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Planned load reduction strategies to maintain optimal repetitions for hypertrophy training in leg press for women

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Abstract
Introduction. According to the ACSM's position stand on resistance training, there is strong evidence (category A) that the optimal number of repetitions to optimize hypertrophy should be between 8 and 12 repetitions per set for each exercise. Aim of Study. We investigated which intensity scheme would maintain 8-12 repetitions during repeated sets of resistance exercise performed until muscular failure. Material and Methods. Twenty-eight resistance-trained women (age = 26.1 ± 6.6 years, body mass = 66.2 ± 5.94 kg, height = 165 ± 6 cm) were tested over a five-week period. In week 1 the subjects were tested for 10RM leg press. In weeks 2-5 the subjects completed four sets of leg presses performed until muscular failure, with 60 s inter-set rest intervals in a randomized, counterbalanced order. Set 1 of each bout was performed at 10RM, with differing intensity for sets 2-4 as follows: (CON) 10RM load for all sets, (RED5) 5% load reduction after each set, (RED10) 10% load reduction after each set, and (RED15) 15% load reduction after each set. Results. The number of repetitions completed differed ($p < 0.001$) depending on the conditions. Repetitions were reduced below set 1 in sets 2-4 under CON ($p < 0.05$) and for sets 3-4 ($p < 0.05$) in RED5. RED10 and RED15 resulted in increased repetitions during sets 2-4 (p 60%) of sets in the range of 8-12 repetitions, where both CON and RED15 resulted in <50% of sets in the range of 8-12 repetitions. Time under tension (TUT) was kept within a 20-70 s per set window for most sets (95% CI) for RED10 and RED15. Conclusions. Load reductions of 5-10% in subsequent sets should allow for the maintenance of 8-12 repetitions for most sets of resistance exercise, with load reductions of 10% more likely to maintain optimal TUT.

KEYWORDS: resistance training, volume, intensity, hypertrophy.

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Introduction

Training to optimize muscle hypertrophy is a common goal for health and performance. Several training variables (intensity level, numbers of sets, number of repetitions per set, movement tempo, rest intervals between sets and sessions, exercise order, etc.) have been proposed as necessary to optimize gains in muscle hypertrophy [5, 7, 8, 14].

The number of repetitions per set, for example, has been typically proposed as a vital program component ensuring optimum hypertrophy. The ACSM points to support from evidence category A (evidence from well-designed randomized control trials) that provide a consistent pattern of findings in the population, for which the recommendation is made [1, 2, 7] that the optimal number of repetitions to optimize hypertrophy should be between 8 and 12 repetitions per set for each exercise. This proposal is shared by several other authors [4, 9, 17]. Related to the number of repetitions performed, the concept of total time under tension (TUT) placed on muscles during an exercise bout is thought to be key to muscle hypertrophy as well, with TUT recommendations to optimize hypertrophy ranging from 20-70 s per set over multiple sets [12-14].

The ability to complete a given number of repetitions, of course, is dependent on the load lifted. It has anecdotally been proposed that loads lifted must be sufficient to accrue a certain degree of fatigue during each work set, independent of the number of repetitions performed [3, 9]. Thus some researchers have proposed that no fixed number of repetitions should be established; instead trainees should rather work to failure (voluntary exhaustion) during every work set [3]. The case for maintaining repetitions in the 8-12 range is enhanced (vs lifting heavier loads for fewer repetitions or lighter loads for more repetitions) by TUT recommendations for achieving hypertrophy [14], which tend to coincide with the 8-12 range. It is still controversial which method would be more efficient to optimize muscle hypertrophy. The major difficulty has been to develop a methodology that allows for an efficient comparison of the two proposals [15, 17].

When training to failure, volume and intensity have an inverse relationship. Thus, when choosing the number of repetitions to perform, the load must allow for completion of all planned repetitions in each set. This format is difficult to fulfill, as has been amply demonstrated in the literature that fatigue from previous sets performed reduces the number of repetitions completed per set and consequent TUT [9, 15, 16]. The length of the rest interval between sets crucially affects performance, with the obvious inverse relationship between the rest interval and the amount of work that may be performed [17]. A fairly short (1-2 min) inter-set rest intervals is recommended to optimize hypertrophy during resistance exercise [1].

