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Planned Load Reduction Versus Fixed Load: A Strategy to Reduce the Perception of Effort With Similar Improvements in Hypertrophy and Strength

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Purpose: To compare muscle thickness and 10-repetition maximum (10RM) between no load reduction and load reductions during 16 wk of resistance training. ***Methods:*** A total of 21 moderately trained men (age 23.2 [4.2] y, body mass 75.1 [7.6] kg, height 175 [4] cm) were randomized into 1 of 3 exercise groups: control (CON, n = 7), all sets with 10RM load; 5% load reduction (RED 5, n = 7); and 10% load reduction (RED 10, n = 7) for set 2 and set 3. The resistance training program consisted of completing 3 sets each of biceps and Scott curls, performed to volitional fatigue 3 d·wk^{-1}. ***Results:*** Volume load lifted over the 16 wk was similar among groups (CON, 38,495 [4397] kg; RED 5, 37,388 [3684] kg; RED 10, 42,634 [6733] kg; $P = .094$). Muscle thickness increased in all groups ($P < .001$), with no differences noted among groups ($P = .976$). Biceps-curl and Scott-curl 10RM increased in all groups ($P < .001$), with no differences noted among groups (Scott curl $P = .238$; biceps curl $P = .401$). Rating of perceived exertion (RPE) was significantly lower for RED 10 (6.8 [0.1]) than for CON (7.0 [0.1]; $P < .001$) or RED 5 (7.1 [0.1]; $P = .001$) for the Scott curl. RPE was significantly lower ($P = .001$) for the biceps curl in RED 10 (6.8 [0.3]) than in CON (7.3 [0.9]), with neither group different from RED 5 (7.0 [0.1]). ***Conclusions:*** Load reduction did not yield a difference in hypertrophy or 10RM as compared with CON. However, RED 10 induced a significantly lower RPE. Thus, load reduction may be a beneficial strategy to reduce the perception of effort during training while achieving similar improvements in hypertrophy and strength.

Keywords: resistance exercise, training, workload, muscle hypertrophy, muscle strength

Skeletal muscle mass is a critical biomarker for maintaining health and optimizing athletic performance. Increasing skeletal muscle mass is a major goal of many exercise regimens. There is a debate about the most effective training model to optimize muscle hypertrophy. Manipulation of several training variables (eg, intensity level, numbers of sets, number of repetitions per set, velocity of execution, rest intervals between sets and sessions, exercise order) has been proposed as necessary to optimize gains in muscle hypertrophy.[1,2]

The number of repetitions per set, for example, has been popularly proposed as a vital program component for ensuring optimum hypertrophy. For example, the American College of Sports Medicine 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)[2,3] 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.[4–7] However, it has anecdotally been proposed that a certain degree of fatigue must be accrued during each work set, independent of the number of repetitions performed. Thus, some have proposed that we should not establish a fixed number of repetitions; rather, trainees should work to failure (voluntary exhaustion) during every work set.[8] It is still controversial which method would be more efficient to optimize muscle hypertrophy. The major difficulty has been to develop a methodology so that the 2 proposals can be compared efficiently.[9,10]

When training to failure, the relationship between volume and intensity must be preserved. Thus, when choosing the number of repetitions to perform, load must be equivalent to allow complete execution of the movements of each set. This format is difficult to fulfill, as has been amply demonstrated in the literature that a given set's performance is affected by previously performed sets. Fatigue from previous sets performed results in a reduction in the number of repetitions in subsequent sets. The length of rest interval between sets crucially affects the performance, with the obvious inverse relationship between rest interval and amount of work that may be performed.[11]

Load reduction, in which the amount of weight lifted is reduced in successive sets, is one strategy to preserve the total volume that an individual may complete in the presence of accumulating fatigue. It is unknown whether the additional volume allowable by load reduction would offset the decrease in intensity in providing the optimal stimulus for producing hypertrophy. Furthermore, in our knowledge, no studies had studied planned load reduction on muscle skeletal adaptations, volume workload, and perceived exertion.

The purpose of this study was to compare muscle thickness and 10 repetition maximum (RM) between no load reduction and load reductions during 16 weeks of resistance training. We hypothesized that load reduction would result in a greater volume

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load lifted and produce greater increases in muscle thickness than a control condition.

Methods

Subjects

A total of 21 men (age: 23.2 [4.2] y, body mass: 75.1 [7.6] kg, height: 175 [4] cm) with at least 2 years of recreational resistance training experience participated in this study (Table 1). 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; biceps curl and Scott experience; repetitions maximum sets (to failure) experience; and 1 to 2 minutes rest intervals between sets.

