm-up of 2-3 sets of 5-10 repetitions per set at ~40-60% of the estimated 1RM before each protocol. The 1RM and 1RMecc tests were performed at a cadence of 3 seconds for the entire range of motion, with a metronome (set at 60 beats per minute) to control the pace.[17] Each test was performed with a maximum of five attempts and rest intervals of 3-5 minutes between each attempt. Five days after the last test session, the volunteers began the experimental protocol. The 1RM test was performed at specific times: 30 minutes and 24, 48, 72, and 96 hours after the beginning of the experimental protocol; DOMS and serum CK activity were assessed 30 minutes before (baseline) and 24, 48, 72, and 96 hours after the end of the protocol to indirectly measure muscle damage. All of the subjects were verbally encouraged to make maximal efforts during the experimental protocol and tests. The tests were performed in the following order: blood sampling, muscle soreness scale, and 1RM test. All of the experimental analyses were performed between 7:00 and 11:00 a.m.

The experimental protocol consisted of only the eccentric phase of movement in the bench press exercise. This phase was performed with 4 sets of 8 repetitions at 70% of 1RMecc with a 2-minute rest interval between sets. In the present study, all participants used an intensity of 70% of 1RMecc which corresponded to ~100% of 1RM. This was to ensure that both groups (SEV and FEV) completed a similar level of volume (4 sets x 8 repetitions, volume load equalized) while varying the velocity, and thus, the time under muscle tension, according to the data obtained from the pilot study. The velocity of execution was 3 seconds for the SEV group and 0.5 seconds for the FEV group (a time ratio of 6:1, similar to Chapman *et al.*[9]). The bar was raised to the initial position of the eccentric exercise in 2 seconds, with the aid of two assistants. A metronome, set at 60 and 120 beats per minute for the SEV and FEV groups, respectively, was used to control the velocity of movement execution. The cadence of movement was also directed using simultaneous verbal instruction.

Delayed onset muscle soreness

Muscle soreness was assessed as a subjective perception of muscle soreness by palpation and slight stretching of the pectoralis major muscle. The palpation was applied by the investigator with the tips of three fingers to the middle and upper third of the pectoralis major for about 3 seconds. The stretch was performed by passive horizontal abduction of both arms by the investigator. The subjects reported their perceived soreness as a value on a scale ranging from 0 to 6 (0=no soreness; 1=dull feeling of soreness; 2=light, continuous soreness; 3=more than light soreness; 4=annoying soreness; 5=severe soreness; 6=intolerable soreness); intermediate values were also permitted. The average of the values that were reported for the palpation and slight stretch were used for data analysis as described by Hackney *et al.*[19] The same investigator assessed the muscle soreness in all subjects.

Blood samples

Blood samples were obtained by venipuncture with dry vacuum (Becton Dickinson, Juiz de Fora, Brazil). The samples were allowed to clot at room temperature for 30 minutes. The serum was separated by centrifugation at 2000 rpm for 20 minutes at 4 °C and was stored at -70 °C for subsequent analysis. Serum CK activity was measured using automated equipment (Konelab 60i; Wiener Lab, Rosario, Argentina) at 37 °C and a test kit (Wiener Lab, Rosario, Argentina). The reference value for serum CK activity using this method was 195 $U \cdot L^{-1}$. The intra-assay coefficient was 4.9% and the inter-assay was 3.9%.

Statistical analysis

Normality and homogeneity of variances of the data were confirmed by the Shapiro-Wilk and Levene's test, respectively. All data are presented as a mean±standard deviation (SD). Then, a two-way repeated measure of analysis of variance (ANOVA) was performed to compare the changes in the outcome measures over time between the systems. For significant interaction effects, a Tukey's post-hoc test was performed for multiple comparisons. Independent *t*-tests were used to compare the total volume of load lifted by each group and the maximum muscle strength baseline tests. The significance was set at 5%. Cohen's formula for effect size (ES) was used and the results were based on the following criteria: <0.35 trivial effect; 0.35-0.80 small effect; 0.80-1.50 moderate effect; and >1.50 large effect, for recreationally resistance-trained subjects, according to Rhea.[20]

Results

No statistically significant differences between the groups (SEV and FEV) were evident for age (P=0.069), body mass (P=0.443), height (P=0.558), percentage of body fat (P=0.445), experience with resistance training (P=0.439), and initial maximum muscle strength, evaluated before the experimental protocol for 1RM (88.8±13.5 kg and 98.4±16.7 kg, respectively, P=0.133) and 1RMecc test (125.4±18.4 kg and 136.9±20.6 kg, respectively, P=0.219). The load values from the 1RMecc tests were significantly higher when compared with those from the 1RM test for the SEV (ES=2.27, P<0.0001) and FEV (ES=1.92, P<0.0001) groups, respectively. However, there were no significant differences when comparing the values from the 1RM (ES=0.70, P=0.133) and 1RMecc (ES=0.57, P=0.219) tests between the two groups.

