Effect of rest interval length on the volume completed during upper body resistance exercise

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Abstract

The purpose of the current study was to compare the workout volume (sets x resistance x repetitions per set) completed during two upper body resistance exercise sessions that incorporated 1 minute versus 3 minute rest intervals between sets and exercises. Twelve trained men completed two experimental sessions that consisted of 5 upper body exercises (i.e. barbell bench press, incline barbell bench press, pec deck flye, barbell lying triceps extension, triceps pushdown) performed for three sets with an 8-RM load. The two experimental sessions differed only in the length of the rest interval between sets and exercises; one session with a 1-minute and the other session with a 3-minute rest interval. The results demonstrated that for each exercise, significantly greater workout volume was completed when resting 3 minutes between sets and exercises ($p < 0.05$). These results indicate that during a resistance exercise session, if sufficient time is available, resting 3 minutes between sets and exercises allows greater workout volume for the upper body exercises examined.

Key words: Recovery, fatigue, strength, muscle endurance, weight training, strength training.

Introduction

Resistance training can increase maximal strength, hypertrophy, power, and localized muscular endurance. The prescriptive variables are numerous, and may include: exercise order, rest intervals between sets and exercises, frequency, velocity of movement, number of sets and repetitions, and load or intensity. All of these variables can be manipulated to meet specific training goals and address individual needs (American College of Sports Medicine, 2002; Baechle and Earle, 2000; Fleck and Kraemer, 2004; Weiss, 1991).

According to Fleck and Kraemer (2004), the length of the rest interval between sets is an important variable when designing a resistance exercise program. Although acknowledged, this variable is rarely monitored precisely in field settings, despite its significant impact on acute and chronic metabolic, hormonal, and cardiovascular responses to resistance training (American College of Sports Medicine, 2002; Baechle and Earle, 2000; Fleck and Kraemer, 2004; Weiss, 1991).

Previous studies that examined rest interval lengths from 1 to 5 minutes between sets for single exercises demonstrated significant differences in repetition performance and the exercise volume completed (Kraemer, 1997; Larson and Potteiger, 1997; Ratamess et al., 2007; Rahimi, 2005; Richmond and Godard, 2004; Willardson and Burkett, 2005; Willardson and Burkett, 2006a; Willardson and Burkett, 2006b).

Ratamess et al. (2007) compared differences in workout volume (resistance x repetitions per set) over five sets of the bench press exercise when performed at two different intensities (i.e. 75% and 85% of a 1-RM) and with five different rest intervals between sets (i.e. 30 seconds, 1, 2, 3, 5 minutes). The findings demonstrated that irrespective of the intensity, workout volume (resistance x repetitions per set) significantly decreased with each set in succession over five sets when 30 seconds and 1 minute rest intervals were used. Workout volume (resistance x repetitions per set) was maintained over two sets for 2 minutes, three sets for 3 minutes, and fours sets for 5 minutes. Consequently, the authors recommended that if more than 2 to 3 sets of an exercise are performed, then at least 2 minutes of rest might be needed to minimize loading reductions and maintain repetition performance for the sets performed at the end of a workout.

However, a limitation of Ratamess et al. (2007) and similarly designed studies (Kraemer, 1997; Larson and Potteiger, 1997; Rahimi, 2005; Ratamess et al., 2007; Richmond and Godard, 2004; Willardson and Burkett, 2005; Willardson and Burkett, 2006a; Willardson and Burkett, 2006b) was the examination of single exercises, when typical resistance sessions consist of multiple exercises for the same muscle groups (American College of Sports Medicine, 2002; Baechle and Earle, 2000; Fleck and Kraemer, 2004; Weiss, 1991). There is a great need for further research to compare the volume completed over an entire resistance exercise session with different rest intervals between sets. This would contribute to general recommendations regarding resistance exercise prescription to maximize volume; an important factor in developing maximal strength (American College of Sports Medicine, 2002; Baechle and Earle, 2000; Fleck and Kraemer, 2004; Weiss, 1991). Therefore, the purpose of the current study was to compare the workout volume completed during two upper body resistance exercise sessions that incorporated 1 minute versus 3 minute rest intervals between sets and exercises.

