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Research Article

A Comparison of Increases in Volume Load Over 8 Weeks of Low-Versus High-Load Resistance Training

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Abstract

Background: It has been hypothesized that the ability to increase volume load (VL) via a progressive increase in the magnitude of load for a given exercise within a given repetition range could enhance the adaptive response to resistance training.
Objectives: The purpose of this study was to compare changes in volume load (VL) over eight weeks of resistance training (RT) in high-versus low-load protocols.
Materials and Methods: Eighteen well-trained men were matched according to baseline strength were randomly assigned to either a low-load RT (LOW, n = 9) where 25 - 35 repetitions were performed per exercise, or a high-load RT (HIGH, n = 9) where 8 - 12 repetitions were performed per exercise. Both groups performed three sets of seven exercises for all major muscles three times per week on non-consecutive days.
Results: After adjusting for the pre-test scores, there was a significant difference between the two intervention groups on post-intervention total VL with a very large effect size ($F(1, 15) = 16.598$, $P = .001$, $\eta p^2 = .525$). There was a significant relationship between pre-intervention and post-intervention total VL ($F(1, 15) = 32.048$, $P < .0001$, $\eta p^2 = .681$) in which the pre-test scores explained 68% of the variance in the post-test scores.
Conclusions: This study indicates that low-load RT results in greater accumulations in VL compared to high-load RT over the course of 8 weeks of training.

Keywords: Heavy Loads, Light Loads, Repetition Scheme, Muscular Failure

1. Background

Resistance training volume is commonly defined as the total number of repetitions performed over a given time period - generally expressed on a per-session or weekly basis. However, while this measure provides a convenient method for calculating volume, it fails to take into account the amount of work performed during the allotted time frame. For example, a bout involving 40 repetitions of an exercise at 80% 1 repetition maximum (RM) would amount to substantially more work completed than the same number of repetitions performed at 50% 1RM. Hence, the concept of volume-load (VL) has been put forth to equate for differences in workload (1). VL is broadly defined as the product of repetitions and amount of weight lifted (i.e., [repetitions (no.) × external load (kg)]) (1). By factoring load into the equation, a more representative perspective on the true effects of volume can be achieved when comparing different resistance training protocols.

The assessment of VL has potentially important implications for muscular adaptations. A clear dose-response relationship has been reported between VL and both muscle strength (2) and hypertrophy (3), where higher volumes are associated with greater adaptations, at least up to a certain threshold. Moreover, higher loads induce greater mechanical tension, which is purported to be a primary driving force with respect to muscular gains (4). It is therefore conceivable that the ability to increase VL via a progressive increase in the magnitude of load for a given exercise within a given number of sets and repetition range could enhance the adaptive response to resistance training.

2. Objectives

To the authors' knowledge, no study to date has directly compared the VL response over the course of a regimented resistance-training program at two differing training loading schemes. Thus, the purpose of this study was to assess the effects of training with high (8 - 12 RM) versus low-loads (25 - 35 RM) on VL over an eight-week training program.

3. Materials and Methods

3.1. Experimental Approach to the Problem

In order to investigate the effects of different loading schemes on VL, an eight-week single-center randomized-controlled trial was completed. The trial took place in Lehman College's weight training facility in Bronx, NY (USA) over the course of the Spring semester. Subjects were pair-matched based on initial strength capacity and then randomly assigned to a group that either performed training at a loading range of 8 - 12 repetitions to muscular failure or a group that performed 25 - 35 repetitions to muscular failure. All other RT variables (e.g., exercises performed, rest, repetition tempo, etc.) were held constant. The training interventions lasted 8 weeks with subjects performing 3 total body workouts per week.

3.2. Subjects

Subjects were a convenience sample of 24 male volunteers, recruited from a university population. Subjects were between the ages of 18 - 35, did not have any existing musculoskeletal disorders, were free from consumption of anabolic steroids or any other illegal agents known to increase muscle size for the previous year (self-report), and were experienced lifters (i.e., defined as consistently lifting weights at least 3 times per week for a minimum of 1 year, and regularly performing the bench press and squat). The range of lifting experience for all subjects was between 1.5 and 9 years of consistent training.

Participants were pair-matched according to baseline strength of back squat 1RM, bench press 1RM, and bench press 50% 1RM times repetitions to failure (endurance), such that each group was statistically similar at baseline, and then randomly assigned to one of two experimental groups: (1) a low-load RT routine (LOW) in which 25 - 35 repetitions were performed to failure, per exercise (n = 12) or a high-load RT routine (HIGH) where 8 - 12 repetitions were performed to failure, per exercise (n = 12). Completion of the program was deemed successful if the subject attended at least 85% of the sessions. Approval for the study was obtained from the Institutional Review Board (IRB) at Lehman College, Bronx, New York. Informed consent was obtained from all participants.