Planned load reductions, in which the load lifted is reduced by a fixed amount over several sets, have been investigated as a strategy to allow for the maintenance of repetition numbers over multiple sets in the face of accumulated fatigue. Several studies have shown that load reductions in the range of 5-15% per set can preserve or even increase the number of repetitions completed over several successive sets [7, 17]. In theory, maintaining repetitions within this range should provide a superior stimulus for hypertrophy, though the only training study investigating load reduction to date [5] found equal results between constant loading and either 5 or 10% load reduction over a 16-week period.

Aim of Study

Thus, several studies have been carried out to verify which would be the best load reduction condition to allow for the maintenance of repetitions in the optimal hypertrophy range [5, 7, 8, 15]. However, only one study [17] employed women subjects, creating a gap in knowledge and making it difficult for athletes and coaches to adopt the method. The purpose of this study is to investigate how much load reduction (in relative terms) is necessary to maintain the majority of repetitions per set and TUT within a target zone (8 to 12 repetitions, 20-70 s) for the leg press exercise in women with a 1-minute interval between sets.

Material and Methods

Experimental approach to the problem

The current study was conducted over five weeks; during the first week anthropometric measures (e.g. height, body mass) were collected and 10RM leg press tests were repeated 72 hours apart to verify reliable loads. During each of the succeeding four weeks the subjects performed one resistance exercise session that involved performance of leg press. During each session one of the following randomly ordered loading condition was applied: a) a constant 10RM load for all the four sets (CON), b) a 5% reduction following each set (RED5) (i.e. 10RM, 95% of 10RM, 90% of 10RM, and 85% of 10RM), c) a 10% reduction following each set (RED10), and d) a 15% reduction following each set (RED15).

The 1-min rest interval between sets has been previously recommended as a training strategy to maximize hypertrophy [1]. The premise behind is that shorter rest intervals increase metabolic and hormonal response to exercise [4, 5], which may have a positive impact on stimulating greater muscle protein synthesis. Multiple sets to failure with short rest intervals are often practiced in hypertrophy training.

Subjects

Twenty-eight women (age = 26.1 ± 6.6 years; body mass = = 66.2 ± 5.94 kg; height = 165 ± 6 cm; BMI = 24.4 ± ± 1.5) with min. two years of recreational resistance training experience participated in the current study. All the subjects were characterized by the following training history: consistent participation in a resistance training program during the two previous years with a minimum training frequency of three sessions per week; one hour per session; three to five sets per exercise; six to fifteen repetitions per set; leg press experience; experience in repetitions maximum sets (to failure); and 1 to 2 minutes rest intervals between sets.

Additional exclusion criteria were: a) subjects could not be using drugs or nutritional supplements that could affect repetitions performance within min. three previous months; b) subjects could not exhibit bone, joint or muscular problems that could limit the effective execution of leg press exercise; and c) subjects could not be performing any extraneous structured exercise for the duration of the study. All the participants read and signed an informed consent form, which thoroughly explained the testing procedures; the experimental procedures were approved by the Unig Campus V Ethics Committee and were in accordance with the Declaration of Helsinki by the World Medical Association (WMA) as a statement of ethical principles for medical research involving human subjects.

Procedures

Each subject completed one exercise session per week for five 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 [4]. The 10RM for each exercise was assessed two times with 72 hours between tests. Before the 10RM tests each subject completed 5 minutes of low-intensity aerobic activity (i.e. 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-ups sets were completed, the load was increased to the perceived 10RM and one set was performed to voluntary exhaustion (i.e. muscle failure). The same spotters closely supervised each 10RM attempt and the subjects were instructed to give a verbal signal when voluntary exhaustion was reached. If fewer than or more than 10 repetitions were accomplished during a given 10RM attempt, the load was adjusted during the next testing session. Load adjustments during these sessions followed this plan – in cases of fewer than 10 repetitions lifted, the load was reduced by 10%. In cases where the subject continued beyond a 10th repetition, testers stopped the subject on the 11th repetition and a subjective determination, from 5-10%, was made for increased load on the second session. Several (three) subjects required a third testing session to establish a 10RM. In these cases an additional 72 h rest was provided before the final 10RM determination.

