SHORT COMMUNICATION

The effects of set number in stepwise load reduction resistance training on training volume and duration

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Objective: This study aimed to clarify the effects of the number of loads used in stepwise load reduction training for upper-body single and multi-joint resistance exercises on the training volume, duration, and the rating of perceived exertion.

Design: Experimental study.

Methods: Eleven young male participants performed three experimental sessions for bench press and dumbbell curls randomly. First, they performed a high load (80% of the one-repetition maximum [1RM]) set, followed by four sets at 65%, 50%, 40%, and 30% 1RM in the five-load reduction condition (5LR), two sets at 50% and 30% 1RM in the three-load reduction condition (3LR), or one set at 30% 1RM in the two-load reduction condition (2LR) until concentric failure, with minimum intervals between the loads. The total exercise duration included exercise movement and non-exercise (setting) durations.

Results: For both tests, the training volume (Load × repetitions; 1028 ± 258 kg in 5LR, 999 ± 160 kg in 3LR, and 1,003 ± 238 kg in 2LR for bench press and 226 ± 74 kg in 5LR, 200 ± 44 kg in 3LR, and 192 ± 36 kg in 2LR for dumbbell curls) and rating of perceived exertion did not differ among the conditions, whereas the total exercise and non-exercise durations in the five-load reduction condition were significantly longer than those in the other conditions ($p < 0.01$ and $p < 0.001$, respectively).

Conclusion: The number of loads for stepwise load reduction training in upper-body single and multi-joint resistance exercises did not affect the training volume and rating of perceived exertion. However, the training duration was shorter under the conditions with fewer loads than that under those with larger loads because of its increased non-exercise duration. The protocol would be more efficient if fewer loads could induce a similar adaptation.
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Key words: resistance training ■ exercise volume ■ free weight exercise ■ rating of perceived exertion

INTRODUCTION

Adaptations in muscle strength and endurance are consistent with the principle of specificity, which supports the hypothesis that a higher load in resistance exercise favors strength gain, whereas a lower load favor increased local muscular endurance, particularly when the training modalities closely reflect the measurement tests.[1-3] Regarding hypertrophy, similar whole muscle growth can be achieved across a wide spectrum of loading ranges, even for equal training volumes among loads.[1-4] Based on this knowledge, the simultaneous execution of both high and low loads in an exercise protocol could result in concomitant increases in muscle strength, endurance, and size. Our recent research revealed that "stepwise load reduction training" (SLRT), which starts at a high exercise load and gradually decreases to a low percentage of a repetition maximum (1RM) within an exercise, induces increased muscle strength, relative endurance, and hypertrophy simultaneously.[5] Moreover, it also induces these adaptations with a lower exercise duration per session than typical high- or low-load training programs. In this research, participants performed a single high-load (80% 1RM) set followed by four consecutive sets at 65%, 50%, 40%, and 30% 1RM while minimizing the interval between sets.[5] Improvements in this tentative protocol might contribute to a more efficient training method. The training volume is an important variable for muscle adaptations; therefore, a protocol with a shorter total exercise duration and a similar or lower rating of perceived exertion (RPE) than previous protocols without a change in the training volume is more efficient. However, a reduction in the number of loads (sets) in SLRT training might achieve a higher efficiency level.

Therefore, this study aimed to clarify the effects of the load number (sets) in SLRT for resistance exercise (SLRT-RE) on the training volume, training duration, and RPE. Our previous research investigated the training effects of dumbbell curls. Therefore, this study adopted both dumbbell curls and bench press to confirm whether upper-body single and multi-joint exercises generated similar results.

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METHODS

Participants

Overall, 11 young male participants majoring in physical education (age: 21 ± 1 years, height: 1.69 ± 0.05 m, body weight: 63.9 ± 10.3 kg) volunteered to participate in this study. Five men engaged in regular resistance training. They were recruited through printed advertisements and verbally and were instructed to maintain their other daily physical activities and dietary patterns throughout the study. However, any individual under medication was excluded. The participants were informed of the methods, procedures, and risks associated with the study, and they signed informed consent documents before participation. This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee for Human Experiments of Tokaigakuen University, Japan (Approval number: 2021-2).

