A Comparison of Three Different Rest Intervals Between Multiple Squat Bouts

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Reference Data


ABSTRACT

The effects of 3 different rest intervals on resistance training performance were examined. Fifteen resistance trained men completed 4 testing sessions. Session 1 was used to establish a 10 repetition maximum (RM). During the next 3 sessions the subjects performed 4 sets of squats to voluntary exhaustion with 85% of their 10-RM. Recovery time among sets was randomly assigned from: achieving a postexercise heart rate of 60% age-predicted maximum (Post-HR); a timed 3-min interval (3-min); and a 1:3 work-rest ratio (1:3 W/R). No significant differences were observed in repetitions to exhaustion, blood lactate concentrations, or RPE among the 3 recovery conditions. Post-HR, 3-min, and 1:3 W/R recovery conditions were equally effective methods of recovery during the 4 sets of parallel squats to exhaustion.

Key Words: work : rest ratio, heart rate

Introduction

During a multiple-set training program it is necessary to establish suitable recovery intervals between successive work bouts for the same muscle group. Given the proper exercise intensities, exercise durations, and rest intervals, the appropriate energy system can be stressed (5). Bodybuilders take very brief rest periods between sets because they are more concerned with muscle hypertrophy than with heavy loads (28). Short rest periods are accompanied by considerable muscle discomfort due to occlusion of blood flow (16), lactate production (14, 25, 27, 30), energy depletion (13, 15, 20), and decreased force production (33). While this is not the only means of building larger muscles, short rest intervals are characteristic of successful bodybuilding programs (14).

Weightlifters, on the other hand, take relatively long rest periods between sets because they are more concerned with using heavy resistance than with muscle hypertrophy. Long recovery intervals are needed to establish normal blood flow, remove lactic acid, replenish energy sources, and reestablish force production capabilities (14).

As a general guideline, the rest interval between sets of an exercise is progressively reduced as one adjusts to the training load, and prolonged as training loads increase (32). Rest intervals may range from 30 to 60 sec for bodybuilders (14, 28) and from 2 to 5 min for weightlifters (14).

Time is often used to determine the rest interval between sets during resistance training. A 1:3 work : rest ratio and a 3-min timed rest interval both establish a large ratio of rest to work. This allows sufficient time for restoring a large portion of the intramuscular stores of ATP and phosphocreatine (5, 14, 32). Some individuals also believe that achieving a specific recovery heart rate (HR) during the rest period is a good indicator as to whether the body is physiologically prepared for another work period. A recovery HR of 100–120 bpm has been suggested as an optimal range for those interested in developing the ATP-phosphocreatine energy system (5, 23). Optimal rest intervals for persons undertaking resistance training have yet to be determined.

The purpose of this study was to compare the achieving of a specific postexercise recovery HR, a fixed 3-min time interval, and a fixed 1:3 work : rest ratio as methods of recovery during a resistance training workout as measured by repetitions to exhaustion, blood lactate concentrations, and rating of perceived exertion.

Methods

Fifteen recreationally resistance-trained men volunteered for the study. Their physical characteristics (mean ± SE) were: age 28.3 ± 1.2 yrs; height 178.3 ± 1.4 cm; weight, 86.6 ± 3.3 kg. All had been training an average of 3 days a week for 1 year and could parallel squat 1.25 times their body weight for 10 repetitions. The procedures were explained to them and each subject provided informed consent in accordance with university guidelines for human experimentation. They were instructed to avoid strenuous lower body resistance exercise for 48 hrs and to refrain from eating 3 hrs prior to each testing session.

There were 4 testing sessions, each separated by a 3- to 7-day period. During the first session each subject had his 10 repetition maximum (10-RM) determined on the barbell squat using a previously described protocol (25). The squatting cadence was one complete repeti-
tion in 5 sec, called out by an investigator using a stopwatch (25). The cadence was a 2-sec descent and a 3-sec ascent. The 10-RM for the subjects was 119.3 ± 5.4 kg.

During the next 3 testing sessions the subjects reported to the laboratory and rested supine for 10 min. They then performed a warm-up of 1 set of 10 reps each at 45, 55, and 65% of their 10-RM. A 5-min rest interval separated each set. They then performed 4 sets to voluntary exhaustion at 85% of their 10-RM, a training load equal to 101.3 ± 4.6 kg. The squatting cadence was the same as used during the testing of the 10-RM. Performance was measured by counting the total number of reps to exhaustion during each set. Voluntary exhaustion was defined as the point at which no more reps could be performed using proper technique (25).

Immediately following each set, the subjects sat in a chair and remained passive during the recovery phase. Rest intervals between sets were randomly assigned using a counterbalanced design for the 3 sessions. The recovery protocols were: achieving a postexercise heart rate equal to 60% of age-predicted HR max (Post-HR), a timed 3-min interval (3-min), and a work:rest ratio of 1:3 (1:3 W/R).

