Planned Intensity Reduction to Maintain Repetitions Within Recommended Hypertrophy Range

Helio S. Medeiros, Jr, Rafael S. Mello, Mayara Z. Amorim, Alexander J. Koch, and Marco Machado

Purpose: The authors tested different loading schemes for the number of repetitions completed during multiple sets of resistance exercise. Methods: Twenty-four resistance-trained men (age 24.0 ± 4.5 y, body mass 78.3 ± 10.2 kg, height 177 ± 7 cm) were tested over a 5-wk period. During week 1 a 10-repetition maximum (10RM) in the leg press was determined. During weeks 2–5 subjects completed 4 bouts of leg presses, in a randomized fashion, consisting of 4 sets with 60 s of interset rest. Set 1 of each bout was performed with 10RM, with differing intensity for sets 2–4 as follows: (1) 10RM load for all sets (CON), (2) 5% load reduction after each set (RED 5), (3) 10% load reduction after each set (RED 10), and (4) 15% load reduction after each set (RED 15). Results: Significant ($P < .05$) decreases in repetitions completed across sets were observed in CON (sets 2, 3, and 4) and RED 5 (sets 3 and 4). Significant increases in repetitions completed across sets (2, 3, and 4) were observed in RED 10 and RED 5 ($P < .05$). RED 5 (8.3 ± 0.9 repetitions) and RED 10 (12.0 ± 1.1 repetitions) allowed subjects to maintain the majority (>60%) of sets in the range of 8–12 repetitions, whereas both CON and RED 15 resulted in <50% of sets in the range of 8–12 repetitions, with the majority of sets performed <8 repetitions for CON and >12 repetitions for RED 15. Conclusion: Reducing load 5–10% in each set should allow maintenance of 8–12RM loads for most sets of resistance exercise.

Keywords: resistance training, volume, fatigue, repetition maximum, recovery
reduce the load. A few previous studies have investigated the use of load reductions on successive sets of resistance exercise to maintain a relatively stable RM in the face of fatigue\textsuperscript{13,14} and have yielded conflicting results. Willardson and Burkett\textsuperscript{13} found that 15\% load reductions were necessary to maintain performance of 10 repetitions in 3 successive sets of back squat and leg curls separated by 1-minute rests in recreationally trained men. In contrast, a 15\% load reduction resulted in increases, rather than a maintenance, of repetitions performed in the back squat in women.\textsuperscript{14} Thus, the current study aims to investigate how different load-reduction (in relative terms) schemes affect volume load completed for multiple sets of leg-press exercise performed until failure, with 1-minute rest intervals between sets.

Methods

Experimental Approach to the Problem

The current study was conducted over 5 weeks; during the first week, anthropometric measures (eg, height, body mass) were collected and 10RM leg-press tests were repeated 72 hours apart to verify reliable loads. During the subsequent 4 weeks subjects performed 1 resistance-exercise session consisting of 4 sets of leg presses. Each session, one of the following randomly ordered loading condition was applied: a constant 10RM load for all 4 sets (CON), a 5\% reduction after each set (RED 5; ie, 10RM, 95\% of 10RM, 90\% of 10RM, and 85\% of 10RM), a 10\% reduction after each set (RED 10), or a 15\% reduction after each set (RED 15).

Subjects

Twenty-four men (age 24.0 ± 4.5 y, body mass 78.3 ± 10.2 kg, height 177 ± 7 cm, 10 RM 248 ± 51 kg) with at least 2 years of recreational resistance-training experience participated in the current study. All subjects were characterized by the following training history: consistent participation in a resistance-training program during the previous 2 years with a minimum training frequency of 3 sessions per week; 1 hour per session; 3 to 5 sets per exercise; 6 to 15 repetitions per set; leg-press experience; RM set (to failure) experience; and 1- to 2-minute rest intervals between sets. Exclusion criteria were that subjects could not be using drugs or nutritional supplements that could affect repetition performance for a least 6 months; subjects could not exhibit bone, joint, or muscle problems that could limit the effective execution of leg-press exercise; and subjects could not be performing any extraneous structured exercise activity for the duration of the study. All participants read and signed an informed consent, which thoroughly explained the testing procedures; the experimental procedures were approved by local ethics committee.

