Rest Interval Between Resistance Exercise Sets: Length Affects Volume But Not Creatine Kinase Activity or Muscle Soreness

Renato Evangelista, Rafael Pereira, Anthony C. Hackney, and Marco Machado

Purpose: To compare differences between two different rest interval lengths between sets on the volume completed, muscle damage and muscle soreness during a resistance exercise bout. Methods: Twenty-eight healthy sedentary men (18 ± 1 y old) volunteered to participate in this study and were divided into the 1 min (1RI; n = 14) or 3 min (3RI; n = 14) rest interval length between sets. They were submitted to maximal voluntary isometric contraction strength (MVC) and then performed a resistance exercise protocol constituted for three sets of biceps curl at 40% of MVC with 1 min (1RI group) or 3 min (3RI group) interval length between sets. Each bout was performed to voluntary fatigue and the workout volume completed was calculated. Subjects provided blood samples before each bout, and at 24, and 48 h following exercise to evaluate serum CK activity. Muscle soreness was analyzed through visual analog scale, which was presented to subjects before first bout, immediately after exercise protocol and at 24, and 48 h following exercise. Results: The results demonstrated that the subjects with longer rest intervals provide greater workout volume as expected, but there were no differences in serum CK activity and muscle soreness between groups. Conclusion: Training with high-volume, low-intensity resistance training, exercising with short rest intervals does not appear to present any additional challenge to recovery in untrained subjects.

Keywords: recovery time, exercise volume, muscle damage, muscular stress, biochemical markers

The rest interval length between sets is one of the variables used when designing a program for resistance training just as is intensity, number of sets and repetitions (ie, volume), order of exercises, movement velocity and training frequency. The manipulation of the rest interval length variable is closely linked with the key objec-
tive proposed in resistance training programs, mainly manipulating the amount of work to be done in a training session. Despite the knowledge of the importance of this variable on physiological and biochemical responses, it has been poorly monitored in research.\textsuperscript{1–3} Previous studies have examined the impact of rest interval lengths of 1 to 5 min duration between sets for single and multiple exercises.\textsuperscript{4–11} These studies demonstrated that the shorter the rest interval length the smaller will be the volume of work performed during a training session when it is done until volitional fatigue.

Serum creatine kinase (CK) activity has been studied extensively and is considered a qualitative marker for skeletal muscle microtrauma.\textsuperscript{12,13} Interestingly, conflicting results appear in the literature when comparing the serum CK activity to resistance exercises when they are performed with different rest interval lengths. Mayhew et al\textsuperscript{14} observed the CK activity in men after 10 sets of 10 repetitions of leg press (65% 1RM) using either a 1 and 3 min rest between sets, the group which executed the sets with rest interval of 1 min had a higher CK elevation than the group who performed with longer intervals (3 min). However, Rodrigues et al,\textsuperscript{15} Machado et al\textsuperscript{16} and Ribeiro et al\textsuperscript{17} observed no differences in CK activity between research groups after completing a session of resistance exercise with different intervals lengths. Pain and soreness are also common complaints after resistance exercise protocols and are associated with muscle damage. In fact, delayed onset muscle soreness after exercise has been extensively studied and is associated with the amount of muscle damage and subsequent local inflammatory processes.\textsuperscript{14,18}

Many aspects of how resistance exercise training parameters effect muscle damage and soreness have been studied. But, the effects of the rest interval length on exercise induced microdamage and muscle soreness still in need of further study due to the existence of conflicting findings. Therefore, the objective of this study was to determine how the rest interval lengths of 1 and 3 min between sets of biceps curls exercise affected the total volume of work performed, serum CK activity and muscle soreness level.

\section*{Methods}

\section*{Subjects}

The study subjects consisted of twenty-eight healthy sedentary men between 18 and 20 y old. They indicated they were not currently using medical drugs, dietary supplements, or anabolic steroids, and were without joint, muscular or cardiovascular diseases. The experimental conditions were conducted in accordance with the norms of the Brazilian National Health Council, under Resolution No. 196, promulgated on 10 October 1996, referring to scientific research on human subjects and Helsinki Declaration (1964, reformulated in 1975, 1983, 1989 and 1996) of the World Medical Association (http://www.wma.net/e/policy/17-c_e.html) and the subjects participated voluntarily.