The 10RM loads established during the preparatory period were used to design subsequent testing sessions. Weeks 2, 3, 4, and 5 were the data collection period, during which the subjects completed one lower-body testing session per week under one of the following load conditions: (a) constant load for all sets (CON), (b) 5% load reduction after each set (RED5), (c) 10% load reduction after each set (RED10), and (d) 15% load reduction after each set (RED15). The conditions were randomized and counter-balanced to control order effects.

Each testing session during the data collection period began with 5 minutes of low-intensity aerobic activity (i.e. 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 four consecutive sets were performed to the point of voluntary exhaustion (i.e. full repetition maximums). The subjects were allowed exactly 1 minute of rest between sets. The rest intervals were precisely controlled through the use of a handheld stopwatch.

Proper execution of the leg press was defined as follows: subjects started in an initial position of 0° knee flexion (extended knees) and then participants were asked to lower the sled by bending their knees and flexing their hips in a controlled manner up to a position of 90° knee flexion and 60° hip flexion, which was set as the turnover point. The subjects' feet were positioned a shoulder-width apart at the middle point on the leg press footplate. Repetitions were performed at a cadence determined by a metronome (2 s between sounds) – with a goal tempo of 2/0/2/0, meaning 2 s each for eccentric and concentric movements and no pause in the transition phase [12].

Statistical analysis

All data are presented as means ± standard deviation. Reliability of the 10RM loads for leg press exercise was assessed with the intraclass correlation (ICC) and reliability was described as 'excellent' for ICC values in the range of 0.8-1.0 and 'good' for 0.6-0.8, whereas values below 0.6 were 'poor' [10]. Repetitions completed were assessed with a two-way mixed model analysis of variance (4 sets × 4 load conditions) with repeated measures. Multiple comparisons were made according to Bonferroni's method with a significance level $p < 0.05$. Volume load (total repetitions completed × load) was calculated and compared between the applied conditions. Statistical analyses were completed using JAMOVI 1.8 software (Sydney, Australia).

Results

We observed a significant difference in the number of repetitions performed depending on the conditions

(ANOVA repeated measures with the Greenhouse–Geisser sphericity correction; $p < 0.001$; $\eta^2 = 0.857$) (Table 1). Sphericity was not assumed (Mauchly's W $p < 0.001$).

Table 1. Number of repetitions per set (mean ± SD [95% CI]) at four conditions: CON (without load reduction), RED5 (with 5% load reduction for each set), RED10 (with 10% load reduction for each set), RED15 (with 15% load reduction for each set)

Condition	1st set	2nd set	3rd set	4th set
CON	11.2 ± 1.0 [10.8 to 11.7]	7.3 ± 0.8 [7.0 to 7.7] (a)	5.8 ± 1.2 [5.3 to 6.4] (a,b)	4.2 ± 1.0 [3.7 to 4.6] (a,b,c)
RED5	11.6 ± 0.9 [11.2 to 12.0] (c,d)	8.4 ± 0.8 [8.1 to 8.8] (a,c,d,e)	7.1 ± 1.3 [6.5 to 7.7] (a,d,e)	5.4 ± 1.4 [4.7 to 6.0] (a,b,e,f,g)
RED10	11.2 ± 1.3 [10.6 to 11.8] (b,c,d,f,g,h)	9.2 ± 1.3 [8.6 to 9.8] (a,b,c d,e,h,i)	8.2 ± 1.2 [7.7 to 8.8] (a,c,d,e,h,i,j)	7.3 ± 1.1 [6.8 to 7.8] (a,c,d,e,h,j,k)
RED15	11.2 ± 1.0 [10.8 to 11.7] (l)	11.7 ± 1.4 [11.0 to 12.3] (l)	13.1 ± 1.4 [12.4 to 13.7] (m)	14.0 ± 1.4 [13.3 to 14.7] (m)

Statistical results from post hoc test (Bonferroni's correction): (a) difference from control 1st set ($p < 0.05$); (b) difference from control 2nd set ($p < 0.05$); (c) difference from control 3rd set ($p < 0.05$); (d) difference from control 4rd set ($p < 0.05$); (e) difference from RED5 1st set ($p < 0.05$); (f) difference from RED5 2nd set ($p < 0.05$); (g) difference from RED5 3rd set ($p < 0.05$); (h) difference from RED5 4th set ($p < 0.05$); (i) difference from RED10 1st set ($p < 0.05$); (j) difference from RED10 2nd set ($p < 0.05$); (k) difference from RED10 3rd set ($p < 0.05$); (l) difference from all other values ($p < 0.05$) except for CON and RED5 1st set; (m) difference from all other values ($p < 0.05$)