Table 1. **Total workout volume (sets x resistance x repetitions per set) for 1 min. versus 3 min. conditions. Data are means (±SD).**

Session	BBP (kg)	IBBP (kg)	PDF (kg)	BLTE (kg)	TPD (kg)
1 min.	1334 (405)	691 (241)	506 (202)	460 (190)	394 (145)
3 min.	1527 (468) *	1118 (329) *	776 (252) *	619 (227) *	655 (246) *

BBP = barbell bench press; IBBP = incline barbell bench press; PDF = pec deck flye; BLTE = barbell lying triceps extension; TPD = triceps pushdown. * Significant difference total workout volume 1 min. versus 3 min. condition ($p < 0.05$).

Methods

Experimental approach to the problem

In order to examine the effect of different rest intervals on the workout volume completed (sets x resistance x repetitions per set), an 8-RM was assessed on three nonconsecutive days for the barbell bench press (BBP), incline barbell bench press (IBBP), pec deck flye (PDF), barbell lying triceps extension (BLTE), and triceps pushdown (TPD) with the highest 8-RM load used to design the two exercises sessions. All machine exercises (i.e. PDF, TPD) were performed on Life Fitness equipment (Franklin Park, IL). Following the 8-RM assessments, subjects completed two experimental resistance exercise sessions with either one or three minutes rest between sets and exercises in a randomized crossover design. The workout volume completed (sets x resistance x repetitions per set) was recorded for each exercise during each session and later compared between the rest interval conditions.

Subjects

Twelve men (23.58 ± 2.53 years; 1.74 ± 0.04 m; 74.33 ± 7.88 kg) with at least two years of recreational resistance training experience, volunteered to participate in the current study. All subjects answered "no" to all questions on the Physical Activity Readiness Questionnaire - PAR-Q (Shephard, 1988) and signed an informed consent form, in accordance with the Declaration of Helsinki.

Repetition maximum testing

The 8-RM assessments were conducted in the following order: BBP, IBBP, PDF, BLTE, and TPD. In order to increase the reliability of the 8-RM assessments, the following strategies were employed: 1) all subjects received standard instructions on exercise technique prior to testing; 2) exercise technique was monitored and corrected as needed; 3) all subjects received verbal encouragement during testing.

During the 8-RM assessments, each subject performed a maximum of three 8-RM attempts for each exercise, with 5 minutes rest between attempts (Miranda et al., 2007). After the 8-RM load for a specific exercise was determined, a 10 minute rest interval was allowed prior to the 8-RM assessment for the next exercise. No pause was allowed between the eccentric and concentric phases of each repetition and a complete range of motion (as normally defined) had to be completed. The 8-RM testing demonstrated intraclass coefficients of BBP = 0.96, IBBP = 0.98, PDF = 0.96, BLTE = 0.97, TPD = 0.98. A one-way ANOVA did not demonstrate significant differences ($p < 0.05$) between the 8-RM loads for the three assessment sessions.

Experimental resistance exercise sessions

In both experimental sessions, three sets of each exercise were performed with 48 to 72 hours between sessions. Warm-up prior to each session consisted of 2 sets of 12 repetitions of the first exercise (BBP) at 40% of the 8-RM load. Subjects were verbally encouraged to perform all sets to voluntary exhaustion. No attempt was made to control the repetition velocity; however, subjects were required to utilize a smooth and controlled motion with no pause between repetitions. The workout volume completed (sets x resistance x repetitions per set) was recorded for each exercise during each session and later compared between the rest conditions.

Statistical analyses

The Shapiro-Wilk normality test and the homocedasticity test were conducted prior to further statistical analysis (Bartlett criterion). All variables presented normal distribution and homocedasticity. For each exercise, a one-way ANOVA was conducted to compare the total workout volume (sets x resistance x repetitions per set) completed for the one minute versus three minute rest condition. A two (rest conditions) by three (sets) by five (exercises) repeated ANOVA was also conducted to compare differences in the repetitions per set between rest conditions. An alpha level of $p < 0.05$ was used to determine the significance of comparisons. The statistical analysis was conducted using the software SPSS 17.0 for Windows (SPSS Inc., Chicago, IL).

Results

The total workout volume completed (sets x resistance x repetitions per set) for all exercises was significantly greater for the three minute rest condition versus the 1 minute rest condition ($p < 0.05$; see Table 1). Within each rest condition, there were significant differences in the repetitions completed for each exercise set ($p < 0.05$; see Table 2). Furthermore, there were significant differences between rest conditions in the repetitions completed for most exercise sets ($p < 0.05$; see Figure 1).

Discussion

The key finding from the current study was that a significantly greater workout volume (sets x resistance x repetitions per set) was completed for each exercise when resting 3 minutes between sets and exercises (see Table 1). Because the resistance was constant for all three sets of each exercise, these differences in workout volume could

Table 2. Comparison repetitions per set (mean ± SD) within 1 min. and 3 min. conditions. Data are means (±SD).

