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Research article

EFFECT OF DIFFERENT REST INTERVALS ON THE EXERCISE VOLUME COMPLETED DURING SQUAT BOUTS

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ABSTRACT

The purpose of this research was to compare effect 3 different rest intervals on the squat volume completed during a workout. Twenty college-aged men volunteered to participate in this study (age 20.73 ± 2.60 years; body mass 80.73 ± 10.80 kg). All subjects performed 3 testing sessions, during which 4 sets of the squat was performed with 85% of a 1RM load. During each testing session, the squat was performed with a 1, 2, or 5-minute rest interval between sets. Volume was defined as the total number of repetitions completed over 4 sets for each rest condition. Statistical analysis was conducted separately for the squat. One-way repeated analyses of variance with Bonferroni post hocs demonstrated significant differences between each rest condition for both exercises tested ($p < 0.05$). The 5-minute rest condition resulted in the highest volume completed, followed in descending order by the 2- and 1-minute rest conditions. The ability to perform a higher volume of training with a given load may stimulate greater strength adaptations.

KEY WORDS: Strength training, recovery, squat, recruitment.

INTRODUCTION

How you intend to use added strength will dictate how you should train. Training is specific in terms of angle, range of motion and even velocity of contractions (Sharkely, 1990). Strength training programs can be designing to emphasize muscular strength, power, hypertrophy, or endurance (Kraemer et al., 2002). When designing strength training programs, many variables such as intensity, volume, frequency, repetition, velocity and rest between sets must be considered (Baechle et al., 2000; Kraemer et al., 2002). The manipulation of training variables as mentioned above is determined by the goals of the program and the needs of the individual. Mistakes in any of these variables in the progression of a program could theoretically result in an overtraining syndrome, therefore the manipulation of these variables must be correct done (Kreider, 1998).

Training volume is a summation of the total number of repetitions performed during a training session multiplied by the resistance used. Training volume has been shown to affect neural (Hakkinen et al., 1987; 1988), hypertrophy (Dolezal, 1998), metabolic (Collins, 1986), and hormonal (Gotshalk, 1997; Kraemer, 1993; Mulligan, 1996) responses and subsequent adaptations to resistance training.

The amount of rest between sets has been considered an important factor that can be manipulated to fit the goal of a program this factor significantly affects the metabolic (Kraemer et al., 1987), hormonal (Kraemer et al., 1990; 1991; 1993) and cardiovascular (Fleck, 1988), responses to an acute bout during resistance exercise, as well as performance of subsequent sets (Kraemer et al.,

1997) and training adaptations (Pincivero et al., 1997; Robinson et al., 1995). When training for increased strength, longer rest periods of 2 and 5 minutes have been recommended to allow for greater recovery and maintenance of training intensity (Baechle et al., 2000; Kraemer et al., 2002; Willardson et al., 2005). Previous studies have shown that the amount of rest between sets has a significant effect on the total volume completed during a workout, which may affect subsequent strength adaptations (Robinson et al., 1995).

An investigation using the effect of a 3-minute rest interval versus a 1-minute rest interval on the total number of repetitions completed over 3 sets of bench press and leg press with a fixed 10 repetition maximum (10RM) load. When resting was 3 minutes between sets, each player was able to complete 10 repetitions for all 3 sets. However, when resting was 1 minute between sets, a significant reduction in the total number of repetitions was observed ($p < 0.05$), (Kraemer et al., 1997).

One study examined the effect of 3 different rest intervals on the total number of repetitions completed over 4 sets of squats with 85% of a 10RM load and reported that no significant differences were observed among 3 different rest intervals [The 3 rest intervals included (a) a post-exercise heart rate (HR) equal to 60% of age-predicted maximum HR, (b) a timed 3-minute interval, and (c) a work : rest ratio of 1 : 3] each rest condition for the total number of repetitions completed. However, within each condition, the number of repetitions performed for each set declined significantly between the first and the fourth set ($p < 0.05$), (Larson et al., 1997).

