The Effect of Training Volume on Lower-Body Strength

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Abstract

Robbins, DW, Marshall, PWM, and McEwen, M. The effect of training volume on lower-body strength. *J Strength Cond Res* 26(1): 34–39, 2012—The objective of this study was to examine the chronic effects on lower-body strength in resistance trained men of performing varying training volumes over 6 weeks. A pretest and posttest design was used to investigate the effects on 1-repetition maximum (1RM) squat strength. Also, 1RM testing was performed at 3 weeks. Participants were randomly assigned to an intensity-matched (80% of 1RM) low (1-SET), moderate (4-SET), or high (8-SET) volume condition. In addition to significant strength increases in all groups at the end of the 6-week period, increases were observed at 3 weeks under the 4- and 8-SET conditions, which were greater than the improvement under the 1-SET condition. At 6 weeks, the magnitude of improvement was significantly greater for the 8-SET, as compared with that of the 1-SET group. The magnitude of improvement elicited in the 4-SET group was not different from that of the 1-SET or 8-SET groups. The results suggest that "high" volumes (i.e., >4 sets) are associated with enhanced strength development but that "moderate" volumes offer no advantage. Practitioners should be aware that strength development may be dependent on appropriate volume doses and training duration.

Key Words squat, strength development, intensity matched, overtraining

Introduction

Resistance training is commonly used to develop strength in athletes of all levels and in the general population. A number of variables are commonly manipulated in the construction of exercise programs with the intention of enhancing the training outcome(s). One of the most commonly manipulated, most-researched, and controversial of these variables is volume.

Training volume refers to the total number of repetitions performed and may be manipulated with respect to a particular exercise, muscle group, training session, cycle within a program, or an entire training program. Prescribed repetitions are commonly presented as a repetition maximum (RM), or a percentage of maximal load (e.g., 80% of 1RM), for a given exercise. Volume dose is commonly prescribed in the form of sets and repetitions (e.g., 3 sets of 10 repetitions). As such, the majority of research investigating optimal training volumes has tended to do so comparing intensity-matched conditions (i.e., similar repetitions) of varying numbers of sets (6,7,11,18,19).

Debate has raged over appropriate doses of volume in terms of the number of sets (3,5,13–17,20). Much of the research has compared single-set protocols with multiple-set protocols involving 3 or 4 sets (6–9,11,18,19). There is a noticeable dearth of literature examining protocols of greater volume (i.e., >3 or 4 sets). Given that resistance trained individuals commonly perform >3 or 4 sets per muscle group, per session (especially for larger muscle groups), such investigations are scarce and inexplicable. In attempting to determine appropriate volumes in trained populations, it would seem intuitive to investigate commonly used set strategies. Thus, the purpose of this study is to compare training volumes, including a "high" volume condition more reflective of training sessions common to experienced resistance trained individuals. It was hypothesized that "moderate" and "high" volume conditions would result in greater development of strength.

Methods

Experimental Approach to the Problem

A randomized, counterbalanced 3 group (1-SET, 4-SET, and 8-SET) pretest and posttest design was used to investigate the effects on strength (1RM squat) of 6 weeks of volume-manipulated training. The 1RM squat was chosen because it is the most commonly used and accepted measure of dynamic lower-body strength. The 6-week intensity-matched exercise was performed after a 2-week training period in which

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Table 1. Characteristics of the participants (mean ± *SE*).*

Group	Age (y)	Height (cm)	Training experience (y)
1-SET ($n = 11$)	25.5 ± 1.4	177 ± 1.5	5.5 ± 3.6
4-SET ($n = 11$)	31.0 ± 3.2	178 ± 1.8	7.1 ± 5.9
8-SET ($n = 10$)	26.0 ± 1.5	179 ± 2.1	7.5 ± 5.1

*1-SET = low volume condition; 4-SET = moderate volume condition; 8-SET = high volume condition.

all the participants performed standardized training before randomization. The intensity was set at 80% of the 1RM throughout the 6-week volume-manipulated period. To determine if an overtraining effect, hindering postprogram performance, would be elicited in the 8-SET group, a standardized program was completed in the 4 weeks after the volume-manipulated 6 weeks of training. Testing was done after the standardization phase (i.e., before initiation of the 6-week program) and at 3 weeks (midpoint of volume-manipulated period), 6 weeks (completion of volume-manipulated period), and 10 weeks. Figure 1 visually depicts the experimental timeline.