Exercise / Sequence	Set 1	Set 2	Set 3
BBP			
1 min.	8.40 (.22) *†	6.42 (.51) ‡	4.17 (.58)
3 min.	8.30 (.16) †	7.33 (.49)	5.92 (1.01)
IBBP			
1 min.	5.00 (.74) †	3.92 (.67)	3.33 (.49)
3 min.	7.25 (.45) †	6.58 (.51)	6.08 (.67)
PDF			
1 min.	4.58 (.79)	3.83 (.72)	3.33 (.78)
3 min.	6.83 (.39)	5.92 (.67)	5.33 (.78)
BLTE			
1 min.	6.50 (.91) *†	4.92 (.90)	3.42 (1.01)
3 min.	7.33 (.65) †	6.58 (.67)	6.01 (.74)
TPD			
1 min.	4.75 (.62) *†	3.08 (.79) ‡	2.00 (.73)
3 min.	6.08 (.67) †	5.33 (.65)	4.92 (.57)

BBP = barbell bench press; IBBP = incline barbell bench press; PDF = pec deck flye; BLTE = barbell lying triceps extension; TPD = triceps pushdown. * Significant difference repetitions first set versus second set; † Significant difference repetitions first set versus third set; ‡ Significant difference repetitions second set versus third set ($p < 0.05$).

be accounted for due to the greater repetitions completed per set for the 3 minute rest condition (see Figure 1). The 3 minute rest condition allowed for greater consistency in repetitions over all three sets, whereas the 1 minute rest condition did not allow sufficient recovery time. For example, there were no significant differences in the repetitions completed between the first and second sets for any exercise when resting 3 minutes between sets; however, there were significant reductions between the first and second sets for three out of the five exercises when resting 1 minute between sets (see Table 2).

These results were consistent with related studies that compared repetition performance and the volume completed during the performance of single exercises (Kraemer, 1997; Larson and Potteiger, 1997; Ratamess et al., 2007; Rahimi, 2005; Richmond and Godard, 2004; Willardson and Burkett, 2005; Willardson and Burkett, 2006a; Willardson and Burkett, 2006b). Willardson and

Burkett (2005) compared repetition performance when completing four sets of the back squat and bench press with an 8- RM load and one, two, or five minute rest intervals. For the back squat, the total repetitions progressively increased as the rest interval increased: one minute (22.47 ± 4.79), two minutes (25.53 ± 4.29), and five minutes (28.80 ± 3.08). The same results were demonstrated for the bench press: one minute (17.13 ± 4.42), two minutes (21.60 ± 4.52), and five minutes (25.73 ± 4.23). These results were consistent with the bench press results of the current study in that the 3 minutes rest (21.3 ± 1.0) allowed for significantly greater repetitions versus the 1 minute rest (18.6 ± 0.5).

Another study by Willardson and Burkett (2006b) compared repetition performance when completing five sets of the bench press with 50% and 80% of a 1-RM and one, two, or three minute rest intervals. Significant increases in total repetitions were demonstrated as the rest
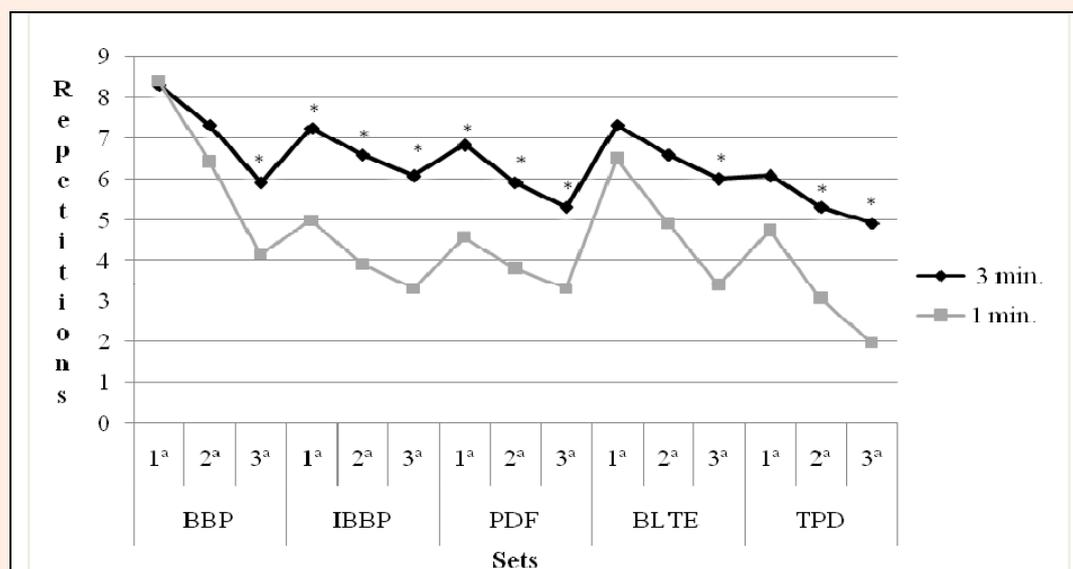