Study design

Each participant visited the laboratory five times at 2–3-day intervals for the measurements. On their first visit, they received instructions on appropriate lifting techniques using submaximal and near-maximal loads for bench press and dumbbell curls. On their second visit, 1RM strength was determined. Therefore, to compare the SLRT-RE training volumes (Load × Repetitions) and durations, three experimental sessions were performed randomly throughout the remaining visits as follows: five-load (5LR: 80%, 65%, 50%, 40%, and 30% 1RM), three-load (3LR: 80%, 50%, and 30% 1RM), and two-load (2LR: 80% and 30% 1RM) reductions. The 5LR condition was used in our previous study [5].

1RM strength test

First, 1RM strength was determined for bench press and, subsequently, dumbbell curls. All participants performed the following warm-up sets: eight, five, and two repetitions at 40%, 60%, and 80%, respectively, of the predicted 1RM. The initial load was estimated from the familiarization session; after each trial, the load was increased or decreased by 0.15 kg (dumbbell curls) or 2.5 kg (bench press) until a true 1RM was achieved in a controlled manner through a full range of motion. For each participant, the 1RM was identified through five trials to minimize the effect of fatigue. Rest intervals of 3–5 min were allowed between trials. The test-retest (inter-session) reliabilities of the 1RM measurements were calculated using intraclass correlation coefficient (ICC), standard error of measurement (SEM), and minimal difference. Previously, these values (ICC, SEM, and minimal difference) were determined among eight young participants (bench press: 0.990, 1.32 kg, and 3.66 kg; dumbbell curls: 0.966, 0.24 kg, and 0.67 kg).

Acute exercise tests

First, Participants performed a single high load (80% 1RM) set in all conditions, followed by four sets at 65%, 50%, 40%, and 30% 1RM in the 5LR, two sets at 50% and 30% 1RM in the 3LR, and one set at 30% 1RM in the 2LR conditions. In all conditions, participants performed each set (load) until concentric failure, with contractions as fast as possible in the concentric phase (approximately 1 s) and 2 s in the eccentric phase using a metronome in a controlled manner through a full range of motion. Each load was exchanged as quickly as possible after failure by supervisors. On each day, considering the amount of training volume (fatigue), the participants initially performed the bench press followed by dumbbell curls with approximately 10-min rest interval durations between each exercise. For each condition, the total exercise duration, comprising both exercise movement and non-exercise (setting) durations, was measured using a digital stopwatch. The exercise movement duration was considered as the time when the participant performed the exercise using a barbell or dumbbell, whereas the non-exercise duration was the interval between the loads (sets), which included exchanging loads in preparation for the subsequent set. The RPE (Borg Scale) was assessed at the end of each exercise test.

Statistical analyses

Statistical tests were performed using SPSS version 23.0 software (SPSS Inc., Chicago, IL, USA). The results are expressed as means and standard deviations. Differences in values among the conditions are represented by means and 95% confidence intervals and were analyzed using a one-way analysis of variance (ANOVA) with repeated measures across conditions. When ANOVA revealed significant effects, the Bonferroni adjustments post-hoc test was used. Statistical significance was set at $p < 0.05$.

RESULTS

1RM strength

Each participant completed all five experimental sessions. The mean 1RM values obtained from bench press and dumbbell curls exercises were 67.7 ± 14.7 kg and 15.4 ± 2.4 kg, respectively.

Acute exercise test in bench press

No significant difference was found in training volume among the three conditions (Figure 1). Meanwhile, a significant difference was found in total exercise duration among the three conditions ($p < 0.01$); post hoc tests demonstrated that the duration of the 5LR condition was significantly longer than that of the 3LR (26.2 [7.9, 44.5] s, $p < 0.01$) and 2LR (26.7 [0.9, 52.6] s, $p < 0.01$) conditions (Table 1). No differences were observed in the total exercise duration between the 3LR and 2LR conditions. The non-exercise duration was significantly longer in the 3LR condition than in the 2LR condition (18.0 [11.1, 24.9] s, $p < 0.001$), whereas it was longer in the 5LR condition than in the 3LR condition (35.7 [22.9, 48.5] s, $p < 0.001$). The number of repetitions at 80% 1RM was significantly greater in the 2LR condition than in the 3LR condition (Table 2). Furthermore, the number of repetitions at 30% 1RM was significantly fewer in the 3LR condition than in the 2LR condition and the fewest in the 5LR condition. No differences were found in RPE between the conditions.