Additional exclusion criteria included the following: (1) subjects could not be using drugs or nutritional supplements that could affect repetitions performance for at least 3 months prior to the experiment; (2) subjects could not exhibit bone, joint, or muscular problems that could limit the effective execution of biceps exercise; and (3) 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, and the experimental procedures were approved by local ethics committee.

Experimental Design

This study was conducted over 17 weeks. During the first week, anthropometric measures (eg, height, body mass) were collected, and 10RM biceps curl and biceps Scott tests were repeated 72 hours apart to verify reliable loads. During each of the succeeding 16 weeks, subjects performed 48 resistance exercise sessions that involved performance of both biceps exercises. Subjects were separated in 3 groups: (1) a constant 10RM load for all 3 sets of both exercises (CON), (2) a 5% reduction following each set (RED 5) (ie, 10RM, 95% of 10RM, 90% of 10RM, and 85% of 10RM), and (3) a 10% reduction following each set (RED 10).

The 1-minute rest interval between sets has been previously recommended as a training strategy to maximize hypertrophy. The premise behind this is that shorter rest intervals increase metabolic and hormonal response to exercise, which may have a positive impact on stimulating greater muscle protein synthesis.[12] Recent work has shown that muscle protein synthesis is likely not impacted by acute changes in circulating hormones after exercise.[13] Nonetheless, multiple sets to failure with short rest intervals are often practiced in hypertrophy training.

Table 1 Subject Characteristics (N = 21)

Variables	CON (n = 7)	RED 5 (n = 7)	RED 10 (n = 7)
Age, y	25.3 (5.4)	22.0 (2.1)	20.9 (3.2)
Height, m	1.76 (0.6)	1.78 (0.7)	1.73 (0.5)
Body mass, kg	80.3 (3.3)	73.4 (5.5)	73.4 (6.7)
10RM biceps curl, kg	33.6 (2.0)	29.7 (3.3)	28.0 (4.8)
10RM Scott curl, kg	32.9 (4.0)	30.9 (4.6)	32.0 (4.3)

Abbreviations: CON, control group; RED 5, 5% load-reduction group; RED 10, 10% load-reduction group.

Methodology

Each subject completed 3 exercise sessions per week for 16 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 biceps curl and Scott curl according to previously published procedures.[7] The 10RM for each exercise was assessed 2 times, with 72 hours between tests. 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-ups sets were completed, 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 2 weeks of testing sessions. In weeks 2, 4, 6, 8, 10, 12, and 14, all subjects performed 10RM test and loads were corrected when necessary. Three times a week (Monday, Wednesday, and Friday), subjects completed training sessions with the following load conditions: (1) constant load for all sets (CON), (2) 5% load reduction after each set (RED 5), and (3) 10% load reduction after each set (RED 10). Subjects were assigned to each condition in a randomized fashion.

Each training session during the data collection period began with 5 minutes of low-intensity aerobic activity (ie, jogging/walking). Two warm-up sets of biceps curl were performed at 50% of the predetermined 10RM for 15 repetitions each.

Three minutes after the warm-up sets, 3 consecutive sets were performed to the point of voluntary exhaustion (ie, full repetition maximums). Subjects were allowed exactly 1 min of rest between sets and 3 min between exercises. The rest intervals were precisely controlled through the use of a handheld stopwatch.

Ultrasound imaging was used to obtain measurements of muscle thickness. A trained technician performed all testing using a B-mode ultrasound imaging unit (LOGIQ S8; GE, Via del Rio, Yorba Linda, CA). Following a generous application of a water-soluble transmission gel to the measurement site, a linear array probe (Model ML6-15; 12 MHz) was placed perpendicular to the tissue interface without depressing the skin. Equipment settings were optimized for image quality and held constant between testing sessions. When the quality of the image was deemed to be satisfactory, the technician saved the image to hard drive and obtained muscle thickness dimensions by measuring the distance from the subcutaneous adipose tissue-muscle interface to the muscle-bone interface. Measurements were taken on the right side of elbow flexors (combination of biceps brachii and brachialis) upper arm. Measurements were taken 60% distal between the lateral epicondyle of the humerus and the acromion process of the scapula. For each measurement, the examined limb was secured to minimize unwanted movement (Figure 1). In an effort to help ensure that swelling in the muscles from training did not obscure results, images were obtained 48 to 72 hours before commencement of the study and after the final training session. To further ensure accuracy of measurements, at least 2 images were obtained for each site. If measurements were within 10% of one another, the