Weir et al. (1994) studied the effect of 4 different rest intervals on a repeated maximal bench press. Each subject performed 2 maximal bench presses, separated by a 1-, 3-, 5-, or 10-minute rest between sets. Results demonstrated no significant differences between rest intervals in the ability to perform a repeated maximal bench press ($p < 0.05$).

Finally, Willardson et al. (2005) studied a comparison of 3 different rest intervals on the total number of repetitions completed over 4 sets of squats with a 8RM load, results demonstrated that the 5-minute rest condition resulted in the highest volume completed, followed in descending order by the 2- and 1-minute rest conditions. The ability to perform a higher volume of training with a given load may stimulate greater strength adaptations.

The results of these studies suggest that the repeatability of performance over multiple sets is dependent on the amount of rest between sets and the load being lifted. However to our knowledge, the impact of 1, 2, or 5-minute rest interval on the squat volume completed over 4 sets with 85% of a 1RM load has not been reported, And resistance-trained athletes, such as bodybuilders or power-lifters, must perform exercises at maximal or near maximal intensities with repeated efforts in order to enhance muscular hypertrophy and/or strength. Recovery between efforts for these athletes may be a critical issue for maximizing performance; however, to our knowledge no investigations have examined this issue. Therefore, the purpose of this study was to compare the effects of 3 different rest intervals on the squat volume completed over 4 sets with 85% of a 1RM load.

METHODS

Experimental approach to the problem

A group of 20 college-aged men volunteered for this research study (age, 21.53 ± 2.50 years; body mass, 77.83 ± 5.50 kg). All subjects were classified as experienced recreational lifters by having consistently performed a minimum of 3 strength workouts per week for the previous 2 years and none of the subjects had an experience with such training styles before the study.

Data collection occurred over a period of 4 weeks with 1 testing session each week. In the first session 1RM in the back squat exercise was determined during preliminary testing. The squat was performed in a power cage. The pins in the power cage were adjusted to allow the subject to descend to the point where the tops of the thighs were parallel to the floor. A successful parallel squat required descending by flexing the knees and hips until the proximal head of the femur reached the same horizontal plane as the superior border of the patella and then 85% of a 1RM load was selected to purpose the load used in testing. Warm-up consisted of performing 5-10 repetitions at 40-60% of perceived maximum, a 3–5-minute rest and stretching period, and the completion of 3-5 repetitions at 60-70% of maximum. 3 to 5 subsequent lifts were then made to determine the 1RM with 5 minutes of rest between lifts. An attempt was considered successful when the movement was completed through a full range of motion without deviating from proper technique and form. Spotters were present to provide verbal encouragement and safety for the subjects. To ensure that all subjects were moving at approximately the same velocity for each repetition, each set was timed using a handheld stopwatch. The spotter called out a cadence for the eccentric and concentric phases of each repetition. The repetition velocity consisted of a 3-second eccentric phase followed by a 1-second concentric phase. During the next 3 testing sessions, 4 sets of the squat was performed with a 1-, 2-, or 5-minute rest interval between sets. A counterbalance procedure was used to determine the order of exercises and the rest interval between sets for each testing session. Subjects were allowed to continue with their normal workouts throughout the duration of the study with the following exceptions: (a) subjects were instructed not to perform the squat in their personal workouts, and (b) subjects were instructed not to work out on the day of their scheduled testing sessions.

Statistical analyses

The results were analyzed with SPS11.5 statistical software. Values from the different sessions were compared using a 1-way analysis of variance (ANOVA) with repeated measures. The alpha level was set at 0.05 in order for a difference to be considered significant. Intraclass reliability was assessed between the last 3 testing sessions. Volume was defined as the total number of repetitions completed over 4 sets for each rest condition. When a significant session effect was detected, a pairwise comparison of the sessions was done using Bonferroni's post hoc test to identify significant differences between sessions.