Procedures

Each subject completed 1 exercise session per week for 5 weeks. Each exercise session was conducted on a consistent day and time each week. A strength and conditioning specialist supervised each exercise session to ensure proper technique and provide spotting and verbal encouragement. Week 1 was the preparatory period, during which 10RM loads were established for the leg press according to previously published procedures.\textsuperscript{19} The 10RM was assessed 2 times with 72 hours between tests (ICC = .945). Before the 10RM tests, each subject completed 5 minutes of low-intensity aerobic activity (ie, jogging/walking). Two warm-up sets preceded testing of each exercise at 50\% of the perceived 10RM load for 10 repetitions each. After the warm-up sets, the load was increased to the perceived 10RM, and 1 set was performed to voluntary exhaustion (ie, muscle failure). The same spotters closely supervised each 10RM attempt, and subjects were instructed to give a verbal signal when voluntary exhaustion was reached. If less than or more than 10 repetitions were accomplished during a given 10RM attempt, the load was adjusted during the next testing session.

The 10RM loads established during the preparatory period were used to design the subsequent testing sessions. Weeks 2, 3, 4, and 5 were the data-collection period, during which subjects completed 1 lower-body testing session per week under 1 of the following load conditions: constant load for all sets (CON), 5\% load reduction after each set (RED 5), 10\% load reduction after each set (RED 10), or 15\% load reduction after each set (RED 15). The conditions were randomized and counterbalanced to control for order effects.

Each testing session began with 5 minutes of low-intensity aerobic activity (ie, jogging/walking). Two warm-up sets were performed at 50\% of the predetermined 10RM for 15 repetitions each. Three minutes after the warm-up sets, 4 consecutive sets were performed to the point of voluntary exhaustion (ie, full RMs). Subjects were allowed exactly 1 minute of rest between sets. The rest intervals were precisely controlled through the use of a handheld stopwatch.

Statistical Analysis

All data are presented as mean ± SD. The reliability of the 10RM loads for leg-press exercise was assessed with the intraclass correlation (ICC) and was described as excellent for ICC values in the range of .8 to 1.0.\textsuperscript{20} Dependent variables were assessed with a 2-way mixed-model analysis of variance (4 sets × 4 load conditions) with repeated measures. Multiple comparisons were made according to the Bonferroni method with a significance level of P < .05. Statistical analysis was completed using SPSS 17.0 for Windows (Lead Technologies).

Results

We observed a significant difference in the number of repetitions performed among the conditions (F\textsubscript{3,60} = 189.432, P < .001, η\textsuperscript{2} = .892, observed power = 1.000). Specifically, there was a reduction in the number of repetitions per set after the first set in both CON (significantly fewer repetitions in sets 2–4, P < .05) and RED 5 (significantly
fewer repetitions in sets 3–4, \( P < .05 \); Figure 1). In contrast, both RED 10 (\( P < .05 \)) and RED 15 (\( P < .05 \)) resulted in a significant increase in the number of repetitions performed in sets 2 to 4 (Figure 2).

Volume load, calculated as sets × repetitions × load in each condition, is displayed in Figure 3. We found a significant difference between conditions (\( F_{3,69} = 59.920, P < .001, \eta^2 = .723, \text{observed power} = 1.000 \)),

---

**Figure 1** — Number of repetitions across sets (mean ± SD) for each condition: CON (control, 10RM load for all sets without load reduction), RED 5 (with 5% load reduction for each set), RED 10 (with 10% load reduction for each set), and RED 15 (with 15% load reduction for each set). *Different from CON (\( P < .01 \)); **different from RED 5 (\( P < .01 \)); ***different from RED 10 (\( P < .01 \)). Gray represents muscle-hypertrophic repetitions target zone for set proposed by the ACSM.²

**Figure 2** — Number of repetitions per set (mean ± SD) in 4 conditions: CON (control, 10RM load for all sets without load reduction), RED 5 (with 5% load reduction for each set), RED 10 (with 10% load reduction for each set), and RED 15 (with 15% load reduction for each set). *Different from first set (\( P < .05 \)); **different from second set (\( P < .05 \)); ***different from third set (\( P < .05 \)).
Figure 4 displays an analysis of the sum of sets that were above, below, or within the recommended target zone. We observed that the conditions RED 5 and RED 10 better maintained the repetitions within the 8–to-12-repetition zone (64% and 61% of sets in target zone, respectively). CON and RED 15 conditions resulted in the majority (more than 50%) above (RED 15) or below (CON) the proposed target zone.