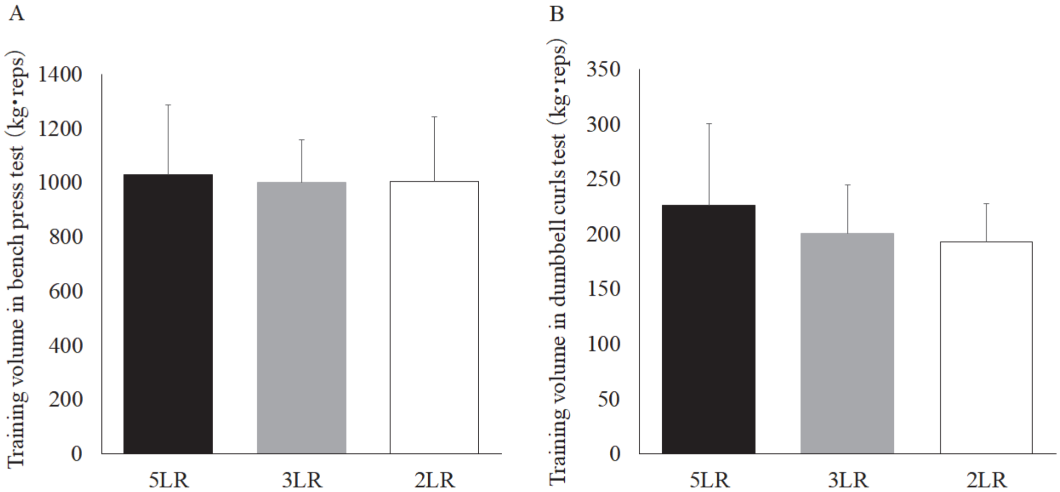

Figure 1 Training volume in the acute exercise tests. Data are presented as means ± SDs. (A) Training volume in the bench press test. (B) Training volume in the dumbbell curls test. 2LR, two-load reduction condition; 3LR, three-load reduction condition; 5LR, five-load reduction condition; SD, standard deviation.

Table 1 Exercise duration in the bench press and dumbbell curls tests

	5LR	3LR		2LR	
Bench press					
Total exercise duration (s)	159.8 ± 16.0	133.6 ± 21.6	**	133.1 ± 33.7	*
Exercise movement duration (s)	84.8 ± 14.6	94.4 ± 18.7		111.8 ± 33.8	*
Non-exercise duration (s)	75.0 ± 14.3	39.3 ± 8.3	***	21.3 ± 4.4	*** †††
RPE	18.3 ± 1.5	17.8 ± 1.3		17.5 ± 1.3	
Dumbbell curls					
Total exercise duration (s)	149.9 ± 44.4	112.5 ± 25.6	**	110.1 ± 31.3	**
Exercise movement duration (s)	85.4 ± 36.5	81.3 ± 23.2		91.9 ± 30.6	
Non-exercise duration (s)	64.5 ± 15.4	31.2 ± 9.9	***	18.2 ± 5.2	*** ††
RPE	18.0 ± 1.5	17.9 ± 1.3		17.9 ± 1.1	

Data are presented as meansSDs.
RPE, ratings of perceived exertion; 2LR, two-load reduction conditions; 3LR, three-load reduction conditions; 5LR, five-load reduction conditions; SD, standard deviation.
* $p < 0.05$ vs. 5LR, ** $p < 0.01$ vs. 5LR, *** $p < 0.001$ vs. 5LR, †† $p < 0.01$ vs. 3LR, and ††† $p < 0.001$ vs. 3LR.

Table 2 Number of repetitions for 80% and 30% 1RM load in the bench press and dumbbell curl tests

	5LR	3LR	2LR	
Bench press				
80% 1RM	7.4 ± 2.2	7.4 ± 2.1	8.2 ± 2.1	3LR < 2LR
30% 1RM	6.7 ± 1.8	13.4 ± 4.1	29.1 ± 10.5	5LR < 3LR < 2LR
Dumbbell curls				
80% 1RM	7.7 ± 2.5	6.8 ± 2.0	7.1 ± 1.9	
30% 1RM	8.7 ± 6.6	12.1 ± 5.7	23.5 ± 10.0	5LR, 3LR < 2LR

Data are presented as the mean ± SD.
5LR, five load reduction conditions; 3LR, three load reduction conditions; 2LR, two load reduction conditions; 1RM, one-repetition maximum; SD, standard deviation.