Heart rates were monitored with a heart rate telemetry unit (Polar Instruments) beginning with the completion of the squat and continuing throughout Post-HR recovery. Time was measured with a digital stopwatch for the 3-min and the 1:3 W/R recovery periods. To calculate recovery time for 1:3 W/R, the duration of the previous work interval was multiplied by 3 (rest interval). The recovery time for 1:3 W/R was 234.0 ± 10.8, 163.0 ± 11.2, 125.0 ± 8.4, and 102.0 ± 8.5 sec for Sets 1, 2, 3, and 4, respectively.

In a subset of 6 subjects, blood lactate concentration ([La]) was measured prior to the warm-up, immediately following the 2nd set, immediately prior to the 3rd set, immediately following the 4th set, and again following the 4th set after the rest interval. A 75-ml blood sample was collected via finger stick method. The [La] was determined using a calibrated Yellow Springs Instrument Model 1500 Sport L-lactate analyzer. Rating of perceived exertion (RPE) was determined immediately before and after each set using Borg's 10-point RPE scale (2).

Repeated measures ANOVA and paired t-tests with Bonferroni correction were used to determine whether there were significant differences for repetitions to exhaustion, [La], and RPE among the 3 recovery conditions. The total repetitions to exhaustion for each recovery condition were analyzed with a one-way ANOVA and paired t-test with Bonferroni correction. Statistical significance for the ANOVAs was set at \( p \leq 0.05 \). All values are reported as means ± SE.

**Results**

The repetitions to exhaustion for each set under the 3 recovery conditions are shown in Table 1; no signifi-

<table>
<thead>
<tr>
<th>Condition</th>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
<th>Set 4</th>
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</thead>
<tbody>
<tr>
<td>Post-HR</td>
<td>15.7 ± 0.7</td>
<td>10.6 ± 0.5</td>
<td>8.8 ± 0.4</td>
<td>7.9 ± 0.6</td>
</tr>
<tr>
<td>3-min</td>
<td>15.5 ± 0.6</td>
<td>10.7 ± 0.7</td>
<td>8.1 ± 0.4</td>
<td>6.5 ± 0.5</td>
</tr>
<tr>
<td>1 : 3 W/R</td>
<td>15.6 ± 0.7</td>
<td>10.9 ± 0.8</td>
<td>8.3 ± 0.6</td>
<td>6.8 ± 0.6</td>
</tr>
</tbody>
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No signific. diff. between conditions \((p > 0.05)\); signific. diff. within each condition using Bonferroni correction factor \((p \leq 0.016)\).

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<tbody>
<tr>
<td>Post-HR</td>
<td>1.1</td>
<td>8.0</td>
<td>8.5</td>
<td>8.9</td>
<td>8.8</td>
</tr>
<tr>
<td>3-min</td>
<td>1.2</td>
<td>±0.1</td>
<td>±0.8</td>
<td>±0.7</td>
<td>±0.5</td>
</tr>
<tr>
<td>1 : 3 W/R</td>
<td>1.3</td>
<td>±0.1</td>
<td>±0.9</td>
<td>±0.6</td>
<td>±1.1</td>
</tr>
</tbody>
</table>

No signific. diff. between conditions \((p > 0.05)\); signific. diff. within each condition using Bonferroni correction factor \((p \leq 0.012)\); Signific. diff. between time points.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pre- Set 2</th>
<th>Pre- Set 3</th>
<th>Pre- Set 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-HR</td>
<td>4.3 ± 0.4</td>
<td>5.4 ± 0.4</td>
<td>6.7 ± 0.3</td>
</tr>
<tr>
<td>3-min</td>
<td>3.7 ± 0.4</td>
<td>5.6 ± 0.4</td>
<td>6.7 ± 0.3</td>
</tr>
<tr>
<td>1 : 3 W/R</td>
<td>4.1 ± 0.5</td>
<td>5.4 ± 0.5</td>
<td>6.9 ± 0.3</td>
</tr>
</tbody>
</table>

No signific. diff. between conditions \((p > 0.05)\); signific. diff. within each condition using Bonferroni correction factor \((p \leq 0.016)\).
rest. No other significant differences were observed within the 1:3 W/R recovery condition, but they were observed within the Post-HR and 3-min recovery conditions. For both conditions the postexercise Set 4 and postrecovery Set 4 differed significantly from the postexercise Set 2 and preexercise Set 3 values (p ≤ 0.016).

RPE values are listed in Table 3. All subjects reported feeling fully recovered (a value of 1 on Borg's 10-point RPE scale) after the warm-up sets and prior to the first set to exhaustion. They also reported putting forth maximal effort at the conclusion of each set to exhaustion (a value of 10 on the Borg scale); therefore that information is omitted from Table 3. Only RPE values for the preexercise measures are listed. No significant differences were observed among recovery conditions, but a significant difference was observed in RPE within each recovery condition, with each value differing significantly from every other value (p ≤ 0.016).