**Discussion**

The key finding of the current study was that RED 5 and RED 10 intensity schemes maintained the loading within the ACSM-recommended muscle-hypertrophy target zone (8–12RM) and consequently produced a greater volume load than CON (Figure 3). For CON, there were large reductions in repetition performance between the first and subsequent sets (9.9 ± 0.3 vs 7.9 ± 0.8 vs 6.3 ± 0.8 vs 4.4 ± 1.2, ANOVA P < .05). These results were consistent with prior studies that examined exercises with a constant load15,16,21 and with load reduction in women.14 On the other hand, RED 15 induced significant increases in repetitions per set (9.4 ± 0.6 vs 11.8 ± 1.4 vs 14.3 ± 2.0 vs 18.3 ± 3.8, ANOVA P < .05).

The volume of load lifted is likely important for resistance-training adaptations including hypertrophy.1,2 If we compare the total volume load (sets × repetitions × load) among loading schemes (Figure 3), we find significantly higher values in the RED 10 condition (RED 10 11,828 ± 2730 kg vs RED 5 8245 ± 1950 kg, P < .01).

This could be an advantage for 10% load reduction. The RED 15 condition, due to the completion of the more repetitions, produced the similarly high volume load to RED 10. But many of the sets completed during RED 15 allowed for the performance of more than 12 repetitions, which may indicate that RED 15 provides an insufficient intensity threshold to yield the best possible gains in hypertrophy. Longer-term studies are needed to determine whether one condition will be better to optimize hypertrophy.

Our experimental design was based on 2 premises common to training for hypertrophy: the use of short rest intervals and training to failure. Short rest intervals between sets are a commonly recommended component of hypertrophy training.4,17,22 Therefore, modifying the load lifted from set to set would be a strategy to maintain adequate (8–12 repetitions) volume throughout an exercise bout under these conditions. The ACSM recommends 1- to 2-minute rest intervals between sets for hypertrophy training.4 The current study, in which 1-minute rest intervals were employed, falls at the lower range of the ACSM’s recommendation for hypertrophy. Thus, it could be argued that a longer (1.5 or 2 min) rest interval might allow for a greater maintenance of intensity and thus be more conducive to hypertrophy. Greater intensity maintained in conditions with longer rest intervals could allow for greater activation of high-threshold motor units, which in theory would induce hypertrophy in the muscle fibers (type II) most susceptible to hypertrophy. Alternatively, performing each set to muscle failure may provide a sufficient stimulus to induce hypertrophy, regardless of a lighter intensity.23,24 While 1-minute rest intervals lie at

**Figure 3** — Volume (sets × repetitions × load) for each condition: CON (control, 10RM load for all sets without load reduction), RED 5 (with 5% load reduction for each set), RED 10 (with 10% load reduction for each set), and RED 15 (with 15% load reduction for each set). aDifferent from CON (P < .01); bDifferent from RED 5 (P < .01).
the low end of ACSM recommendations, other sources recommend as little as 30 seconds between sets\textsuperscript{17} during hypertrophy training, and short rest appears to be common practice among bodybuilders and other athletes seeking to increase hypertrophy.\textsuperscript{22} However, the theory that short rest intervals are optimal for hypertrophy training is not without controversy.\textsuperscript{10} Short-rest interval training is recommended for achieving optimal hypertrophy because shorter rest intervals establish a hormonal milieu: specifically, greater levels of growth hormone, testosterone, and insulin-like growth factor 1, which is thought to stimulate greater muscle protein synthesis.\textsuperscript{18} However, recent work has shown that muscle protein synthesis is likely not affected by acute changes in circulating hormones after exercise.\textsuperscript{25} By implication, this would cast doubt on the efficacy of shorter rest periods as a means to optimize hypertrophy, other than as a means to allow completion of a greater volume load within a finite time frame. However, such debate extends beyond the scope of the current experiment.