Subjects

Forty-three healthy, resistance trained men volunteered to participate in this study. Attrition and noncompliance throughout the experimental period resulted in the data of 32 participants being suitable for analysis. Inclusion criteria included regular performance (at least twice per week for the 2 years before initiation of the study) of whole-body resistance exercise, no history of knee or low back injury within the year before the study, and a minimum barbell squat strength of 130% of the body weight. The participants' descriptive data are given in Table 1. The participants were excluded if they reported taking any performance-enhancing supplements (e.g., creatine and anabolic steroids). The study was approved by the University Human Research Ethics Committee and was conducted in accordance with the Declaration of Helsinki. All the participants were briefed on the testing protocols, equipment, and the nature of the study before signing an informed consent form.

Procedures

To improve our ability to blind participants to the intent of the conditions and to enhance recruitment and program adherence, whole-body (i.e., including upper body) programs were provided to all participants over all training phases. With the exception of the volume-manipulated barbell back squat over the 6-week phase, all training programs were similar for all participants.

Training Programs

Standardization Phase. Before randomization, all the participants underwent 2 weeks of standardized training. A 3-day split program was implemented in which the chest and biceps were targeted on day 1, back and triceps on day 2, and legs on day 3. Four sets of 6–12 repetitions were prescribed for each of 6 exercises on each day. Each of the 3 training days was performed 3 times during the 2-week period. No barbell squat exercise was prescribed during the initial standardization phase.

Volume-Manipulated Phase. Based on prescription of the barbell back squat exercise, the participants were randomly assigned to a low (1-SET), moderate (4-SET), or high (8-SET) volume condition. Intensity was set at 80% of the baseline 1RM and was adjusted after 1RM testing at T1 (3 weeks) to ensure progressive overload. Of the 11 participants in the 1-SET group, training loads were increased in 8, not changed in 1, and decreased in 2 participants, respectively. Training loads were increased in all 4-SET participants and all but 1 (no change) 8-SET participants. During the 6-week phase, a 2-day split program was implemented in which the upper body (chest, shoulders, arms) was targeted on day 1 and back and legs were targeted on day 2. The barbell squat was the only lower back or leg exercise prescribed during the volume-manipulated training period. All muscle groups were trained twice per week. All squat repetitions were performed to a depth of 90° knee flexion, and repetition cadence was set at 2-second descent and 1-second ascent. A pause >3seconds between repetitions resulted in the set being terminated. All the sets were performed to volitional failure with 3-minute rest intervals

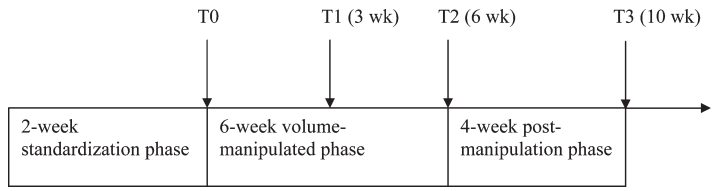

Figure 1. Experimental timeline.