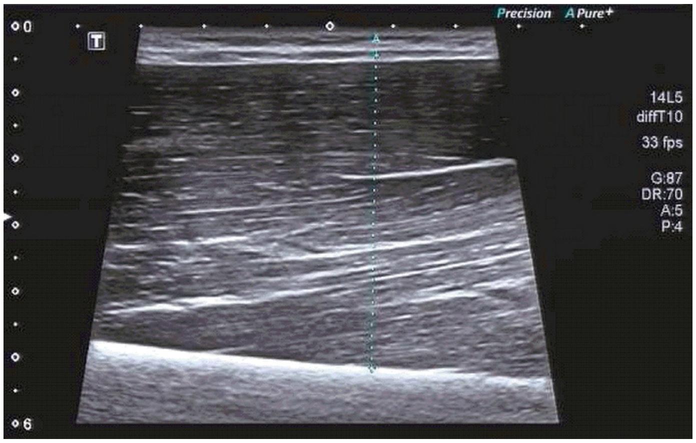

Figure 1 — Ultrasound imaging (LOGIQ S8, GE) used to obtain measurements of muscle thickness. A linear array probe (Model ML6-15; 12 MHz) was placed perpendicular to the tissue interface without depressing the skin.

figures were averaged to obtain a final value. If measurements were more than 10% of one another, a third image was obtained, and the closest 2 measurements were averaged.

Statistical Analysis

All data are presented as means (SD). Data were tested for normality of distribution using Kolmogorov–Smirnov tests. Repeated measures analyses of variance (2 time points × 3 groups) were used to compare differences in 10RM and biceps thickness over the 16-week period. Total volume load (reps lifted × kg load) completed during the training sessions for both exercises was computed and compared among groups using a 1-way analyses of variance. Average daily rate of perceived exertion (RPE) was calculated over each condition and compared between groups using a 1-way analyses of variance. In the presence of significant main effects, post hoc analyses were accomplished using Tukey HSD. Pearson product–moment correlations were used to test the relationships among volume load lifted, rating of perceived exertion, 10RM performances, and changes in biceps thickness. All statistical analyses were accomplished using SPSS version 21 (IBM Corp, Chicago, IL). Statistical significance was set at $P \leq .05$.

Results

Muscle Thickness

Biceps thickness significantly increased over the training period (time effect $P < .001$) in all groups. No between-groups differences in the change in biceps thickness were revealed (group × time interaction $P = .976$). Figure 2 displays the changes in biceps thickness among groups.

Biceps Strength

Significant increases in 10RM occurred in all groups (Figure 3), for both the Scott curl (time effect $P \leq .001$, Figure 3A) and the biceps curl (time effect $P < .001$, Figure 3B). No between-groups differences were noted (Scott curl group × time interaction $P = .238$; bicep curl group × time interaction $P = .401$).

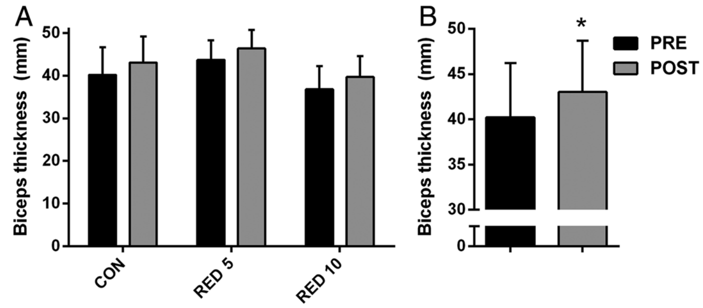

Figure 2 — Muscle thickness. Mean (SD) for each group (A) and all groups (B). CON indicates control group; RED 5, 5% load-reduction group; RED 10, 10% load-reduction group. *Significant difference ($P < .05$) to both conditions versus pretraining moment.

Volume Load and RPE

Volume load for the biceps curl was similar ($P = .649$, Figure 4A) among groups (CON: 40,767 [3111] kg; RED 5: 42,926 [2624] kg; RED 10: 41,196 [6733] kg). Likewise, volume load for the Scott curl ($P = .094$, Figure 4B) was not different among groups (CON: 38,495 [4397] kg; RED 5: 37,388 [3684] kg; RED 10: 42,634 [6733] kg).

Average daily RPE was significantly different for biceps curl ($P = .002$, Figure 4C) and Scott curl ($P < .001$, Figure 4D) among groups. Tukey tests revealed a significantly lower RPE for the biceps curl in RED 10 (RPE: 6.8 [0.3]) than in CON (RPE: 7.3 [0.9]), with neither group different from RED 5 (RPE: 7.0 [0.1]) (Figure 4C). For the Scott curl, RPE was significantly lower ($P = .001$) for the RED 10 (RPE: 6.8 [0.1]) as compared with CON (RPE: 7.0 [0.1]; $P < .001$) or RED 5 (RPE: 7.1 [0.1]; $P = .001$) (Figure 4D).