Along with employing short rest intervals, training to failure has been recommended by some as advantageous for inducing hypertrophy and strength.\textsuperscript{26} Some previous studies\textsuperscript{11,12} did not demonstrate advantages between failure and nonfailure training for strength or power, but those studies did not measure the cross-sectional area of the muscles trained. Izquierdo et al\textsuperscript{12} showed a possible advantage for nonfailure training, because they found a reduction of resting serum cortisol (catabolic) and augmentation of resting total testosterone (anabolic), but this result is inconclusive and subject to criticism.\textsuperscript{10} A recent study by Sundstrup et al\textsuperscript{27} found EMG activity in untrained women performing lateral raises plateaued 3 to 5 repetitions before failure, raising questions as to whether training to failure presents any advantages to novices.

In an earlier study on load reduction, Willardson and Burkett\textsuperscript{13} examined and compared men’s performance on back-squat, leg-curl, and leg-extension exercises. They found that back squat and leg curl required 15% load reductions per set to maintain repetition performance, and load reductions were not necessary for the leg extension. Women’s performance on bench press, wide-grip front lat pull-down, and back squat with 5%, 10%, and 15% load reductions was compared with nonreduced load in the Willardson et al\textsuperscript{14} study. In that case the authors found that for the wide-grip front lat pull-down and back squat, a 10% load reduction was necessary after the first and second sets to accomplish 10 repetitions on all 3 sets. For the bench press, a load reduction between 10% and 15% was necessary. For the back squat, 15% load reduction resulted in an increase in the number of repetitions performed (9.8 ± 0.3 vs 14.0 ± 1.7 vs 14.5 ± 1.4). One possible reason for the discrepant findings between Willardson and Burkett\textsuperscript{13} and Willardson et al\textsuperscript{14} is the training status of the subjects. Willardson and Burkett\textsuperscript{13} employed

![Figure 4](image.png)

**Figure 4** — Number of sets performed above (black column), within (light gray column), or below (gray column) repetitions per set target zone.
men who were classified as recreationally trained and familiar with the exercises tested. In contrast, Willardson et al.\textsuperscript{14} used female subjects with a more extensive training history, specifically, a minimum training frequency of 3 d/wk for a period of 2 years before the experiment. The female subjects employed by Willardson and Burkett\textsuperscript{13} had a training history similar to that of the men who participated in the current experiment, which may explain their similar responses (ie, increasing, as opposed to maintaining, performance of repetitions in response to 15\% intensity reduction) observed to multiple sets of resistance exercises to failure.

In the current study, both RED 5 and RED 10 allowed subjects to complete a high number of sets (~50\%) with repetitions within the recommended range of 8–12RM, but not all. Following the RED 5 regimen brought the mean number of repetitions completed to 8 (8.3 ± 0.9), while RED 10 enabled the completion of approximately 12 repetitions (12.0 ± 1.1) per set. We can thus speculate that an ideal load reduction, allowing maintenance of ~10RM relative intensity per set, would have been between these values (ie, approximately 7.5\% reduction in intensity per set). More studies will be conducted for data confirmation.

### Practical Application

The results of the current study, in which either a 5\% or a 10\% intensity reduction allowed for maintenance of the majority of sets in the range of 8 to 12 repetitions, may be applied to the training of similarly trained men in a variety of exercises. The ACSM supports training with multiple sets of 8RM to 12RM as ideal for optimizing muscle hypertrophy.\textsuperscript{4,5,9} Coaches and athletes who are planning hypertrophy training consisting of multiple sets performed to failure may wish to employ a 5\% to 10\% intensity reduction in successive sets of resistance exercises to maintain that repetition range.

### Conclusion

In conclusion, for maintenance of repetitions in the recommended range, it is necessary to reduce load by 5\% to 10\% each successive set. The 10\% reduction allows maintenance of a higher volume load than 5\%, which could potentially lead to greater gains in hypertrophy.

### References


