THE EFFECTS OF DESCENDING RESISTANCE SETS COMPARED TO CONSTANT RESISTANCE SETS ON THE VOLUME COMPLETED DURING A HIGH INTENSITY FREE WEIGHT BACK SQUAT EXERCISE

By

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ABSTRACT

THE EFFECTS OF DESCENDING RESISTANCE SETS COMPARED TO CONSTANT RESISTANCE SETS ON THE VOLUME COMPLETED DURING A HIGH INTENSITY FREE WEIGHT BACK SQUAT EXERCISE

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Improving anabolic hormone production is an important training adaptation in resistance training; however, no previous research has developed optimized descending resistance sets to increase training volume. The purpose of this research was to compare two different loading protocols of constant resistance sets (CRS) and descending resistance sets (DRS) on the free weight back squat. Eleven resistance trained male participants (mean ± SD, age = 22 ± 3 yr, and back squat 1RM ratio (1RM/body weight) = 1.65 ± 0.2) completed 4 experimental sessions over 2 weeks, during which 4 sets of the back squat were performed with 85% 1RM and 30 second rest period. The 1st experimental session was a 1RM test, 2nd experimental session was the CRS protocol followed by 1 week of rest and subjects completed the final 2 experimental sessions in a counterbalance design of CRS and DRS which was determined by the repetitions completed in the CRS condition based on the %1RM-Repetition Relationship table from the NSCA. Data was analyzed using both a one and two-way ANOVA with repeated measures. As sets progressed significant increase in repetitions between sets 2-4 (DRS: 6.3, 4.9, 4.1, 4.3; CRS: 5.8, 3.0, 2.0, 2.0) were found and significant increases in training volume (DRS: 2279; CRS: 1646) in DRS compared to CRS. Resistance trained males, with the goal of

increased repetitions and greater training volume during strength training would benefit from DRS; specifically, with 30 second rest periods and 85% 1RM over 4 sets of the back squat exercise.

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INTRODUCTION

Resistance training is a tool used daily to help individuals with athletic performance and rehabilitation to increase muscular strength and power (1). Resistance training and exercise elicit a host of physiological responses and chronic adaptations, which are critical to increase muscular strength, power, hypertrophy, and local muscular endurance (1). These physiological responses may be manipulated by different training variables such as, exercise choice, exercise order, number of sets in an exercise, repetitions, training intensity, velocity of movement, and length of rest between sets and exercise (10). Previous research has shown the number of repetitions completed with a given load can result in distinct neuromuscular adaptations (2, 3, 22). For example, low repetitions with high intensity loads with 3 to 5-minute rest periods can cause adaptations to muscular strength. Contrarily, high repetitions with low intensity loads and short rest times can lead to increases in muscular endurance (2, 3, 22). Manipulation of these training variables can lead to different stimuli, creating different adaptations in several biological systems (4). Some of these biological responses can lead to increases in anabolic hormone such as testosterone and growth hormone, causing even greater increases in muscular strength and power (5, 6, 21, 23). To elicit this anabolic hormone response the National Strength and Conditioning Association (NSCA) (4) has recommended a specific protocol to increase serum testosterone concentration, which requires large body movements (deadlifts and squats) (5, 6, 12), high-intensity of 85-95% one repetition max (13), moderate to high repetition count, young adults (18-25) men (11,

14) with two years of resistance training (5, 6, 11), and short rest between thirty seconds to 1 minute (14).

While performing multiple sets of resistance exercise, staying within the suggested repetition range should help to achieve the muscular adaptations necessary for a specified training goal (2). Although the NSCA suggests short rest periods of thirty seconds to 1-minute, previous research as shown sustaining moderate to high repetitions is difficult due to muscular fatigue (14, 17). This previous research found significant decreases in repetitions with the free weight back squat exercise when resting for 1 minute (25). Willardson and Burkett (25) examined college aged men with two years of resistance training for repetition performance of the back squat over 4 sets with a constant 8RM load (80% 1RM) and 1-minute rest periods between sets. This study showed repetitions decrease with constant resistance sets (CRS) and high intensity with short rest periods (23). Other research by Robinson (19) showed that weight-trained college aged men used short rest times of 30 seconds have shown decreased training volume and the subjects were unable to complete all the repetitions in each of the sets of free weight back squat in 5 sets and 10RM (75% 1RM). However, the NSCA (4) states it requires at least 5 minutes to recover from heavy resistance training ($\geq$85% 1RM). Hernandez (7) showed it may take up to 8 minutes to fully recover from muscle fatigue with heavy resistance training of 85% 1RM to sustain all repetitions over 4 sets, in a free weight bench press exercise (7). Therefore, not being able to complete all the repetitions will lower the training volume completed during an exercise and limit the amount of adaptation to muscle strength and power (24).