Correlations Among Volume, Strength, RPE, and Biceps Thickness

Pearson product-moment correlations revealed no relationships ($P > .216$) between total volume load lifted, RPE, or change in biceps thickness. Modest correlations were found between volume load lifted for biceps curls and change in biceps curl 10RM ($r = -.522$, $P = .015$, Figure 5A) and between RPE for biceps curls and changes in 10RM Scott curl ($r = -.469$, $P = .032$, Figure 5B).

Discussion

Load reduction has been proposed as a training strategy to increase hypertrophy by enabling trainees to complete a greater number of repetitions than could be achieved by lifting a constant load. In this study, neither the 5% nor 10% load reductions implemented resulted in a difference in total volume load lifted over the training period. In addition to a similar volume load lifted, load reductions (RED 5 and RED 10) yielded similar improvements in strength and muscle size to CON. Subjects in RED 10 experienced a significantly lower perception of effort, despite the completion of every set to volitional fatigue.

It was expected that load reduction would result in a greater volume load lifted as compared with CON. This hypothesis was not supported. Neither RED 10 nor RED 5 produced a significant change in volume load lifted versus CON; thus, it is unsurprising

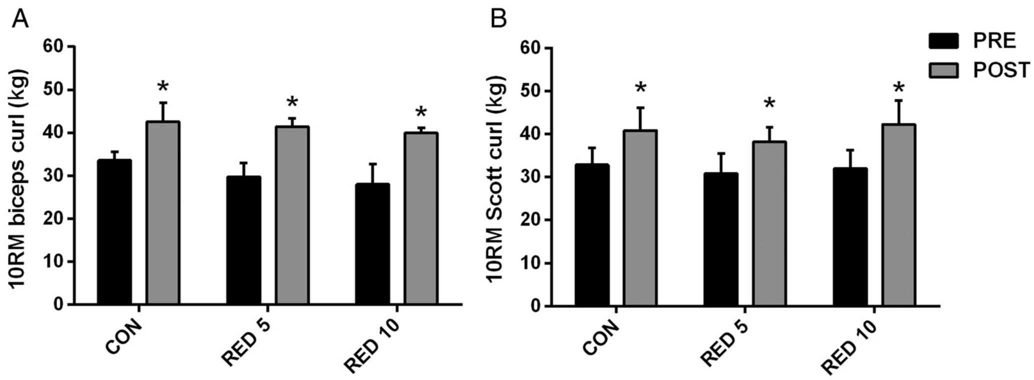

Figure 3 — Biceps strength. Mean (SD) for each group for 10RM biceps curl, (A) Scott curl, (B) and all groups. CON indicates control group; RED 5, 5% load reduction group; RED 10, 10% load reduction group. *Significant difference ($P < .05$) to both conditions versus pretraining moment.

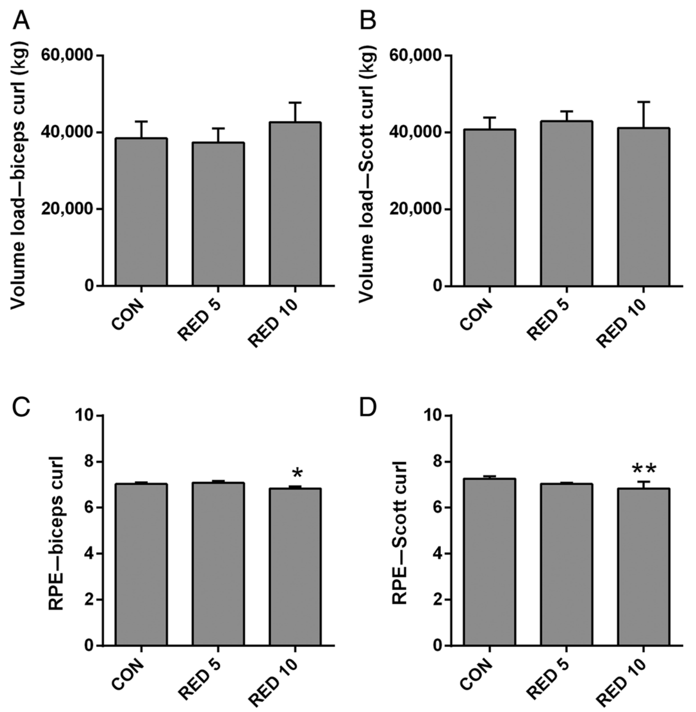

Figure 4 — Volume load and RPE. Mean (SD) for each group for volume load (A and B) and RPE (C and D) for biceps curl (A and C) and Scott curl (B and D). CON indicates control group; RED 5, 5% load reduction group; RED 10, 10% load reduction group; RPE, rate of perceived exertion. *Significant difference ($P < .05$) to RE10 versus CON and **significant difference ($P < .05$) to RE10 versus CON and RED 5.