Table 2. Average number of repetitions (mean ± SD [95%CI]) across sets and volume load (sets × repetitions × load) for each condition: CON (without load reduction), RED5 (with 5% load reduction for each set), RED10 (with 10% load reduction for each set), RED15 (with 15% load reduction for each set)

	CON	RED5	RED10	RED15
Average repetitions per set (range)	7.2 ± 0.7 [6.9 to 7.5]	8.2 ± 0.7[a,c] [7.8 to 8.5]	9.0 ± 0.9[a,b,c] [8.6 to 9.4]	12.5 ± 1.0[a,b] [12.0 to 13.0]
Volume load completed per bout (kg)	5575 ± 540 [5326 to 5825]	5965 ± 481 [5743 to 6187]	6078±627[a] [5788 to 6368]	7410 ± 569[a,b,c] [7148 to 7673]

[a] difference with CON ($p < 0.01$); [b] difference with RED5 ($p < 0.01$); [c] difference with RED10 ($p < 0.01$)

Table 3. Time under tension (seconds) per set (mean ± SD [95%CI]) at four conditions: CON (without load reduction), RED 5 (with 5% load reduction for each set), RED10 (with 10% load reduction for each set), RED15 (with 15% load reduction for each set)

Condition	1st set	2nd set	3rd set	4th set
CON	44.9 ± 4.0 [43.0 to 46.7]	29.3 ± 3.4 [27.8 to 30.9] (a)	23.3 ± 4.8 [21.1 to 25.6] (a,b)	16.7 ± 3.9 [14.8 to 18.5] (a,b,c)
RED5	46.2 ± 3.4 [44.6 to 47.8] (c,d)	33.8 ± 3.1 [32.3 to 35.2] (a,c,d,e)	28.4 ± 5.3 [26.0 to 30.9] (a,d,e)	21.6 ± 5.7 [18.9 to 24.6] (a,b,e,f,g)
RED10	44.7 ± 5.2 [42.3 to 47.1] (b,c,d,f,g,h)	36.9 ± 5.2 [34.6 to 39.3] a,b,c.d,e,h,i)	32.9 ± 4.9 [30.6 to 35.1] (a,c,d,e,h,i,j)	29.1 ± 4.3 [27.1 to 31.1] (a,c,d,e,h,j,k)
RED15	44.9 ± 4.0 [43.0 to 46.7] (l)	46.7 ± 5.7 [44.1 to 49.3] (l)	52.2 ± 5.7 [49.6 to 54.9] (m)	56.0 ± 5.7 [53.4 to 58.6] (m)

Statistical results from post hoc test (Bonferroni's correction): (a) difference from control 1st set ($p < 0.05$); (b) difference from control 2nd set ($p < 0.05$); (c) difference from control 3rd set ($p < 0.05$); (d) difference from control 4rd set ($p < 0.05$); (e) difference from RED5 1st set ($p < 0.05$); (f) difference from RED5 2nd set ($p < 0.05$); (g) difference from RED5 3rd set ($p < 0.05$); (h) difference from RED5 4th set ($p < 0.05$); (i) difference from RED10 1st set ($p < 0.05$); (j) difference from RED10 2nd set ($p < 0.05$); (k) difference from RED10 3rd set ($p < 0.05$); (l) difference from all other values ($p < 0.05$) except for CON and RED5 1st set; (m) difference from all other values ($p < 0.05$)

The analysis of variance (ANOVA) showed a statistically significant difference ($p < 0.001$) when comparing the average number of repetitions performed per condition (Table 2) and TUT (Table 3).
Specifically, for sets 2-4 all RED conditions allowed for more repetitions performed and longer TUT than CON ($p < 0.001$). Total volume load lifted across all the sets was increased ($p < 0.01$) above CON in RED10 (+9%) and RED15 (+33%) (Table 2).
We also found a large effect size ($\eta^2 = 0.859$). Homogeneity of variance (Levene's $p = 0.186$) and the normality test (Shapiro–Wilk's $p = 0.211$) were adequate for ANOVA. Similar results were found in total load (sets × repetitions × load) ($p < 0.001$; $\eta^2 = 0.620$).