**Discussion**

The data from the present study indicate that Post-HR, 3-min, and 1:3 W/R recovery periods are equally effective as methods of recovery during multiple sets of parallel squats to exhaustion. The repetitions performed for each condition were similar despite differences in recovery time. Recovery times decreased for the 1:3 W/R protocol and increased for the Post-HR protocol. The 1:3 W/R rest period progressively decreased after Set 1 and was 43% shorter than the 3-min protocol at the end of Set 4. Although not recorded, Post-HR recovery time increased across the 4 sets, which is consistent with previous findings (25, 32).

Several explanations have been presented as to what factors contribute to fatigue during high intensity intermittent exercise. Some researchers have reported that the replenishment of ATP stores requires 3–5 min (6, 10, 24, 32) and that phosphocreatine (PCr) restoration occurs in 5 min (6, 10, 24). Of itself, this information suggests that if given adequate time to recover, subsequent performance is not impaired. However, other researchers have observed that PCr and ATP are almost completely restored following 4 min of recovery, indicating that the energy contribution to successive bouts from ATP and PCr is unchanged (10, 20, 22). According to Fleck and Kraemer (6), almost 90% of the ATP and PCr stores should be replenished in 1 min by oxidative metabolism. It is generally agreed that it is impossible to deplete ATP stores more than 20 to 25% in voluntary exercise (9). Therefore, it is believed that a low level of ATP is not the direct cause of metabolic fatigue (8).

Researchers have begun to focus more on the metabolic end-products (4, 17), especially those of the phosphate energy system. Of the wide range of metabolic end-products examined, inorganic phosphate (P) and hydrogen ions (H+) have been shown to have the most profound effect on mechanical function (4, 17).

Hydrogen ion concentration continues to be recognized as an important metabolite that contributes to fatigue during longer periods of heavy activity, after [P] has peaked (3, 18). High intensity exercise results in lactate accumulation and can disturb the concentration differences between Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻, and other anions such as proteins and phosphate ions, resulting in a lowered intracellular pH (11, 12). At low pH values, both the peak isometric force and the maximal velocity of shortening are substantially depressed (4).

The time needed for peak cellular lactate ion and H⁺ efflux from contracting tissue has been shown to be 4 to 10 min (11). With high intensity exercise, such as completing 4 sets of squats to exhaustion, recovery intervals of less than 4 min may not be long enough to neutralize the intracellular effects of ion and pH disturbances (19, 25).

The lack of a significant difference in [La] among the 3 recovery conditions sheds light on the primary contributing factors to fatigue in this study. When the lactate data are viewed collectively with previous research on ATP and CP restoration as well as changes in [P], [H⁺], and [Ca²⁺], the data suggest that increased H⁺ may have been the main contributor to reduced force production. Because each recovery condition was similarly influenced by the force-inhibiting qualities of increased H⁺ concentrations, the repetitions performed during each ensuing set were similar. The significant differences in [La] observed within the 3 recovery conditions were expected and are consistent with previous studies involving high intensity intermittent exercise (14, 25).

Subjects in this study demonstrated elevated [La]. When compared to previous studies (13, 14, 25, 27, 31), however, these levels were noticeably lower than those of trained subjects but higher than for untrained subjects. The trained subjects from previous research (14, 25, 27) who had higher [La] levels were competitive bodybuilders, powerlifters, or Olympic weightlifters. The subjects in the present study were recreationally trained and 13 of the 15 performed 30 min of aerobic activity at least 3 days a week.

Two possibilities emerge from the literature to explain the differences in [La]. Both animal (30) and human studies (26, 29) have indicated that lactate accumulates faster in fast-twitch than in slow-twitch exercising muscle fibers. Competitive bodybuilders, powerlifters, and weightlifters would most likely have a greater distribution of fast-twitch to slow-twitch fibers than recreationally trained individuals, therefore lactate production would be greater. Furthermore, the metabolic profile of slow-twitch and aerobically trained fast-twitch can be assumed to be more efficient in oxidizing lactate, due to differences in isoenzyme patterns and a change in lactate dehydrogenase activity (1, 21, 29, 30).

Research has demonstrated that RPE can help predict relative metabolic demands (7). Therefore, if the metabolic demands are similar among recovery condi-
tions, the RPE values will also be similar. In the present study, as the metabolic demands increased with each set to exhaustion, so did the RPE values. These values did not change even though recovery time was variable among the 3 conditions.

Practical Application

The results of this study indicate that Post-HR, 3-min, and a 1:3 W/R ratio produce similar results when completing 4 sets of squats to exhaustion. This indicates that shorter rest intervals such as those used in the 1:3 W/R recovery condition would benefit athletes seeking to maximize their time in the weight room. Those who might benefit most from a 1:3 work : rest protocol include athletes whose sports allow limited recovery time.

An optimum recovery period between sets depends on training objectives, type of exercise, training load, number of repetitions per set, repetition cadence, and other factors. Athletes and strength coaches must be able to manipulate these variables effectively to ensure maximum gains in strength and conditioning for a specific sport. Using a work : rest protocol establishes a rest interval that is sport specific, measurable, can be changed as periodized phases of training alter training loads, and is based on work performed.

References