In the past, drop set training has been used to increase training volume by decreasing resistance and performing another set of the same exercise to fatigue with little or no rest time between sets. This load reduction has not been strictly defined in the past when performing drop sets (10). Some researchers have used load reduction methods to increase total training volume, while keeping the rest time constant (20, 26, 27). Willardson (26) recruited recreationally trained college aged men and compared four different loading protocols for three sets of 10RM (75% 1RM) with 1-minute rest periods in three different lower body exercises, which included, free weight back squat, leg extension, and leg curl. The loading protocols were a constant load and descending loads of 5%, 10%, and 15% on subsequent sets. Willardson (26) found decreasing the load by 15% between sets increased the total training volume produced for the exercises performed and sustained repetitions throughout free weight back squat. Other research by Willardson et. al. (27) used a similar protocol for young adult females with at least 2 years of resistance training to compare four different loading protocols (constant, 5% decrease, 10% decrease, and 15% decrease) for 3 sets of 10RM (75% 1RM) with 1-minute rest in three different exercises, which included, free weight back squat, free weight bench press, and wide grip lat pull down. Contradicting results were found that 10% load decrease showed sustainability of repetitions throughout 3 sets (27). Silva (20) used recreationally trained college aged men and compared 3 different loading protocols (constant, 5% decrease, and 10% decrease) for three sets of 10RM (75% 1RM) with 1-minute rest period of leg press. Silva (20) found training volume in leg press was increased the most in 10% DRS. Therefore, decreasing the resistance between sets can

allow more repetitions to be completed while keeping the rest time constant and may achieve specified muscular responses depending on the repetition range and intensity (24).

Despite certain findings, longer rest intervals of 5-8 minutes were the most successful at sustaining and increasing the repetitions performed with high intensity (≥85%1RM) resistance training (7, 18). Even though the NSCA protocol recommends short rest periods of 30 seconds to 1 minute with high intensity of 85-95% 1RM, previous research as shown repetitions decrease in successive sets. This NSCA protocol may require a modified training protocol to increase training volume and sustain repetitions throughout multiple sets. Further research is needed to find the optimal load reduction with a higher intensity related to the NSCA recommendations of higher intensity (85-95% 1RM) to increase training volume with short rest intervals (30 sec to 1 minute).

When an experienced resistance-trained individual (≥2 years resistance training) performs multiple sets with constant resistance and short rest periods, the number of repetitions will be reduced due to muscle fatigue of the fast twitch muscle fibers (26). Due to the decrease in repetitions training volume will decrease, which is an important training variable for muscular adaptation. However, there is no standard method for optimizing resistance to maximize training volume when using multiple sets with short rest periods to increase training volume in resistance training and keep repetitions consistent throughout high intense multiple sets. Furthermore, no previous descending load research has been completed on 85% 1RM with 30 second rest periods over 4 sets. Therefore, the purpose of this study was to compare the sustainability of repetitions and

the training volume completed on constant resistance sets (CRS) and descending resistance sets (DRS). It was hypothesized that CRS would decrease repetitions over subsequent sets while DRS would sustain repetitions throughout subsequent sets and DRS would have increased training volume compared to CRS.

METHODS

Experimental Approach to the Problem

The study included a total of four experimental days where subjects performed high-intensity squat exercises. To examine the effect of CRS and DRS on repetition sustainability and training volume. The squat exercise was chosen because compound exercises produce higher levels of testosterone compared to isolation exercises (10) Initially, each subject's 1RM load was assessed for the squat exercise. Following the 1RM assessments, subjects completed CRS using 85% of 1RM with 30 seconds rest over 4 sets. The number of repetitions and workout volume completed (total repetitions × resistance) was recorded for each subject during each CRS session and used later to find the fatigue ratio using the NSCA %1RM – repetition relationship to calculate the resistance of DRS. After one week of rest, subjects were split into two groups and instructed to complete a counterbalance of CRS and DRS to limit training advantages. Group one completed CRS followed by DRS and group two completed DRS followed by CRS. There was at least a 48-72-hour period between each session or longer for those who experienced excess soreness (28).