Discussion

The main finding of the present study is that short rest intervals (60 s) greatly reduce the training volume performed over successive sets, but this can be compensated by an adequate load reduction. These results were consistent with prior studies that examined exercises with a constant load [6, 14] and with load reduction in men [5, 7, 11] and women [17]. On the other hand, RED15 induced significant increases in repetitions per set.

In an earlier study on load reduction Willardson and Burkett [15] compared men's performance in 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 leg extension. In another study women's performance on the bench press, wide grip front lat pulldown and back squat with 5, 10 and 15% load reductions was compared with a constant load [17]. In this case the authors found that for the wide grip front lat pulldown and back squat a 10% load reduction was necessary following the first and second sets to accomplish 10 repetitions on all three sets. For the bench press a load reduction between 10% and 15% was necessary. For the back squat a 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).

In our study of the leg press CON (7.2 ± 0.7), RED5 (8.2 ± 0.7) and RED10 (9.0 ± 0.9) completed an average of <10 repetitions per set. This is an issue if the trainer or athlete intends to work 10RM loads with short rest intervals between sets. We can speculate that even shorter intervals (such as 30 or 45 s) will possibly unproductively reduce the volume of repetitions.

Similar to the prior findings of Willardson et al. [17] for the back squat exercise, the present study found the RED15 resulted in an increase in the number of leg press repetitions performed over consecutive sets. In both cases the increase in repetitions performed over successive sets led to repetition numbers higher than the 8-12 window recommended for hypertrophy, which may indicate that the load was lightened below optimal levels for developing hypertrophy.

Findings in the present study are similar to those of Medeiros et al. [7], who investigated load reduction in the leg press exercise in men under very similar conditions. In both studies four sets of leg press with 60 s rest were compared under CON, RED5, RED10 and RED15 conditions in recreationally trained subjects. Similarly to the present data, Medeiros et al. [7] found both RED5 and RED10 allowed for the maintenance of most repetitions within an 8-12 range.

Time under tension and repetition tempo are not as often addressed as the number of repetitions training variables; however, they are recognized as important contributors to muscle hypertrophy [14]. Logically TUT is related to the number of repetitions performed, while in the present study, in which repetitions were performed at a set (2/0/2/0) cadence, the pattern of change between TUT over sets was identical to the pattern seen with the number of repetitions (Table 3). Namely, RED5 and RED10 maintained TUT above levels seen on CON, while RED15 resulted in an increased TUT above all conditions. The optimal window for TUT has been suggested to be between 20 and 70 s per set [14]. Under RED10 and RED15 conditions most subjects (95% CI) were able to maintain this level of TUT over four successive sets, but not for CON and RED5.

In theory, load reduction should allow for the completion of a greater volume load lifted over time and consequently provides a greater stimulus to develop skeletal muscle hypertrophy. Todate, evidence supporting this theory is lacking. Lima et al. [5] provided the only longitudinal study comparing the effects of training with load reduction (RED5 and RED10) to constant loading. In their study recreationally-trained men completed 16 wks of $3d \cdot wk^{-1}$ training on two forms of bicep curls. At the conclusion of 16 wks no measurable differences were observed in muscle hypertrophy, 10RM bicep curl strength, or average volume load lifted throughout the intervention. The subjects who trained with a RED10 protocol during this study did achieve similar results to the other conditions, although while experiencing a lower perception of effort during training [5].

Conclusions

Our work has the novel aspect that it evaluated performance on leg press and focused on women subjects. The volume load lifted could be important for resistance training adaptations [2, 5, 9]. Counterintuitively, load reduction had more effect on the number of repetitions than on volume load, as all load reductions differed from CON in repetitions completed (Table 2). Of note in this experiment, RED10 produced a maintenance of repetitions in the 8-12 range, TUT within the recommended optimal window and a significantly higher volume load lifted than CON, all of which may possibly be advantageous for increasing muscle hypertrophy over chronic training periods. This result is not supported by previous studies [5, 7, 11, 15, 17], but as the number of studies is still low, an analysis of how the total weight lifted is affected by the sex of the participants needs to be further evaluated.

Conflict of Interest

The authors declare no conflict of interest.

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