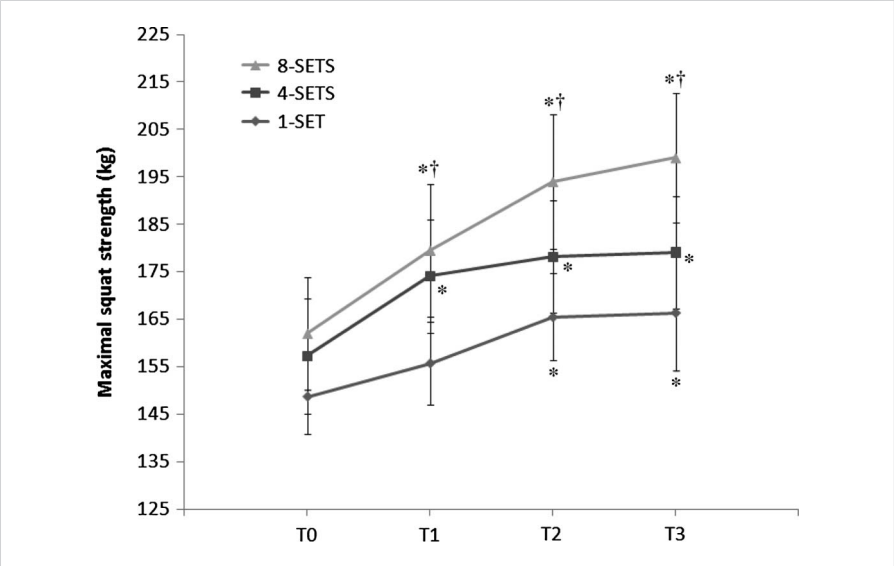

Figure 2. Maximal squat strength over the 10-week period. T0 = baseline; T1 = 3 weeks; T2 = 6 weeks; T3 = 10 weeks. *Significant difference as compared with T0; †Significant difference as compared with 1-SET group ($p < 0.05$). Data are mean ± *SE*.

between sets. Training protocols were based on previous conclusions (2,17,19), suggesting that the recommended optimal intensity of resistance exercise is 80% of 1RM, performed twice a week. This informed the 2-way split used in this study. These recommendations also suggested that 4 sets was the optimal volume. Three-minute rest intervals were implemented based on previous research, suggesting that this is an adequate period in which to recover and subsequently perform a similar amount of work (15). Before performing working set(s), a standardized warm-up was performed by all groups. Specifically, a set of 10 body weight squats preceded a set of 10 repetitions at 50% of 1RM, followed by single repetitions at 60 and 70% of the 1RM. Load and repetitions completed were recorded for all sets in all sessions.

Postprogram Phase. After the volume-manipulated 6-week phase, 4 weeks of standardized whole-body training was completed. During this phase, the participants performed 4 sessions per week with muscle groups being targeted twice weekly. A barbell back squat dose of 3 sets of 4RM was prescribed for all the participants.

Test Procedures

All testing was completed approximately 48 hours after the previous lower-body training session and was always completed on non–lower bodytraining days. The testing procedure was similar at each time point.

One-Repetition Maximum Testing. One-RM testing was performed pre, mid, post, and 4 weeks post–volume manipulated program. Testing was performed in a power squat rack, with safety parallel bars, using an Olympic bar. After a warm-up set of 10 repetitions at approximately 50% of 1RM (self-determined at T0) and sets of 1–2 repetitions at approximately 70 and 80% of 1RM, maximal attempts were made. Weights were progressively added with successful attempts. Subsequent attempts were made upon self-determined recovery, which was typically between 3 and 5 minutes. The last successful attempt was recorded as the participant's 1RM. All 1RMs were achieved between 3 and 5 attempts. The participants were instructed to place the bar across the posterior deltoids using a self-determined grip and to keep a neutral spine while facing forward (not looking down) during descent and ascent. For a test to be deemed valid, the participants were instructed to adopt a shoulder-width stance and achieve knee flexion of 90° without assistance and in a controlled manner. A 3-point person spot was provided for all trials. Knee angle verification was monitored by a single study investigator throughout the various trials (7,12). The participants were verbally encouraged throughout the 1RM attempts.

Statistical Analyses

To investigate the influence of volume on the development of strength, data analysis was undertaken to determine if any significant differences exist within or between the 3 conditions. Training effects were assessed using a 2-way analysis of variance with repeated measures (group × time). Tukey's post hoc procedures were performed to locate any pairwise differences between means. Because of the relatively small sample sizes, effect size calculations were performed, and modified Cohen (4) effect size thresholds were implemented. Specifically, effect size thresholds of 0.2–0.49, 0.5–0.8, and >0.8 were considered to be small, medium, and large, respectively. Data are presented as mean ± *SE*. Statistical significance was considered at $p \leq 0.05$.