Participants

This study included 15 healthy college aged (18-25) volunteer males (Table 1). Inclusion criteria for participants were 2 or more years of resistance training experience with consistent participation in a resistance training program for three or more days per week. Subjects were screened for cardiovascular and musculoskeletal disease using a medical history questionnaire, an activity questionnaire, and the Physical Activity Readiness Questionnaire (PAR-Q). None of the subjects had lower back, knee, or ankle injuries during the previous year, and all subjects had performed the free weight back squat exercise on a weekly basis as part of their resistance training programs. The subjects were instructed to refrain from lower-body resistance training the day before each data collection period and the use of ergogenic aides. Participants were informed of the potential risks of participation in the study and signed an informed consent form. This study was approved by Humboldt State University IRB before any research was conducted.

PROCEDURES

Day 1: 1RM Test. The 1RM assessments for the free weight back squat exercises were conducted during the first session. To increase the reliability of the 1RM 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; and 3) all subjects received verbal encouragement during testing sessions (15).

Prior to all experimental sessions, subjects performed a warm-up consisting of: 10 repetitions at 50% of (predicted) 1RM, 5 repetitions at 70% of 1RM, 3 repetitions at 80% of 1RM, and 1 repetition at 90% of 1RM (14). During the 1RM assessments, each subject had a maximum of five 1RM attempts for the free weight back squat, with a 2 to 4-minute rest period between attempts (15). There was no pausing between eccentric and concentric phases and complete range of motion was required for the repetition to be counted. Bar speed was not controlled. The highest load obtained was the subject's 1RM load and used to calculate 85% of 1RM load.

Day 2: Constant resistance sets. The CRS experimental session consisted of subjects performing 4 sets at 85% of 1RM to failure with 30 seconds rest between sets of the free weight back squat (4). Repetitions to failure defines the maximum repetitions without assisting using correct technique that subjects can carry out before volitionally terminating the test (4). Repetitions performed in each set were counted and used later to determine total training volume (total repetitions × resistance). Immediately after the set, subjects reported their perceived exertion using the Borg Rating of Perceived Exertion Scale (RPE). During both visits, subjects were asked if they had any soreness or injury to their quadriceps, gluteus, and hamstrings. In the presence of any soreness, the session was postponed one additional day.

Day 3 and Day 4: Counterbalance descending resistance sets and Constant resistance sets. After one week, participants were split into two groups with a counterbalance

design. One group completed CRS followed by DRS, while the other group completed DRS followed by CRS. The CRS protocol was the same as the previous protocol but sets 2 through 4 of the DRS were calculated using NSCA %1RM-Repetition Relationship table based on the repetitions completed in the CRS. All sets were completed to failure with a 30 second rest period. An example of the DRS calculation is shown below.

DRS equation example.

Subject completed 6, 3, 2, 1 repetitions

1RM = 100 kg and 85% 1RM = 85 kg

6 (85%) 85 kg/85% = 100 kg original 1RM

3 (93%) 85 kg/93% = 91.4 kg new predicted 1RM

85% of 91.4 kg = 80 kg new 85% 1RM

2 (95%) 85 kg/95% = 89.47 kg new predicted 1RM

85% of 89.47 kg = 75 kg new 85% 1RM

1 (100%) 85 kg/100% = 85 kg new predicted 1RM

85% of 85 kg = 70 kg new 85% 1RM

Therefore, this subject would complete four sets using 85 kg for set 1, 80 kg for set 2, 75 kg for set 3, and 70 kg for set 4.

Power Analysis

The number of subjects was based on a power analysis using data from Silva (20). Mean exercise volume (kg) of control trial was 6799 ± 1583 (Mean ± SD). Using the standard

deviations from Silva's (20) data, approximately 10-15 subjects would be sufficient to detect a significant difference in average total volume between DRS and CRS trials (α=0.05 and a power of 0.9). Therefore, 15 healthy, resistance-trained male subjects were recruited for this study.

