The effects of time-equated various rest intervals on training volume.
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Original Scientific Research Study
THE EFFECTS OF TIME-EQUATED VARIOUS REST INTERVALS ON TRAINING VOLUME.

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BLUF

The volume of a training session consisting of 4 sets to failure at 80% of 1-RM is likely to be similar between increasing, decreasing and consistent rest intervals when the total rest interval is the same.

ABSTRACT

Achieving higher training volume at high intensity recruits more motor neurons and results in higher muscle activation, an essential phenomenon for muscle adaptation. The aim of this study was to compare the effect of three different rest intervals on training volume completed at 80% of One Repetition Maximum (1RM). Sixteen healthy young men completed three training sessions with constant (90-90-90 seconds), decreasing (120-90-60 seconds) and increasing (60-90-120 seconds) rest intervals in a randomly ordered design. Each training session consisted of four sets of bench press at 80% of 1-RM. The number of repetitions and training volume of each set and the entire training session were compared across different rest intervals. At the end of each training session, participants were asked to rate the difficulty of the training session using the Borg’s scale. There was a significant main effect of set on number of repetitions and training volume across sets (p<0.01). There was also a significant interaction of sets and rest intervals on repetitions and volume (p<0.01). A Bonferroni post-hoc test showed that the training volume of set 4 in decreasing rest interval was significantly lower than increasing rest interval (p<0.01). However, the total training volume of the entire training sessions were not significantly different between constant, increasing, and decreasing rest intervals (p>0.05). There was also no significant difference in Rate of Perceived Exertion (RPE) between different rest interval conditions (p>0.05).

In conclusion, in a training session consisting of 4 sets at 80% of 1-RM, the repetitions and training volume is likely to be similar between constant, increasing, and decreasing rest interval when the total rest interval is held constant.

Key Words - Maximum repetitions, time efficient program, rest protocols.

INTRODUCTION

Training at higher intensity, recruits both lower and higher threshold motor units (14) and is essential for muscle adaptations. The results of previous studies showed higher peak and mean muscle activation when training to failure at higher intensity compared to lower intensity (1, 4, 14). In addition to intensity, training volume is also an important factor in muscle adaptations to resistance training and should be considered when designing programs.

To increase muscle strength and hypertrophy, scholars and health professionals often recommend four sets of lifts for each muscle group (13). Nevertheless, additional training volume does enhance muscle strength and hypertrophy to some extent; therefore, competitive bodybuilders attempt to maximise training volume by training to failure in each set. This method of training may need a longer rest period between sets for recovery and will result in a lengthy training session.

Rest period or rest interval is defined as the duration of inactivity between sets of exercises (7). The results of previous studies showed that intensity and rest interval determine the repetitive performance and exercise volume completed (10, 11); in which longer rest intervals resulted in higher total workout volume (10). Scudese et al. (15) examined the effect of 1, 2, 3, or 5 minutes rest intervals between 5 sets on 3RM. The results showed significantly greater bench press repetitions in 2, 3 and 5 minute rest intervals compared to 1 minute rest intervals (15).

Yet, the time that lifters can dedicate to training is limited. Athletes need to fulfil many other commitments in their life, such as work, family, and education, at the same time as their athletic career. Indeed, previous studies have demonstrated that time is the main obstacle to physical activity, as reported by college students (5) and obese patients (6). Therefore, lifters strive to maximise training volume in the shortest time possible. Training programs that diminish the time that is squandered during a training session, perhaps by manipulating rest periods, are thus warranted.

One simple solution to reduce the length of each training session is to reduce the rest period between sets. This reduction, however, may result in fatigue (3) and consequently a reduction in the number of repetitions completed in the
last set (10). The solution to achieve the same training volume in shorter time, perhaps, is various rest intervals, not reducing all rest periods between sets. In varying rest intervals, the period of inactivity in between sets varies between sets to maximise physiological and psychological recovery required to complete the next set.

No previous study has investigated the effect of increasing, constant and decreasing rest intervals on training volume completed by healthy males in one training session. Therefore, the purpose of the current study was to investigate the effect of time-equated various rest intervals on training volume, completed in a single exercise session.

**METHODS**

**Approach to the Problem**
The current study was a randomised crossover design in which training volume completed during the barbell bench press was assessed in three randomly ordered training sessions differing in the rest interval between sets. Participants underwent a familiarisation session followed by one repetition maximum (1-RM) assessment and three experimental sessions. During the first familiarisation session, participants received both verbal and visual instructions to perform correct and consistent bench press movements and were given the opportunity to follow procedures and practice one repetition maximum assessment. To minimise the effect of potential fatigue from the familiarisation session, one repetition maximum was assessed two days after the familiarisation session. Each participant completed three experimental resistance exercise sessions with constant (90 seconds rest between all sets), decreasing (120 seconds rest between set 1 and 2, 90 seconds rest between set 2 and 3, 60 seconds between set 3 and 4), and increasing (60 seconds rest between set 1 and 2, 90 seconds rest between set 2 and 3, 120 seconds between set 3 and 4) rest intervals separated by two days. The volume of each set was calculated by multiplying loads and successful repetitions.