3.3. Resistance Training Procedures

The RT protocol consisted of three sets of seven exercises per session targeting all major muscle groups of the body. The exercises performed were: flat barbell press, barbell military press, wide grip lat pulldown, seated cable row, barbell back squat, machine leg press, and machine leg extension. The exercises were chosen based on their common inclusion in bodybuilding- and strength-type RT programs (5, 6). Subjects were instructed to refrain from performing any additional resistance-type or high-intensity anaerobic training for the duration of the study.

Training for both routines consisted of three weekly sessions performed on non-consecutive days for eight weeks. All sets were carried out to the point of momentary concentric muscular failure; i.e., the inability to perform another concentric repetition while maintaining proper form. Cadence, or tempo, of repetitions was carried out in a controlled fashion, with a concentric action of approximately one second and an eccentric action of approximately two seconds, which was the same for both groups. Both groups were afforded 90 seconds rest between sets. The load was adjusted for each exercise as needed on successive sets in order to ensure that subjects achieved failure in the target repetition range. All routines were directly supervised by the research team, which included a national strength and conditioning association certified strength and conditioning specialist and certified personal trainers, to ensure proper performance of the respective routines. Attempts were made to progressively increase the loads lifted each week within the confines of maintaining the target repetition range. For example, should a subject in the HIGH group successfully complete 12 repetitions with a load, the following set, whether it be that day or the following training session, the load would be increased so that the subject would fail before reaching 12 repetitions. Prior to training, the LOW group underwent 30-RM testing and the HIGH group underwent 10 RM testing to determine individual initial training loads for each exercise. Repetition maximum testing was consistent with recognized guidelines as established by the national strength and conditioning association (5).

3.4. Volume Load Calculation

VL was calculated from training logs filled out by research assistants for every participant that completed the entire 8-week training program. VL was assessed for each exercise over the first three sessions and last three sessions of the eight-week protocol. Upper body VL was determined by combining values for the flat barbell press, barbell military press, wide grip lat pulldown, and seated cable row; lower body VL encompassed the combined sum of barbell back squat, machine leg press, and machine leg extension. Total VL was the sum of all seven exercises. Only repetitions performed through a full range of motion were included for analysis.

3.5. Statistical Analyses

Descriptive statistics were used to explore the distribution, central tendency, and variation of each measurement for both groups. Descriptive statistics for aggregated upper body exercise total VL, lower body exercise total VL and all exercise total VL were reported at baseline, at eight weeks, and as change from baseline. To determine differences between groups at eight weeks, a one-way between-groups analysis of covariance was conducted. The outcome consisted of the aggregated total VL produced using all seven resistance-training exercises after the intervention (i.e. post-test scores). Due to the non-equivalence of the groups prior to the intervention, it was decided to treat the combined volume score at the pre-test as a covariate. Preliminary checks were conducted to ensure that there was no violation of the assumptions of linearity, homogeneity of variances and homogeneity of regression slopes. Two-tailed alpha was set a priori at 0.05.

4. Results

Complete data were obtained from a total of 18 subjects (age = 23.3 years; body mass = 82.5 kg; height = 175 cm; resistance training experience = 3.4 years): 9 subjects in LOW and 9 subjects in HIGH. Overall attendance was 95.1% in LOW and 93.7% in HIGH. Six subjects dropped out prior to completion; 2 because of minor injuries sustained during training (one in each group) and 4 for personal reasons. No significant differences were noted between groups in any baseline measure (Table 1).

Volume loads were aggregated for the pre-intervention measurement and the post-intervention measurement for the four upper body exercises, the three lower body exercises and for the total VL for all exercises. All outcomes by group were normally distributed. Descriptive data is presented in Table 2.

After adjusting for the pre-test scores, there was a significant difference between the two intervention groups on post-intervention total VL with a very large effect size ($F(1, 15) = 16.598$, $P = .001$, $\eta p^2 = 0.525$). There was a significant relationship between pre-intervention and post-intervention total VL ($F(1,15) = 32.048$, $P < .0001$, $\eta p^2 = .681$) in which the pre-test scores explained 68% of the variance in the post-test scores. The covariate adjusted group means are displayed in Table 3.

5. Discussion

The present study demonstrates a discordant VL response across high (8 - 12RM) and low (25 - 35RM) loading intensities when training is carried out to concentric failure. This is highlighted by the fact that LOW displayed greater increases in VL, even when adjusting for pre-test scores. Disparities between high- and low-load resistance training are well documented in the literature. It has long been known that the number of repetitions increases as training intensity decreases (7, 8), and this increase is disproportionate to the change in load such that greater VL is accomplished at lighter loads (9). The present study also indicates that the greater sessional VL ultimately results in a greater rate of change in VL in response to consistent, low-load training.