The total volume load (sets x repetitions x load [kg]) of the eccentric exercise session was similar between groups (P=0.219), with 3,064±153 kg and 2,809±130 kg for the FEV and SEV groups, respectively.

Maximum muscle strength (1RM test)

The SEV group showed significant declines in maximum muscle strength 30 minutes (ES=0.53, P<0.001) and 24 hours post-exercise (ES=0.54, P<0.001) when compared with the baseline values. The FEV group showed a significant decrease in maximum muscle strength 30 minutes (ES=0.53, P<0.001), 24 hours (ES=0.48, P<0.001), and 48 hours (ES=0.37, P<0.01) postexercise. Regarding recovery time, the SEV group returned to the baseline values within 48 hours postexercise, while the FEV

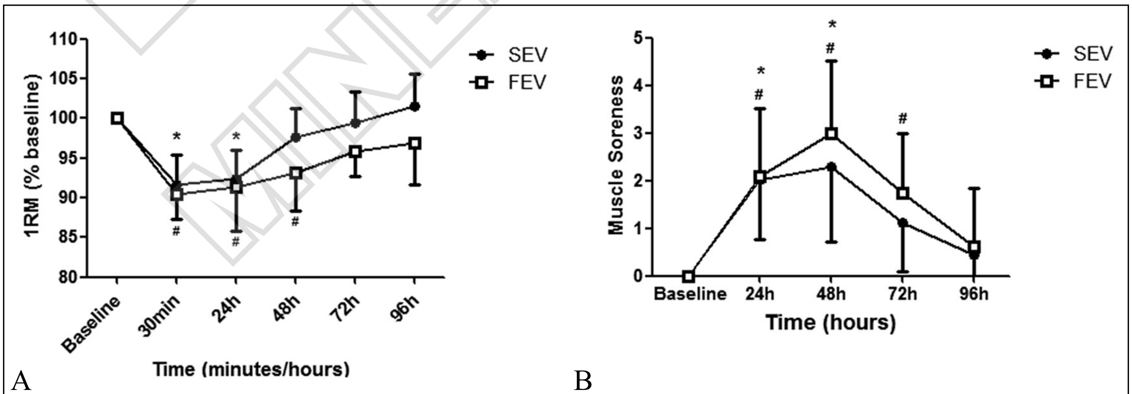

Figure 1.—Mean and standard deviation of the time course of (A) normalized one-repetition maximum (1RM) bench press (data are expressed as the percentage [%] change from the baseline values) and (B) delayed onset muscle soreness (DOMS) at the following times: baseline, 30 minutes, and 24, 48, 72, and 96 hours postexercise. # significant difference (P<0.05) compared with the baseline values for the FEV group;* significant difference (P<0.05) compared with baseline values for the SEV group.

group took 72 hours. When comparing the values of maximum muscle strength between the two groups, we found no significant differences at any time post-exercise. Figure 1A presents the changes in normalized 1RM bench press.

Delayed onset muscle soreness

DOMS increased significantly 24 ($P<0.001$), 48 ($P<0.001$), and 72 ($P<0.01$) hours post-exercise in the FEV group when compared with the baseline values. The SEV group had significantly higher DOMS after 24 ($P<0.001$) and 48 ($P<0.001$) hours post-exercise. The peak values were reached 48 hours post-exercise for both groups. There were no significant differences between the two groups at any time post-exercise (Figure 1B).

Serum CK activity

As show in Table I, both the SEV and FEV groups had significant increases ($P<0.05$) in serum CK activity and reached peak values 72 hours postexercise. No significant differences were found at any time post-exercise when comparing the serum CK concentrations between the two groups.

Discussion

The aim of this study was to evaluate the effects of fast and slow eccentric velocities on neuromuscular performance (1RM tests), DOMS, and serum CK activity after an acute bout of bench press exercise in resistance trained men. The main finding of this study is that there were no significant differences between the two groups (FEV and SEV) on the indirect markers of muscle damage, indicating that the velocity of eccentric muscle action did not influence the magnitude of muscle damage when the total volume of loads was equalized.

These findings are similar to a study using isokinetic protocols by Chapman et al.[9] which assessed the influence of eccentric velocity on the behavior of indirect markers of muscle damage. This study reported that the impact of eccentric velocity was not evidenced on the magnitude of muscle damage when the number of eccentric muscle actions was less than 30 repetitions.

Alternatively, the velocity of eccentric action exerted a significant influence on the recovery time for neuromuscular performance posteccentric exercise in resistance-trained men. This data may be observed in Figure 1 where the time to recover to baseline values for the FEV group was slower (72 hours) compared with the SEV group (48 hours). Although there was no significant interaction between groups, a time effect is an important variable for the trained population. This group requires optimal recovery time for neuromuscular performance between resistance training bouts. Therefore, during fast eccentric muscle actions the acceleration of the external load could increase the magnitude of mechanical stress[21] thereby influencing the time needed to recover to baseline values.