**Subjects**
Sixteen young healthy men with at least six months experience in resistance training volunteered to participate in the current study: group age, 27±8.08 years; body mass, 78.62±10.84 kg; height, 179±5.7 cm. All participants had experience performing barbell bench press with a frequency of three training sessions per week. Prior to commencement of the study, all participants completed PAR-Q (16) and did not report any medical condition. Subjects were informed about the benefits and risks involved in the project and signed the informed consent approved by the Human Ethics Committee.

**PROCEDURES**

**One Repetition Maximum (1-RM) Assessment**
One repetition maximum was assessed two days after the familiarisation session following the protocol suggested by Kraemer et al. (9). During familiarisation session, all participants received verbal feedback to ensure safe and consistent movements were performed in a full range of motion for each repetition. One repetition maximum assessment and three experimental sessions were performed in three randomly ordered training sessions differing in the rest interval between sets. Participants started with a warm up phase of 10 push-ups. After one-minute rest, participants completed 10 repetitions with 40% of 1-RM. After three minutes rest, each participant performed the maximum number of correct movements with 80% of 1-RM to failure. No attempt was made to control the movement velocity. However, subjects were required to perform a smooth and controlled motion with no pause between repetitions.

Each training session consisted of 4 sets with either constant (CO: 90 sec), increasing (IN: 60, 90, 120 sec) or decreasing (DE: 120, 90, 60 sec) rest intervals between sets. At the end of each training session, participants were asked to rate the intensity of the training from 6-20 based on Borg’s scale (2). The total volume of each set and each training session was calculated using the following formulas:

Total volume of each set = load × repetitions

Total volume of each session = summation of the total volume completed in each set

**Statistical Analysis**
Data was analysed using SPSS 24.0 (SPSS Inc, Chicago, IL). To compare the effect of the three different rest intervals on total number of repetitions, total training volume and RPE in each training session, a one-way ANOVA was used. A two-factor (Sets × Rest Intervals) repeated measures ANOVA was used to compare differences across sets and rest intervals. The Mauchly’s sphericity test was used to test for homogeneity of covariance for within subject factors. To correct for non-homogenous values, the Greenhouse-Geisser test was used. When repeated measures ANOVA interactions were significant, adjusted Bonferroni post hoc tests were also performed. The probability level of statistical significance was set at p < 0.05 and descriptive statistics were expressed as means ± SD. Effect sizes were calculated.
using partial eta squared ($\eta^2_p$) with values of 0.2, 0.6, and above 1.2 considered to be a small, medium and large effects (8).

RESULTS

The average of one repetition maximum was 99.19±21.04 and relative to body mass, the average strength in bench press was 1.27±0.25 kg.kgBW$^{-1}$.

Table 1 - Training volume (kg) completed in each set and training session and rate of perceived rate of exertion in constant, increasing, and decreasing rest interval.

<table>
<thead>
<tr>
<th></th>
<th>Constant</th>
<th></th>
<th>Increasing</th>
<th></th>
<th>Decreasing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Set 1</td>
<td>627</td>
<td>187</td>
<td>620</td>
<td>150</td>
<td>628</td>
<td>206</td>
</tr>
<tr>
<td>Set 2</td>
<td>445</td>
<td>142</td>
<td>416</td>
<td>133</td>
<td>465</td>
<td>163</td>
</tr>
<tr>
<td>Set 3</td>
<td>385</td>
<td>127</td>
<td>351</td>
<td>106</td>
<td>341</td>
<td>124</td>
</tr>
<tr>
<td>Set 4</td>
<td>307</td>
<td>112</td>
<td>367</td>
<td>102</td>
<td>253</td>
<td>93</td>
</tr>
<tr>
<td>Total</td>
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<td>526</td>
<td>1754</td>
<td>430</td>
<td>1687</td>
<td>556</td>
</tr>
<tr>
<td>RPE</td>
<td>15</td>
<td>1</td>
<td>15</td>
<td>2</td>
<td>15</td>
<td>2</td>
</tr>
</tbody>
</table>

There was a significant main effect of set on training volume $F(1.87, 84.33) = 178.92, p < 0.001, \eta^2_p =0.80$. But, the main effect of rest interval on training volume was not significant $F(2, 45) = 0.11, p =0.90, \eta^2_p =0.005$. The interaction of set and rest interval on training volume was also significant $F(3.75, 84.33) = 4.03, p =0.006, \eta^2_p =0.15$.