Statistical Analysis

All data recorded were analyzed using STATISTICA version 7.1 software (StatSoft, Inc., Tulsa, OK, USA). In order to determine a difference between the average repetitions performed between each set and between each treatment group, a two-way repeated measures ANOVA was used. Additionally, to determine any differences between training volumes completed using CRS and DRS, a one-way repeated measures ANOVA was used. When a significant F-ratio was obtained, a Tukey's Honestly Significant Difference test was performed. Statistical significance was accepted at an alpha level of $p < 0.05$. All data was presented as the mean ± *SD*.

RESULTS

Repetition Sustainability

To determine the effects of two different training conditions on the average repetitions performed between each set and between each training group a two-way repeated measures ANOVA was run. Results were reported for the average repetitions performed each set (Table 2). A total of 15 participants completed the study, but box plots were used to eliminate four outliers. Average repetitions were normally distributed ($p > .05$) as

assessed by Shapiro-Wilk's test of normality. Mauchly's test of sphericity indicated that the assumption of sphericity was not violated for the two-way interaction, $\chi2(2) = 7.272$, $p > 0.05$. There was a statistically significant two-way interaction between training conditions and sets, $F (3, 30) = 7.84$, $p < 0.05$.

Within Conditions

Constant Resistance Sets

Post hoc pairwise comparisons indicated that significantly greater repetitions were accomplished within the CRS for set 1 vs. set 2-4 ($p < 0.05$) and for set 2 vs. set 3 and 4 ($p < 0.05$). Within the CRS there was no significant difference between sets 3 and 4 ($p = 0.9$), as seen in Table 3 and Figure 1.

Descending Resistance Sets

Within the DRS significantly greater repetitions were accomplished for set 1 vs. set 2-4 ($p < 0.05$). For DRS there was no significant difference between set 2 vs. set 3 and set 4 ($p = 0.1$) and for set 3 vs. set 4 ($p = 0.9$), as shown in Table 3 and Figure 1.

Between Conditions

Post hoc pairwise comparisons also indicated that, when averaged across conditions, the repetitions accomplished for set 1 were not significantly different between DRS (6.3 ± 0.9) vs. CRS (5.8 ± 1.3) ($p > 0.05$). For set 2, significantly greater repetitions were accomplished within the DRS condition (4.9 ± 1.2) vs. the CRS condition (3.0 ± 0.8) ($p < 0.05$). For set 3, significantly greater repetitions were accomplished within the DRS condition (4.1 ± 1.0) vs. the CRS condition (2.0 ± 0.9) ($p < 0.05$). For set 4, significantly

greater repetitions were accomplished within the DRS condition (4.3 ± 0.9) vs the CRS condition (2.0 ±1.0) ($p < 0.05$), as seen in Table 3 and Figure 1.

Training Volume

A one-way repeated measures ANOVA was run to determine the effects of two different training conditions on the average training volume performed between each set and between each training group. Results were reported for the total training volume performed each set (Table 3). Average training volume was normally distributed ($p > .05$) as assessed by Shapiro-Wilk's test of normality on the studentized residual. Mauchly's test of sphericity indicated that the assumption of sphericity was not violated for the two-way interaction, $\chi2(2) = 6.791$, $p > 0.05$. There was a statistically significant greater training volume with DRS (2279 kg ± 337) compared to CRS (1646 kg ± 421), $F (1,10) = 20.52$, $p < 0.05$, as shown in Table 4 and Figure 2.

DISCUSSION

This is the first study of our knowledge, to assess the impact of DRS on high intensity (85% 1RM) free weight back squat with short rest period (30 sec). The current study compared the difference between two different conditions (CRS and DRS) on the sustainability of repetitions over four sets and the training volume completed during high-intensity (85% of 1RM) free weight back squat with a short rest period of 30 seconds. CRS had decreased repetitions over successive sets, which agreed with hypothesis 1. However, hypothesis 2 cannot be accepted due to the inability of DRS to sustain

repetitions throughout successive sets. Additionally, the average number of repetitions completed was significantly greater for DRS compared to CRS for sets 2 to 4 ($p \leq 0.05$). Therefore, DRS had greater sustainability of repetitions compared to CRS over sets 2 to 4, which led to a greater number of repetitions throughout ($p \leq 0.05$). Furthermore, the DRS obtained a significantly greater training volume than the CRS condition ($p \leq 0.05$) because of this greater training volume in DRS hypothesis 3 will be accepted. These results were consistent with previous studies that examined free weight back squat with a descending load (20, 26, 27,).