Acute exercise test in dumbbell curls

Similar to the bench press, the dumbbell curl exercise indicated no significant difference in the training volumes among the conditions (Figure 1). Meanwhile, a significant effect was determined in total exercise duration ($p < 0.001$) (Table 1). Post hoc tests demonstrated that the duration of the 5LR condition was significantly longer than that of the 3LR (37.5 [13.0, 61.9] s, $p < 0.01$) and 2LR (39.8 [12.0, 67.6] s, $p < 0.01$) conditions. However, no significant difference was found in the total exercise durations between the 3LR and 2LR conditions. The non-exercise duration was significantly longer in the 3LR condition than in the 2LR condition (13.0 [3.5, 22.6] s, $p < 0.001$), and it was longer in the 5LR condition than in the 3LR condition (33.4 [20.4, 46.3] s, $p < 0.001$). No significant difference was found in the number of repetitions at 80% 1RM among the three conditions (Table 2). The number of repetitions at 30% 1RM in the 2LR condition was significantly greater than that in the 3LR condition and tended to be greater than that in the 5LR condition ($p = 0.055$). No differences were observed in the RPE among the conditions.

DISCUSSION

This study's main finding was that the number of sets performed in SLRT did not affect the training volume or RPE in the upper-body single or multi-joint resistance exercise. However, the total exercise duration was shorter in the 3LR and 2LR conditions than in the 5LR condition. This finding resulted from a longer non-exercise duration in the 5LR condition than in the 3LR or 2LR condition.

Previous studies reported that the training status and rest interval between the sets could influence the number of repetitions and training volume.[6,7] First, Hoeger et al. demonstrated that the number of repetitions performed at a certain 1RM% (i.e., 40%, 60%, and 80% 1RM) is lower in untrained individuals than in trained individuals for the arm curl rather than for the bench press.[6] In this study, 5 of 11 male participants engaged in regular resistance training; nonetheless, the number of repetitions did not differ in the 80% 1RM for both bench press and dumbbell curls between trained and untrained participants. Therefore, the training status did not influence the number of repetitions at an identical relative load in this study. Hernandez et al. demonstrated that the training volume with 8-min rest intervals was higher than that with 5-min rest intervals, and it was even lower with 3-min rest intervals in the bench press exercise.[7] Furthermore, even a minor difference in the rest interval (i.e. 1-min vs. 2-min vs. 3-min) affects the training volume.[8] In this study, the minimum interval (non-exercise) duration between the loads was approximately 15–20 s per load, which was similar among all conditions. Therefore, using a greater number of loads resulted in a longer total non-exercise duration, although it did not generate greater training volume in the upper-body single or multi-joint exercise. An increase in the number of minimum intervals for SLRT-RE, rather than in the rest interval between typical resistance exercise sets, may not evidently affect the training volume, at least when the ranges of load use in SLRT are equal. Since training volume is one of the important variables for muscular adaptations,[4,9] 2LR or 3LR condition, which comprises a shorter total exercise duration and an RPE similar to that of 5LR, is a more efficient training protocol.

To consider the effects of the number of loads on the training volume, this study reported the number of repetitions for 80% and 30% 1RM in each condition (Table 2). The number of repetitions for 80% 1RM was significantly greater only in 2LR than in 3LR for bench press. However, the difference was < 1 repetition, which was impractical. For dumbbell curls, no significant difference was found among the three conditions. Meanwhile, the fewer load condition had greater repetitions at 30% 1RM for both bench press and dumbbell curls. Nevertheless, no significant difference was found in the training volume among the three conditions, suggesting that the number of loads < 80% 1RM did not influence the training volume, at least upon minimizing the intervals between loads.

For acute exercise tests, the participants performed bench press and dumbbell curls sequentially with approximately 10-min rest intervals between each exercise. Therefore, despite the impact of bench press on the training volume, exercise duration, and RPE in dumbbell curls, the conclusions would remain similar because the exercises were performed in an identical order for all sessions. Additionally, the exclusion of women in this study should be noted.

CONCLUSION

This novel study demonstrated that the number of loads used for SLRT in upper-body single and multi-joint resistance exercises did not affect the training volume. However, the total exercise duration was shorter in the conditions with fewer loads (3LR or 2LR) than in the 5LR condition with higher loads. This resulted from the difference in the non-exercise duration, composed of the interval duration between loads. However, the total exercise duration and RPE did not significantly differ between the 3LR and 2LR conditions. Therefore, SLRT with three loads is preferred over that with two loads because training sessions with higher loads can obtain a broader range of physical adaptations based on specific muscle adaptations to the loads.[10] However, further research is needed to clarify whether the difference in the number of loads for SLRT results in variations in physical adaptations.

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Conflict of interest

The author reports no relationships that could be construed as a conflict of interest.

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