As previously indicated in the literature, eccentric exercise promotes DOMS and increases CK activity in response to muscle damage.[5, 6] In the present study, serum CK activity reached peak values 72 hours post-exercise with significant increases (compared with the baseline values) of 130% and 173% in the SEV and FEV groups, respectively. The muscle soreness values demonstrated that both groups significantly developed DOMS with peak values observed at 48 hours (Figure 1B). These data indicate that both velocities induced muscle dam-

TABLE I.—*Mean±SD and P value of the SEV and FEV groups postexercise for serum cretine kinase activity (U/L^{-1}).*

Group	Baseline	24 hours	48 hours	72 hours	96 hours
SEV (U·L^{-1})	226.8 ± 154.1	449.8 ± 262.1	439.4 ± 289.7	521.9 ± 486.2 *	397.3 ± 307.8
FEV (U·L^{-1})	185.1 ± 85.6	261.3 ± 103.9	446.0 ± 371.1	506.4 ± 404.4 *	406.8 ± 269.6

SEV: slow eccentric velocity; FEV: fast eccentric velocity; *significant difference ($P<0.05$) compared to baseline values.

age. However, there were no significant differences between the groups, which demonstrate that the eccentric velocity did not influence the magnitude of DOMS or serum CK activity in resistance-trained individuals. Possibly the homogeneity between groups (SEV and FEV) along with neuromuscular adaptations promoted by long periods of resistance training [22] explain why we could not uncover differences between velocities using equalized loads. Both the number of repetitions and the total volume load were not significantly different between the two groups.

Our data are corroborated by a study by Barroso *et al.*[10] who did not observe significant differences in the indirect markers of muscle damage between slow and fast eccentric velocities in untrained men. This group reported these results using a protocol where the total work produced in an isokinetic exercise was not different between groups.

Our results differ from those obtained by Chapman *et al.*[8] who investigated muscle damage with fast and slow eccentric velocities equalizing the time under muscle tension between groups in untrained men and women. The results revealed that FEV led to a greater magnitude of muscle damage compared to SEV. However, the total volume repetitions (SEV=30 and FEV=210 repetitions) and work (SEV=56.6 and FEV=373.2 J) in the isokinetic exercise differed between the two groups, factors that may have influenced the results.

Additionally, Ide *et al.*[7] investigated the influence of the velocity of dynamic muscle actions (eccentric and concentric) with free-weight exercises for the lower limbs in resistance-trained men. The results indicated that fast velocity of movement resulted in a significant decrease in neuromuscular performance (measured with a horizontal jump and a 1RM test) for a longer period of time post-exercise compared to the slow velocity of movement. This suggests a greater magnitude of muscle damage from fast velocity of movement. However, the total volume load performed by the groups was not reported. This fact may have influenced the results and precludes a comparison with our data.

The load values from the 1RM and 1RMecc tests showed that the maximum muscle strength generated for the eccentric muscle actions was 42% greater than that of the concentric muscle actions. Our data are supported by the results of Hollander *et al.*[17] who evaluated maximum eccentric and concentric muscle strength using free-weight exercises and demonstrated differences of 20-60% between eccentric and concentric muscle actions in resistance-trained men. These results indicate the importance of eccentric muscle strength in determining the intensity of exercise protocols with free weights.

Our study has some limitations that need to be addressed. First, different cadences (3 and 0.5 seconds) have a specific inertial component and a different force-velocity relationship. Second, the 1RMecc test involved maximal eccentric muscle action prior to the experimental protocol, a stimulus that can possibly induce a repeated bout effect.

It has been reported that only a small number of eccentric muscle actions, even if they are submaximal, may result a significant protective muscle effect.[23-25] However, these studies involved the participation of sedentary and/or untrained individuals, therefore not providing a direct application to the resistance-trained population.

During the training process, adaptations occur at the level of the muscle fibers, connective tissue, and the neural system. These adaptations have been implicated as possible adaptive mechanisms that may improve the repeated bout effect.[26, 27] Therefore, we employed volunteers were already well adapted to resistance training prior to our tests.

However, symptoms arising from muscle damage persist even in athletes and/or well-trained individuals, although to a lesser degree than in untrained individuals.[28] Therefore, our results provide an innovative method for obtaining data with free-weight exercises, a method that can be employed in the resistance-trained population.

Conclusions

In conclusion, the results of this study demonstrate that a six-fold difference in eccentric velocity was not sufficient to induce a significant difference in the indirect markers of muscle damage when the total volume load was equalized. However, FEV required a longer period to recover neuromuscular performance, when compared with baseline values.

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