\section*{Design}

Subjects were divided according to a computer generated randomization process into the 1 min (1RI; \( n = 14 \)) or 3 min (3RI; \( n = 14 \)) rest interval length between sets groups. Comparisons of both protocol groups in terms of age, height, body,
and weight was done before initial strength testing and they were found to be not significantly different from one another \((P > .05)\). Descriptive characteristics of the subjects are displayed on Table 1.

### Methodology

To determine the weight (ie, resistance setting) for exercise protocol, each subject was seated on a custom-made preacher curl bench with his shoulder joint angle at 45° (0.79 rad) flexion with 0° abduction, and a bar connected to a load cell (EMG System Brazil, Sao Jose dos Campos, SP) was held with both arms. The elbow joint angle was set at 90° (1.57 rad), and the subject was asked to flex the elbow joint maximally while keeping the forearm supinated. This measurement was taken immediately before the exercise experimental protocol, three times with a 45 s rest between trials for each occasion, and the average of the three measurements was used to determine the weight for the exercise protocol, which was set as 40% of the subject’s maximal voluntary isometric contraction strength (MVC). The MVC was used, rather than the 1-RM, in order to minimize the influence on serum CK through the repeat bout effect and 40% of MVC was chosen based upon recommendations in the literature.19

The exercise experimental protocol constituted of three sets of biceps curl at 40% of MVC with a 1 min (1RI group) or 3 min (3RI group) rest interval length between sets. The subjects were instructed to extend the elbows from an elbow flexed (50°, 0.87 rad) to an extended position (170°, 2.97 rad) and return to the flexed position in 4–5 s (approx. 2 s to each concentric and eccentric phase). Subjects were then verbally encouraged and guided to maintain a consistent velocity by following the count given by the investigator. Each bout was performed to voluntary exhaustion and the numbers of repetitions per set were recorded.

### Muscle Soreness

The level of muscle soreness from the exercised arm was assessed using a visual analog scale consisting of a 100 mm line representing “no pain” at one end (0 mm), and “very, very painful” at the other (100 mm). The subjects were asked to indicate the level of pain on the line when the investigator extended the elbow joint maximally. The same investigator assessed the muscle soreness each time for all subjects to eliminate inter-investigator error. The muscle soreness was assessed four times: before, immediately after, 24 h after and 48 h after the exercise protocol.

### Table 1  Anthropometric and physical characteristics of the subjects

<table>
<thead>
<tr>
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<th>RI1 ((n = 14))</th>
<th>RI3 ((n = 14))</th>
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<tr>
<td>Age (y)</td>
<td>18.3 ± 0.5</td>
<td>18.5 ± 0.7</td>
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<tr>
<td>Weight (kg)</td>
<td>64.7 ± 9.5</td>
<td>67.9 ± 12.8</td>
<td>0.466</td>
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<tr>
<td>Height (cm)</td>
<td>173 ± 5</td>
<td>177 ± 8</td>
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Blood Samples Analyses

Blood samples were obtained from the subject while in a seated position from antecubital vein. Samples were placed into plain evacuated tubes. Samples were collected before exercise, after an 8h overnight fast before each bout, and at 24, and 48 h following exercise. Immediately following collection, blood samples were centrifuged at 1600 × g for 20 min. The serum was removed and the serum CK activity was analyzed with an enzymatic method at 37°C (CK-UV NAC-optimized; Biodiagnostica, Brazil) in a Cobas Mira Plus analyzer (Roche—Germany). The delta for CK activity was calculated by subtracting the baseline value from the highest value obtained (ie, at 24 or 48 h) after the exercise protocol. The CK assessments procedures demonstrated high reliability on quality control standards (intraclass r = .87).