When performing multiple sets to failure, staying within a specified repetition range with a given load can lead to neuromuscular adaptations, such as increases in muscular strength and endurance (1, 2, 22). However, when using short rest periods (30 seconds to 1 minute) it may be difficult to sustain repetitions throughout multiple sets, which may require load reductions as suggested by previous research when using free weight back squats with 10RM (75% 1RM) Kraemer (14) and Willardson (24). This can be seen in the present study when viewing the repetition reductions in the CRS condition, where significantly less repetitions were completed (Table 2).

Previous research by Willardson (26, 27) used load reductions of 5%, 10%, and 15% after each set and have found inconclusive results. In 2010 Willardson recruited eleven recreationally trained men to complete a 10RM (75%) with a one-minute rest period of free weight back squat, but only the 15% load reduction was able to retain repetition performance throughout all three sets. Meaning the 15% load reduction was able to produce the most repetitions. However, in a similar study by Willardson (27)

thirty-two women with at least two years of resistance training completed the same conditions as the previous study but were able to sustain repetitions at 10% of load reduction. The previous research by Willardson (26, 27) was based on a specific load reduction of 10-15%. In the current study we used DRS based on the repetitions of the CRS to find the DRS of each subject creating a different DRS protocol for each subject. This average fatigue ratio of all subjects was 85% 1RM at the 1^{st} set, 76% 1RM at the 2^{nd} set, 74% 1RM at the 3^{rd} set, and 72% 1RM at the 4^{th} set. This shows a reduced load of 9% between the 1^{st} and 2^{nd} set, 2% reduction between 2^{nd} and 3^{rd} set, and 2% between 3^{rd} and 4^{th} set compared to a 10%-15% load reduction for each set from Willardson's studies (26, 27). Although, subjects significantly increased repetitions during sets 2 to 4 for DRS compared to CRS condition, they were unable to sustain repetitions throughout DRS condition when using 85% 1RM (6RM) over 30 second rest period, due to high intensity of exercise or not enough recovery time between sets due to muscular fatigue.

In the current study we used the NSCA %1RM-Repetition Relationship table, which could have led to the inability to sustain repetitions throughout all four sets. Even though the NSCA table can be used to assign training loads, previous research has shown constraints with the table (8, 9). Table 2 assumes there is a linear relationship between repetitions and the load lifted; However, several studies have shown a curvilinear relationship (8, 9). Meaning some subjects would be able to produce different repetitions at a given %1RM. However, Hoeger (8, 9) mentioned that resistance-trained individuals may be able to perform more repetitions than the table recommends at any %1RM, especially in lower body exercises, such as squats. This can be seen in the current study

where some subjects were able to complete more than six repetitions in the first set at 85% 1RM. Possibly the most important constraint of the table is the repetitions are based on a single set, so muscle fatigue after the first set is not taken into consideration and it may take upwards of 8 minutes for the muscles to fully recover after 1 set (7, 8, 9). Therefore, loads determined by the table should be taken into consideration as a protocol to find a repetition range for a %1RM. All the constraints of Table 2 caused it to overestimate the amount of repetitions that should be completed at a given %1RM. This was shown in the current study after the 1st set by the inability to sustain repetitions over all four sets with the DRS condition.

Training status has been an important consideration in previous studies by Willardson (26, 27) when using descending load. Willardson (27) has shown subjects with a higher training level (2 years of resistance training) produced repetition sustainability at a lower percent descending load, than recreationally trained individuals. In the current study all subjects were considered trained because they had at least two years of resistance training and the average ratio of 1RM/BW was 1.65. Therefore, the amount of descending resistance may depend heavily on training background and the amount of fatigue resilience achieved from training adaptations (27) Other research by Kraemer (14) compared 9 competitive bodybuilders to 8 competitive powerlifters on the ability to maintain repetitions over short rest periods (10 sec, 30 sec, and 60 sec) with 10RM over 10-station resistance exercise circuit with 3 sets per station and found the bodybuilders were able to maintain more repetitions with less drop sets than the powerlifters, due to their adaptations obtained from their training style.