RESULTS

The volume completed for the squat was significantly different between the 1- and 5-minute rest conditions and between the 2- and 5-minute rest conditions ($p < 0.001$, 0.002; see Table 1). However, the volume completed was not significantly different between the 1- and 2-minute rest conditions ($p = 0.190$; see Table 1). Intraclass reliability for the squat was 0.97.

DISCUSION

The results demonstrated that, as the rest interval between sets increased, the total number of repetitions completed also increased. There was not a significant difference in the squat volume completed between the 1- and 2-minute rest conditions ($p = 0.190$).

When lifting a submaximal amount of resistance, the slow and fast-twitch muscle fibers are recruited but at first the slow-twitch muscle fibers exert force and when the slow-twitch muscle fibers become progressively fatigued, the fast-twitch muscle fibers continue to produce sufficient force. Finally, when all available muscle fibers are fatigued and cannot produce sufficient force, the set is ended (Sale et al., 1987; Zatsiorsky, 1995). When considering the rest interval between sets, slow-twitch muscle fibers would require shorter recovery due to their oxidative characteristics, whereas fast-twitch muscle fibers would require longer recovery due to their glycolytic characteristics (Weiss, 1991).

Because fast-twitch muscle fibers rely heavily on anaerobic glycolysis for energy production, these fibers would accumulate higher levels of lactic acid during high intensity exercise. The accumulation of lactic acid has been shown to lower intracellular pH through the dissociation of hydrogen ions (H+), which results in muscle fatigue (Jones et al., 1986; Taylor et al., 1990), But Robergs, et al 2004 demonstrated that there is no biochemical support for lactate production causing acidosis, Lactate production retards, not causes, acidosis. Similarly, there is a wealth of research evidence to show that acidosis is caused by reactions other than lactate production (Corey, 2003; Kowalchuk, 1988; Tafaletti, 1991). Every time ATP is broken down to ADP and Pi, a proton is released. When the ATP demand of muscle contraction is met by mitochondrial respiration, there is no proton accumulation in the cell, as protons are used by the mitochondria for oxidative phosphorylation and to maintain the proton gradient in the intermembranous space. It is only when the exercise intensity increases beyond steady state that there is a need for greater reliance on ATP regeneration from glycolysis and the phosphagen system. The ATP that is supplied from these nonmitochondrial sources and is eventually used to fuel muscle contraction increases proton release and causes the acidosis of intense exercise. Lactate production increases under these cellular conditions to prevent pyruvate accumulation and supply the NAD^+ needed for phase 2 of glycolysis (Robergs et al. 2004).

It is important to note that lactate production acts as both a buffering system, by consuming H^+, and a proton remover, by transporting H^+ across the sarcolemma, to protect the cell against metabolic acidosis. The cause of metabolic acidosis is not merely proton release, but an imbalance between the rate of proton release and the rate of proton

Table 1. Mean (±SD) values for repetitions completed.

Time rest	Set 1 (reps)	Set 2 (reps)	Set 3 (reps)	Set 4 (reps)	Total (reps)
1-minute	7.70 (.80)	4.80 (1.23)	3.50 (1.05)	2.20 (.61)	4.55 (2.25) †
2-minute	7.35 (.81)	5.40 (1.35)	4.45 (.82)	3.20 (1.15)	5.10 (1.84) §
5-minute	7.35 (.93)	6.70 (1.21)	6.00 (.85)	4.65 (.85)	6.17 (1.39) † §

† Significant difference between 1- and 5-minute rest conditions ($p < 0.05$).