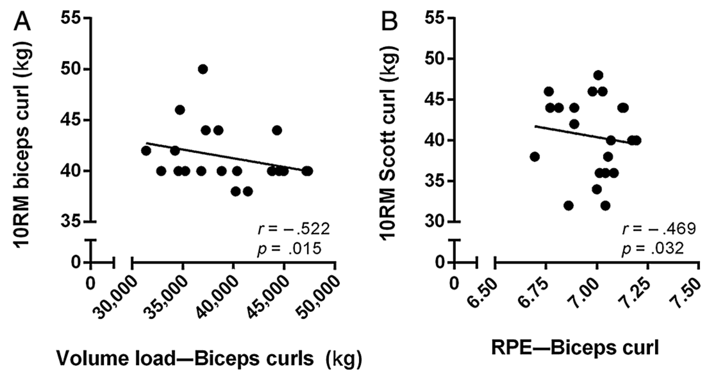

Figure 5 — Correlations among volume, strength, and RPE. Pearson's correlation between volume load—biceps curls (kg) versus 10RM biceps curl (kg) (A), and between RPE—biceps curl versus 10RM Scott curl (kg). The value of "r" has shown a significant and moderate correlation between variables. RPE indicates rate of perceived exertion.

that increases in muscle thickness were similar among the 3 conditions. Prior studies have related greater volume load lifted with greater anabolic intracellular signaling (phosphorylation of p70S6K and rpS6) for muscle hypertrophy.[14–16] Since volume lifted has been shown to affect the anabolic intracellular signaling, it would be expected that a greater volume would produce greater hypertrophy than single-set training. However, several training studies (10–14 wk duration) of resistance training have found no difference between multiple and single sets in provoking skeletal muscle hypertrophy.[17–20]

Further, Mitchell et al[20] found no relationship between the extent of intracellular anabolic signaling activated during exercise and hypertrophy. By contrast, others have found that multiple sets (greater total workout volume) produce more hypertrophy than a single set.[21] Terzis et al[15] compared the acute effect of 1, 3, and 5 sets of resistance exercise. The authors found no significant difference in phosphorylation of p70S6K and rpS6 between 1 and 3 sets; however, the exercise-derived activation of these kinases occurred only after the execution of 3 and 5 sets. Furthermore, 5 sets were more anabolic than 1 and 3 sets. In this study, only 3 sets of each exercise were performed. Thus, it is possible that total volume performed among all groups in this study was insufficient to detect differences in hypertrophy among conditions.

Average daily RPE was significantly lower for RED 10 versus CON or RED 5 for the Scott curl. Furthermore, average daily RPE was significantly lower for RED 10 versus CON for the biceps curl. This indicates that a 10% load reduction can reduce the perception of effort, despite the completion of each set to volitional fatigue. Furthermore, RED 10 produced equal improvements in both hypertrophy and strength to the other conditions. The modest, negative correlations found between RPE and 10RM strength indicate that a greater perception of effort was mildly related to lower improvements in 10RM. Thus, there was no measurable advantage from experiencing a higher RPE in this study, and RED 10 was able to produce similar results with a lower perception of effort. However, we should reiterate that it is unknown whether the benefits of RED 10 will apply to multijoint exercises (such as squats), and therefore, more research should be conducted to determine if this effect occurs in multijoint exercises.

Practical Applications

In this study, load reduction did not alter the total volume lifted during 16 weeks of resistance training. While no significant differences in 10RM nor muscle thickness were noted among groups, RED 10 achieved similar results to the other 2 conditions while inducing a lower RPE. Achieving equal gains in performance while experiencing a lower perception of difficulty is practically meaningful for any athlete, and these data support the use of RED 10 as a training strategy to promote hypertrophy while reducing effort, which in turn may enhance exercise adherence.

Conclusions

Load reduction did not yield a difference in hypertrophy or 10RM as compared with CON. However, RED 10 induced a significantly lower RPE. Thus, load reduction may be a beneficial strategy to reduce the perception of effort during training while achieving similar improvements in hypertrophy and strength.

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