In conclusion, constant resistance sets decreased throughout all four sets, and descending resistance sets decreased over 4 sets. However, descending resistance sets had a greater increase in repetitions performed throughout 4 sets based on NSCA %1RM-Repetition Relationship table overestimating repetition completion at a given %1RM with 85% 1RM and 30 second rest period. Even with two years of resistance training in the current study subjects were unable to maintain repetitions. There have been limitations found with the NSCA %1RM-Repetition Relationship table with the ability to assign repetitions after the 1st set due to linear relationship. Therefore, load reductions are recommended to maintain repetitions over multiple sets with short rest period of 30 seconds and 85% 1RM. Future research should consider using multiple DRS or further reduction based on 1st DRS results at 85% 1RM with 30 second rest period to sustain repetitions throughout all 4 sets. However, $\geq$85% 1RM is one of the values that causes stress to produce anabolic hormones (13) and the average % intensities of DRS were 76% 1RM at the 2nd set, 74% 1RM at the 3rd set, and 72% 1RM at the 4th set, all of which are higher than 70% 1RM; therefore, exercise intensity is not likely too low to fail to cause enough stress to the body.

PRACTICAL APPLICATION

A short rest period of 30 seconds between sets and exercise to volitional fatigue of DRS starting at 85% of 1RM allows a greater training stimulus (high volume with short rest intervals), which may promote a greater recruitment of type II motor units and a greater secretion of growth promoting anabolic hormones than when sets are not carried to

failure with longer rest periods between sets (10) than the CRS used in present studies. Therefore, DRS with short rest period can be used to manipulate a resistance training program to increase performance and strengthen musculoskeletal components in hopes to provide added benefits for those who use resistance training. We founded that the average % descending resistance comparing the 1RM of DRS was 85%, 76%, 74%, and 72% of 1RM through 4 sets of a squat exercise. Practically, trainees can exercise to exhaustion using these descending resistances without the CRS test. Trainees may not complete all repetitions using these decreased resistances, but it can be a good initial DRS intensity for them.