There was a significant reduction in work volume across sets during constant and decreasing rest interval. However, there was no significant difference between the work volume in set 2 and 3 with set 4 in increasing rest interval (p>0.05). The results of a post-hoc analysis showed a significant difference between the work volume of set 4 between increasing and decreasing rest intervals (p≤0.05). However, the total training volume of the three training sessions were not significantly different (p>0.05).

Figure 1 - Number of repetitions in each set during constant, increasing, and decreasing rest interval.

There was a significant main effect of set on repetitions $F(3, 135) = 243.26, p < 0.001, \eta^2_p =0.84$. But, the main effect of rest intervals on repetitions was not significant $F(2, 45) = 0.14, p =0.87, \eta^2_p =0.006$. The interaction of set and rest intervals on training volume was also significant $F(6, 135) = 5.70, p =< 0.001, \eta^2_p =0.20$.
There was a significant reduction in the number of repetitions in each set during constant and decreasing rest intervals. However, there was no significant difference between the number of repetitions completed in set 2, 3 and 4 during increasing rest interval (p>0.05). The results of a post-hoc analysis showed a significant difference between the repetitions of set 4 between increasing and decreasing rest intervals (p≤0.05). However, the total repetitions of the three training sessions were not significantly different (p>0.05).

There was no significant difference between the reported RPE in three rest intervals (p>0.05).

**DISCUSSION**

Hypertrophy is a predominant response to resistance training and is predicated upon recruitment of more motor units and achieving higher firing rate in involved muscles for a sufficient length of time (18). To increase the time under tension and achieve high training volume at high intensity, the key determinant of muscle activation, some scholars and practitioners recommend longer rest period between sets (12).

Nevertheless, lengthy rest period between sets increases the duration of training, and may not be suitable for individuals with limited training time. To investigate the effect of various rest intervals on the work volume completed in each set and the total training volume completed in one training session, the current study compared three alternatives: Constant rest interval, decreasing rest interval and increasing rest interval.

In this study, the total length of rest period in each training session was identical (270 seconds) across three rest interval conditions. The only difference between three conditions was the allocation of 270 seconds of rest between the 4 sets of bench press. The results revealed that when recovery time is limited, decreasing rest interval results in significant reduction of repetitions and the work volume competed in the set 4 compared to increasing rest interval. This could be explained by longer rest period between the third and fourth set of increasing rest interval which allowed better recovery and ATP resynthesis.

In the current study, only 4 sets of bench press were performed during each training session. The results did not show any significant difference in the work volume completed in set 4 between constant and increasing rest intervals. However, the difference between constant and increasing rest intervals might be prominent for a training session consisted of 5 sets or more.

Many athletes perform more than 4 sets of exercise in a training session. For instance, weightlifters and powerlifters tend to achieve higher training volume over multiple sets in each muscle group. The effect of different rest intervals on training volume completed in more than 5 sets was not investigated. However, the results of current study suggested the repetitions and training volume of the first three sets to be similar between the constant, decreasing and increasing rest intervals. It is likely that the effect of different rest intervals on repetitions and training volume be pronounced after the fourth set. Presumably, the increasing rest between the later sets facilitated recovery by restoring energy sources, removing by products, and restoring force production (17, 19).

Similarly, the protocol in which the rest periods increased could generate another benefit, a benefit that is observed only after multiple sessions. Specifically, if participants apply this protocol, they realise they can perform many repetitions during their last set. Consequently, they might not withhold effort during earlier sets, a tendency that could limit training volume. Because of these reasons, the protocol in which rest period increases over time, might augment training volume over multiple sessions, but not a single session.

Participation in multiple training sessions per week is related to the level of difficulty of each training session. Training sessions which are less exerting might be appealing to general population and gym users. The results of this study showed no significant difference between constant, increasing and decreasing rest interval of the rate of perceived exertion. This lack of difference in RPE could be explained by the design of the current study.

Participants of the current study were instructed to achieve maximum number of repetitions in each set. As such, RPE did not differ across different rest conditions. It is, however, interesting to note that participants reported the same levels of difficulty in increasing rest interval in which they completed more repetitions and achieved higher training volume in set 4 compared to decreasing rest interval. This could be due to longer rest period before the final set, which resulted in training sessions perceived to be slightly easier and more manageable compared to decreasing rest interval session.

**Practical Applications**

The results of the current study suggest that the repetitions and training volume completed in one training session consisting of 4 sets of a single exercise, is likely to be similar between contestant, increasing, and decreasing rest intervals. For athletes who complete more than 4 sets of exercise per training session, increasing rest interval may result in achieving higher work volume in final sets when compared to decreasing rest interval.
REFERENCES