Figure 1. Comparison repetitions per set between 1 min. versus 3 min. conditions. BBP = barbell bench press; IBBP = incline barbell bench press; PDF = pec deck flye; BLTE = barbell lying triceps extension; TPD = triceps pushdown.
* Significant difference repetitions between 1 min. versus 3 min. condition ($p < 0.05$).

interval increased, irrespective of intensity. At 50% of 1-RM, the total repetitions increased as follows: one minute (59.13 ± 10.31), two minutes (74.81 ± 12.36), and three minutes (87.69 ± 13.51). At 80% of 1-RM, the total repetitions increased as follows: one minute (18.06 ± 4.64), two minutes (23.06 ± 5.95), and three minutes (27.06 ± 5.37).

A limitation of these (Willardson and Burkett, 2005; Willardson and Burkett, 2006b) and related studies (Kraemer, 1997; Larson and Potteiger, 1997; Rahimi, 2005; Ratamess et al., 2007; Richmond and Godard, 2004; Willardson and Burkett, 2005; Willardson and Burkett, 2006a; 2006b) was the evaluation of single exercises. One study to date has compared different rest intervals in the context of a typical resistance exercise session consisting of multiple exercises (Miranda et al., 2007). Miranda et al. (2007) compared repetition performance during upper body resistance exercise that emphasized the shoulder extensor (e.g. latissimus dorsi, posterior fibers of the deltoid) and elbow flexor (e.g. biceps brachii, brachialis, brachioradialis) muscle groups. Six exercises were performed with 8-RM loads for three sets with either one minute or three minutes rest between sets and exercises; similar to the current study, significantly greater repetitions were completed for all exercises when resting three minutes between sets (Miranda et al., 2007).

The resistance exercises examined in the current study emphasized the shoulder horizontal adductor (e.g. pectoralis major, anterior fibers of the deltoid) and elbow extensor (e.g. triceps brachii) muscle groups. Therefore, the findings of the current study when combined with the findings of Miranda et al. (2007), suggest similar performance patterns for antagonistic muscle groups of the upper body in recreationally trained men.

The results of the current study are easily applied when prescribing resistance exercises for the muscle groups examined. Instituting three minutes rest between sets and exercises may result in a significantly greater workout volume completed. However, it should be noted that the findings of the current study are not applicable to a sequence of lower body resistance exercises, which should be examined alone or in combination with upper body resistance exercises in future research.

Conclusion

The results of the current study add to the growing body of knowledge regarding acute and chronic responses to different rest intervals between resistance exercise sets. If sufficient time is available, instituting longer rest intervals (e.g. three minutes) allows for greater repetitions and workout volume versus shorter rest intervals (e.g. one minute). This performance enhancement has been demonstrated across a wide variety of exercises and muscle groups. 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. Future research should examine strength

gains resulting from long-term training with shorter versus longer rest intervals between sets. The results of this study may have the greatest relevance to programs designed for maximal strength for the maintenance of the load and repetitions per set.

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Key points

- The length of the rest interval between sets is an important variable when designing a resistance exercise program and may vary depending on the characteristic being emphasized (i.e. maximal strength, hypertrophy, localized muscular endurance, power).
- Although acknowledged, this variable is rarely monitored precisely in field settings.
- Previous studies that examined rest interval lengths from 1 to 5 minutes between sets for single exercises demonstrated significant differences in repetition performance and the exercise volume completed.
- There is a need for further research to compare the workout volume (sets x resistance x repetitions per set) completed over an entire resistance exercise session with different rest intervals between sets.
- The results of the current study indicate that during a resistance exercise session, if sufficient time is available, resting 3 minutes between sets and exercises allows greater workout volume for the upper body exercises examined.

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