Although the absolute increases were compared via statistical analyses, differences in relative increases in VL were also greater in the LOW condition, but to a much lesser extent (Table 2). For example, LOW's total VL increased 31305 kg from baseline, which corresponded to a 144.3% increase, and HIGH's 10714 kg increase represents a 118.3% increase from baseline. In other words, LOW's absolute increase is 292.2% greater than HIGH's absolute increase, but only 26% greater than HIGH's relative increase. Utilizing relative measures may help put things into perspective, as research has shown similar hypertrophy in both high- and low-load conditions (10-13), and may thus be a more applicable measure of changes in VL.

Endurance, or resistance to fatigue, played a crucial role in determining VL, as each subject completed repetitions to momentary muscular failure. It is well established that higher-repetition resistance training elicits greater endurance adaptations than does low repetition training (11, 14). Therefore, it is likely that the LOW condition experienced greater endurance adaptations from the greater number of repetitions performed, and thus, were able to increase the number of repetitions and consequently load used in order to increase overall VL. The HIGH may have had to rely more on the strength adaptation side of the strength-endurance continuum in order to increase repetitions and load, as the load used was closer to subjects' 1RM.

A potential limitation of the study was that the LOW condition was a novel stimulus also must be taken into account. Initial interviews revealed that none of the participants performed more than 15 repetitions during the course of their normal routines. Thus, the novelty of this loading zone conceivably allows greater opportunity for adaptation compared to a familiar stimulus. Further study is warranted to better understand this phenomenon.

Table 1. Descriptive Data[a]

Variable	Low	High
Height, cm	174.68 ± 7.38	175.25 ± 4.74
Weight, kg	80.43 ± 16.25	84.6 ± 16.84
Age, y	22.11 ± 2.97	24.44 ± 3.50
Experience, y	3.66 ± 1.88	3.22 ± 2.31

[a] All data are expressed as the mean ± SD.

Table 2. Group Means for Each Exercise Group and Measurement Point[a]

	10 RM						30 RM					
			Increase				Increase					
	Week 1, kg	Week 8, kg Absolute, kg		Relative,%	Week 1, kg Absolute, kg	Week 8, kg Relative, %						
Upper body exercises	21935 ± 3145	19518, 24351	24014 ± 3534[b]	21298, 26731	2079	109.5	31828 ± 4995	27988, 35667	39996 ± 5728[b,c]	35593, 44400	8168	125.7
Lower body exercises	36500 ± 8972	29603, 43397	45134 ± 5542[b]	40873, 49395	8634	123.7	38904 ± 9929	31268, 46536	62041 ± 16346[b,c]	49475, 74606	23137	159.5
All exercises	58435 ± 10058	50704, 66166	69149 ± 7735[b]	63202, 75095	10714	118.3	70732 ± 13664	60229, 81690	102037 ± 20522[b,c]	86262, 117812	31305	144.3

[a] Values are reported as mean ± SD or CI.
[b] Significantly greater than baseline.
[c] Statistically greater than 10RM.

Table 3. Adjusted Group Means at Post-Test

	Mean ± SE	95% Confidence Interval
10 Rep group, kg	75709 ± 3230	68825, 82592
30 Rep group, kg	95478 ± 3230	88594, 102361

5.1. Conclusions

The present study demonstrates that low intensity resistance training results in greater VL accumulated over the course of an 8-week program. While the present study cannot define a physiological mechanism responsible for such an effect, it is possible that the differential effects of high versus low-intensity training promoted the hypertrophy of specific fiber-type populations based on the demands of the activity, preferentially stimulated the mitochondrial fraction, and/or had a greater impact on buffering capacity thereby increasing fatigue resistance and higher volume loads with low-intensity training.

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Footnotes

Authors' Contribution: Brad J. Schoenfeld conceived and designed the study, oversaw data collection, interpreted data, and was involved in writing and revising the manuscript. Dan Ogborn analyzed and interpreted data and was involved in writing and revising the manuscript. Bret Contreras analyzed and interpreted data and was involved in writing and revising the manuscript. Tom Cappaert performed the statistical analysis and was involved in analyzing and interpreting data. Alex Silva Ribeiro analyzed and interpreted data and was involved in writing and revising the manuscript. Brent A. Alvar analyzed and interpreted data and was involved in writing and revising the manuscript. Andrew D. Vigotsky analyzed and interpreted data and was involved in writing and revising the manuscript.

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