§ Significant difference between 2- and 5-minute rest conditions ($p < 0.05$).

buffering and removal. As previously shown , proton release occurs from glycolysis (An accumulation of NAD+H^+ produced by the Glyceraldehyde 3-phosphat dehydrogenas reaction) and ATP hydrolysis. However, there is not an immediate decrease in cellular pH due to the capacity and multiple components of cell proton buffering and removal. The intracellular buffering system, which includes amino acids, proteins, Pi, HCO_3^-, creatine phosphate (CrP) hydrolysis, and lactate production, binds or consumes H^+ to protect the cell against intracellular proton accumulation. Protons are also removed from the cytosol via mitochondrial transport, sarcolemmal transport (lactate$^-$/H^+ symporters, Na^+/ H^+ exchangers), and a bicarbonate-dependent exchanger (HCO_3^-/Cl^-). Such membrane exchange systems are crucial for the influence of the strong ion difference approach at understanding acid-base regulation during metabolic acidosis (Kowalchuk, 1988; Corey, 2003). However, when the rate of H^+ production exceeds the rate of the capacity to buffer or remove protons from skeletal muscle, or when no enough time to buffer or remove H^+ production, metabolic acidosis ensues and results in muscle fatigue.

Short rest intervals of 1 minute or less have been shown to significantly increase lactic acid levels during heavy strength training exercise (Kraemer et al., 1987). The time needed for lactic acid clearance following high-intensity exercise has been shown to be 4-10 minutes (Jones et al., 1986). In the current study, the 5-minute rest condition likely enough time to uptake H^+ and delayed fatigue, which allowed subjects to complete a higher volume of training, versus the 1- and 2-minute rest conditions.

The results of the current study were different from those demonstrated by Kraemer (1997) who found that when subjects rested 3 minutes between sets, they were able to complete all 10 repetitions over 3 sets of bench press with a 10-RM load. In the current study, subjects failed to complete maximum repetitions over 4 sets of squat with 85% of a 10RM load, even when resting 5 minutes between sets the repetitions decreases from set-1 to set-4 (see Table 1). These differences in results may be accounted for by differences in the training status of subjects.

The subjects utilized by Kraemer (1997) were Division I football players accustomed to training with maximal exertion over multiple sets. These subjects possibly had adapted to the point that more repetitions were possible with shorter rest intervals between sets. By contrast, the subjects in the current study lifted recreationally and rarely trained with maximal exertion over multiple sets. Larson et al. (1997) utilized a sample of recreationally trained men and demonstrated results that were consistent with the current study, with a significant decline in the number of repetitions completed over 4 sets of squats with 85% of a 10RM load.

Weir et al. (1994), however, showed no differences in the ability to repeat a maximal bench press following 1-, 3-, 5-, or 10-minute rest interval between sets. A limitation of this study was that subjects only performed 2 sets with 1RM load. Had more than 2 sets been attempted, longer rest intervals may have resulted in superior performance. In the current study, subjects were able to maintain training volume to the greatest extent when resting 5 minutes between sets.

The data in the present investigation are in agreement with several other studies involving the use of 3 different rest intervals on the squat volume (Kraemer et al., 1987; Larson et al., 1997; Willardson et al., 2005). Although Robinson et al. (1995) demonstrated that a 3-minute rest interval resulted in a higher training volume, a longer rest interval may have produced an even higher training volume and, consequently, greater strength gains. The current study demonstrated a dose-response relationship between the amount of rest between sets and the volume of training completed. However, the practicality of longer rest intervals must also be considered, and there may be a point of diminishing returns, yet to be determined, where a longer rest interval yields no additional volume.

CONCLUSION

The squat is a common exercise prescribed in strength training programs. When designing strength training programs, the amount of rest prescribed between sets is likely dependent on the goal, the training status of the individual, and the load being lifted. This study demonstrated that a 5-minute rest interval between sets allowed for the highest volume to be completed when training with 85% of a 1RM load. The ability to perform a higher volume of training with a given load may stimulate greater strength adaptations (Robinson et al., 1995). A limitation of the current study was that gains in strength were not measured and subjects were not separated into groups designated by different rest intervals. Future research should continue to examine changes in muscular strength, dependent on differences in the rest interval between sets.

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KEY POINTS

- There is no significant difference in the squat volume between the 1- and 2-minute rest conditions.
- A 5-minute rest interval between sets allow for the highest volume to be completed when training with 85% of a 1RM load.

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