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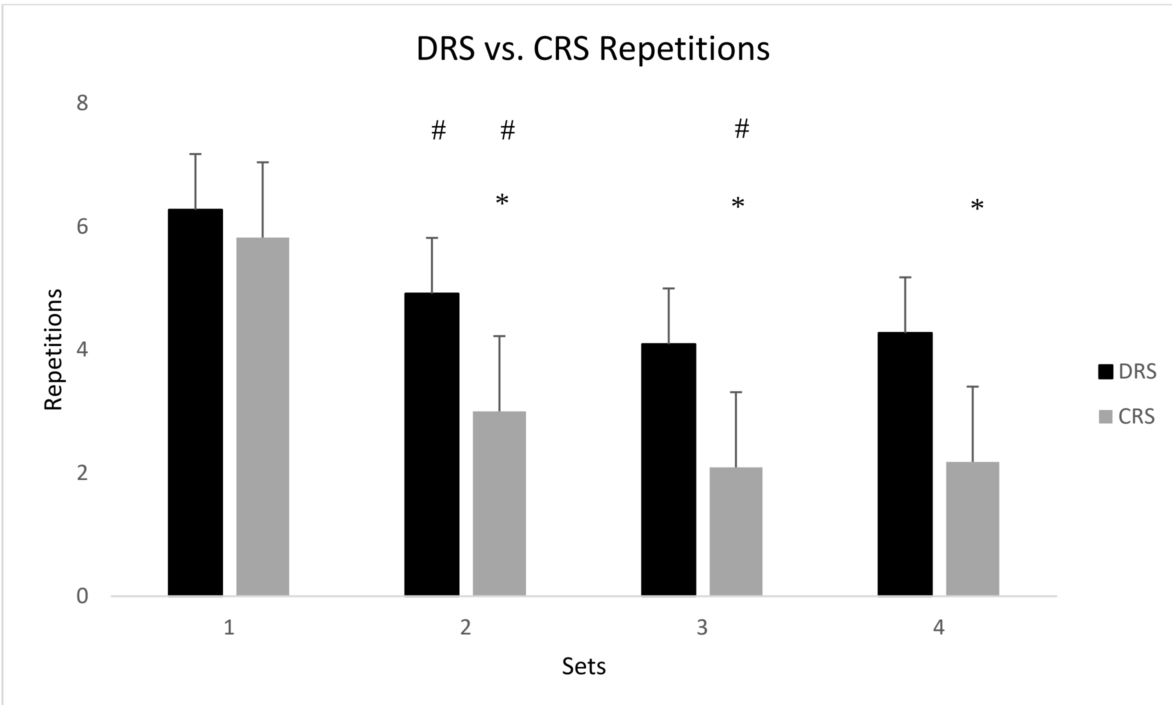
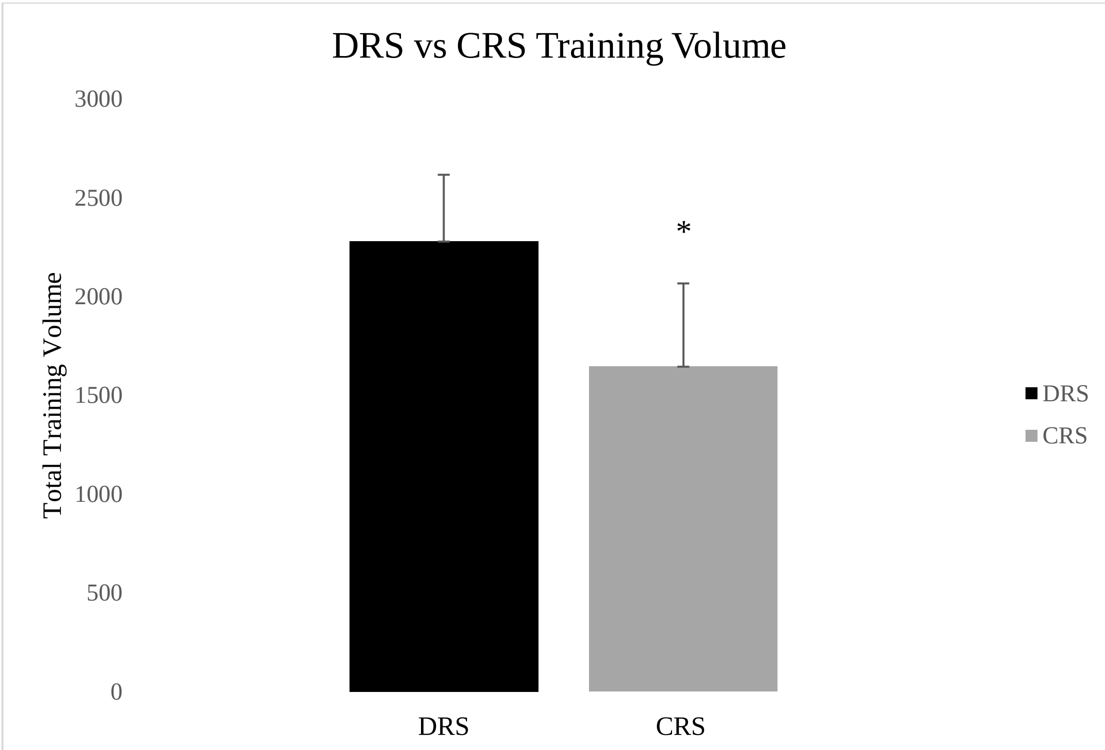
FIGURES AND TABLES

Figure 1. Repetition sustainability



**p* < 0.05, value significantly different between conditions. #*p* < 0.05, value significantly different from previous set.

Figure 2. Total training volume completed for each condition



*$p < 0.05$, value significantly different between conditions.

Table 1. Subject characteristics (n = 11). †

Age (y)	Body weight (kg)	Height (cm)	1RM (kg)	Experience (y)	*1RM Ratio
22 ± 3	90 ± 17	179 ± 5	148 ± 18	4 ± 2	1.65 ± 0.2

†Values are given as mean ± SD.
*1RM/body weight

Table 2. %1RM-Repetition Relationship

%1RM	Number of Repetitions allowed
100	1
95	2
93	3
90	4
87	5
85	6

(4)

Table 3. Repetitions Sustainability (n=11). †

Condition	Set 1	Set 2	Set 3	Set 4
CRS	5.8 ± 1.3	3.0 ± 0.8*#	2.0 ± 0.9*#	2.0 ±1.0*
DRS	6.3 ± 0.9	4.9 ± 1.2#	4.1 ± 1.0	4.3 ± 0.9

† Values are given as mean ± SD.

*$p < 0.05$, value significantly different between conditions.
#$p < 0.05$, value significantly different from previous set.

Table 4. Total training volume (n=11). †

Condition	Total Training Volume (kg)
CRS	1646 ± 420*
DRS	2279 ± 337

† Values are given as mean ± SD.
*$p < 0.05$, value significantly different between conditions.