Statistical Analysis

Data are presented as means (±SD). Comparisons of characteristics between groups were performed with Student’s t test. To compare repetitions and volume, a 2 (groups) × 3 (sets) ANOVA were utilized. To compare serum CK activity and muscle soreness, a 2 (groups) × 3 (CK) and a 2 × 4 (muscle soreness assessments times) ANOVA were utilized. The alpha level was set at less than 0.05 for a difference to be considered significant. Significant effects were further analyzed using pairwise comparisons with Tukey’s post hoc. The reliability of the MVC and CK activity assessments was assessed with the intraclass correlation (ICC) and the reliability was described as “excellent” for ICC values in the range of 0.8–1.0 and “good” for 0.6–0.8, whereas values below 0.6 were “poor.”20 The relationship between delta CK activity and total volume completed was performed using Pearson Correlation. Statistical procedures were carried out with software package SPSS (13.0) for Windows.

Results

The maximal voluntary isometric contraction strength (MVC) was measured three times and the reproducibility of the tests were assessed. No differences were found between groups for MVC and the responses were highly reproducible (Table 2).

The number of repetitions per set and the volume for work performed is shown in Figures 1 and 2. The 1RI group display 56% lower (P < .001) repetitions and 65% lower repetitions (P < .001) per set, in 3RI group the reduction was 46% (P

<table>
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<th>Table 2 Results for each maximal voluntary isometric contraction strength (MVC) (kgf), mean, and reliability between tests</th>
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< .001) and 60% (P < .001). The number of repetitions in the second set displays a significant difference between groups (P = .034), but in third set the difference was not significant (P = .174). The 1RI group display 56% lower (P < .001) and 64% lower (P < .001) volume per set, in the 3RI group the reduction was 45% (P < .001) and 60% (P < .001). The total volume per set in the second set displays a significant difference between groups (P = .034), but in third set the difference was not significant (P = .149).

The 2 × 3 ANOVA revealed no significant interaction between rest interval length and measurement time for CK activity (P = .963). However, CK activity increased significantly at 24 h (P < .001 for RI1; P < .001 for RI3) and 48 h (P < .001 for RI3).

Figure 1 — Mean (±SD) of repetitions per set. (a) Different from set 1 (P < .05); (b) Different from set 2 (P < .05).

Figure 2 — Mean (±SD) of volume (repetitions × load) per set. (a) Different from set 1 (P < .05); (b) Different from set 2 (P < .05). *Difference between groups (P < .05).
.001 for RI1; *P* < .001 for RI3) when compared with preexercise measure in both
groups (Figure 3). The same result was found for muscle soreness (Figure 4).

No significant relationships were found between delta CK activity and total
volume for 1 RI (*r* = .04) or 3 RI (*r* < .01). Neither of these correlation coefficients
were significant (*P* > .05).

**Figure 3** — Delta serum CK activity (mean ± SD). (a) Different from 0 (*P* < .05).

**Figure 4** — Muscle soreness (mean ± SD). (a) Different from 0 (*P* < .05); (b) Different
from post (*P* < .05).

**Discussion**

Serum CK activity commonly serves as a marker of the status of muscle fiber
membrane damage following bouts of strenuous exercise.12,13 Serum CK activity
can be elevated for 24 h following exercise bouts, with a gradual return to the basal
levels in 72-96 h.18,22 The current study corroborates with previous investigations on
this trend. That is CK activity was significantly elevated above preexercise levels
at 24 h, and 48 h postexercise. Our results represent a typical resistance response where the subjects tend to be submitted to standard exercise, unlike many studies which use isokinetic exercises. Thus the present results obtained under this design display findings which could be used by coaches and fitness professional in day-to-day exercise prescription and evaluation.

We did not identify differences in serum CK activity between groups which corroborates with the findings of others. However, the present result does not agree with the findings of Mayhew and colleagues. In Mayhew’s study the subjects performed leg press exercises and the total work had been equalized between short and long rest interval conditions, whereas in this study each group performed bicep curls to volitional fatigue for each set (intervals modulate the number of sets and the total volume) for the biceps curl exercise. In addition, Saka and colleagues demonstrated that the upper and lower body differently modulates the activity of serum CK (lower body exercise results display lower CK activity variation when compared with upper body), which can explain some of the differences we have from that of Mayhew and colleagues.

Our findings are further supported by Hudson et al. They examined oxidative stress markers in response to two resistance exercise protocols. In their study, subjects completed two bouts of back squat exercise in a randomized order. One bout was a hypertrophy protocol (4 × 10 repetitions at 75% 1RM with 90 s rest intervals), the other bout was a strength protocol (11 × 3 repetitions at 90% 1RM with 5 min rest intervals). The two bouts were equalized in terms of the total amount of work (Joules) completed. Similar to the present study, Hudson et al originally hypothesized that the hypertrophy bout, due in part to its shorter rest intervals, would elicit a higher oxidative stress response. However, like us, they were surprised to find that there were no differences in the presence of plasma biomarkers of oxidative damage (lipid hydroperoxides and protein carbonyls) between the bouts. The subjects in Hudson et al were well trained before the experiment (average back squat 1RM = 1.9 × body mass), although no specific mention was made of the rest intervals with which they were accustomed to in their training. Based on these findings, Hudson et al concluded that moderate-(hypertrophy) or high (strength) intensity back squats yield similar oxidative damage responses. Although our study was limited to the measurement of serum enzymes as markers of muscle damage, we suspected free radicals to contribute to the extent of muscle damage and that, in part, was why we hypothesized that shorter rest intervals would induce higher levels of serum CK activity. Our finding of similar CK levels, regardless of rest interval, lead us to conclude that perhaps our choice of resistance exercise was of an insufficient load to produce the mechanical stress to induce enough chemical damage from free radicals with the shorter rest intervals. This may be a limitation to our design protocol. Nevertheless, our findings, along with Rodrigues et al, Ribeiro et al, and Hudson et al, suggest that interval length is not a determining factor in the extent of postexercise muscle damage. Yet more definitive work is necessary on this topic before more conclusive interpretations can be reached.

The analysis of muscle soreness demonstrated an increase of pain complaints immediately after the exercise protocol, which was maintained up to 48 h in both groups. Similarly to the serum CK activity, pain complaints were not different between groups (1RI vs 3RI). The greater workout volume completed for the group 3 min may justify the maintenance of the pain complaints for a longer time into recovery. It is important, however, to note that the pain perception is subjec-
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tive and its evaluation causes a great variation on muscle soreness, which possibly influenced the statistical procedures.

Buresh et al\textsuperscript{26} proposes the differences caused by exercise with short versus long rest intervals will depend less on the rest interval employed and more on the total volume (sets $\times$ repetitions per set $\times$ load) of work completed. We tested this by examining the correlation between total volume (sets $\times$ repetitions per set $\times$ load) with delta of serum CK activity. Our results display no correlation ($r = .036$ and $r = .003$, for 1 and 3 min intervals respectively) between measures. These data are difficult to interpret because the variation of CK induced by exercise is great among the population and may depend on age, sex, and there are subjects which present disproportional alteration of serum CK activity.\textsuperscript{16,27} That is, there are so-called high responders (HR) and normal responders (NR) have dramatically different responses in serum CK activity independent of the volume of work. The factors associated with this disproportional CK release by HR have not been elucidated yet. What is known is that the analysis of individuals without the separation of groups (ie, HR vs NR) can perhaps create erroneous results and a lack of proper comprehension of the phenomena being observed.

**Conclusion**

The results of the current study add to the growing body of knowledge regarding acute responses to different rest intervals between resistance exercise sets. Results show if sufficient time is available, instituting longer rest intervals (eg, 3 min) allows for greater repetitions and total workout volume versus a shorter rest interval (eg, 1 min). Regarding the series of resistance exercises examined in the current study, it is not known whether resting more than three minutes between sets would further increase the workout volume completed. There might be a point of diminishing returns at which the rest interval between sets would become excessive, and yield no further increases. This last point, however, needs to be invested further.

**Practical Applications**

The data from the current study would be useful when prescribing resistance exercise and determining a sufficient recovery between training sessions. If recreationally trained men are performing multiple sets of full repetition maximums, greater than 3 d (ie, 72 h) between workouts for the same muscle groups might be necessary to allow for sufficient muscle repair, recovery, and ultimately adaptation. However, if the men are accustomed to training with short rest intervals, the length of rest interval between sets does not appear to have any effect on the extent of muscle damage. Thus, at least to untrained subjects, training with high-volume, low-intensity resistance training, exercising with short rest intervals does not appear to present any additional challenge to recovery.

**References**