Results

Maximal Strength

There were no statistically significant differences in squat strength or group characteristics (Table 1) between groups at T0. Significant strength increases were observed at T1 (midpoint of the volume-manipulated period) under the 4-SET and 8-SET conditions, with the improvement under the 8-SET condition being significantly different as

Table 2. Barbell back squat repetitions completed in the first set, average per set, and total completed over the 6-week volume-manipulated phase (mean ± *SE*).*

Group	Set 1 repetitions	Average repetitions per set	Total repetitions
1-SET	10.9 ± 0.7	10.9 ± 0.7	131.3 ± 8.5
4-SET	9.0 ± 1.0	7.7 ± 0.8	370.2 ± 40.1
8-SET	8.2 ± 0.9	7.0 ± 0.6	669.7 ± 59.0

*1-SET = low volume condition; 4-SET = moderate volume condition; 8-SET = high volume condition.

compared with that in the 1-SET condition ($p < 0.05$). Significant increases were observed at T2 (end of 6-week volume-manipulated period) under all conditions ($p < 0.05$). The magnitude of improvement was significantly greater for the 8-SET group (19.5 ± 3.3%) as compared with that for the 1-SET group (10.8 ± 2.8%; $p < 0.05$). The magnitude of improvement elicited under the 4-SET group (14.4 ± 2.3%) was not different from that of the 1-SET group (effect size for difference $d = 0.46$) or that of the 8-SET group (effect size for difference $d = 0.67$). During the final 4-week phase (T2 to T3), no significant changes in squat strength were observed in any group. Maximal squat strength results are presented in Figure 2. Repetitions completed in the first set and over the 6-week phase are presented in Table 2. Analysis of repetitions completed in the first set determined no differences among groups.

Discussion

Much controversy and research exist regarding the efficacy of single-set training as compared with multiple-set training. The measure in this study is 1RM squat strength. Although over the course of the experimental period increases in squat strength were observed under all 3 protocols, the highest volume group (8-SET) realized significantly greater gains as compared to those of the lowest volume group (1-SET). The observed strength increase under the 4-SET group is not different from those elicited by either the 1-SET or 8-SET conditions. This, in conjunction with moderate effect sizes between 1-SET and 4-SET ($d = 0.46$) and 4-SET and 8-SET ($d = 0.67$), suggests that volumes much greater (e.g., 8 times) than those offered by single-set protocols are necessary to realize enhanced (e.g., greater than single set) gains in maximal squat strength. The outcomes of the present research suggest that the development of strength is dependent upon appropriate volume doses.

The present research provides support for the notion that high volumes, as compared with low volumes, are superior with respect to strength development. It is possible that higher volumes are associated with relatively greater central and peripheral adaptation. A previous research study has suggested that greater volumes result in increased strength gains and may be associated with neural mechanisms (10).

Research studies investigating volumes similar to that of the highest volume group (i.e., 8-SET) in this study are scarce (7,10). The fact that the magnitude of the improvement in strength was greater under the 8-SET condition as compared with that under the 1-SET condition, but similar to the 4-SET condition, indicates that relatively large increases in volume must be performed to realize enhanced strength gains. This is supported by the lack of difference between the 1-SET and 4-SET conditions. Specifically, volume increases of 200% (4 sets, as compared with 8 sets) and 400% (1 set as compared with 4 sets) were insufficient with respect to eliciting greater strength gains. Enhanced strength development is observed upon an approximately 8-fold increase in volume of training performed. It should be noted that because sets were performed to failure, repetitions completed are not exactly 2, 4, and 8 times that of those completed under comparative conditions. The fact that such dramatic differences in the volume are necessary to enhance results needs to be considered in relation to other variables (e.g., time, overtraining). The results of the present study suggest that none of the three protocols, including the 8-SET condition, resulted in overtraining and the associated negative outcomes.

Closer examination of the chronological outcomes reveals some interesting data with respect to strength development. Over the initial 3-week period (T0–T1), both the 4-SET and 8-SET conditions resulted in strength increases. This was not the case in the 1-SET group, suggesting that over relatively short periods (e.g., 3 weeks), higher volumes may be preferred if immediate gains are a desired outcome. Over a somewhat longer period (i.e., 6 weeks), the difference between the 1-SET and 4-SET conditions was negated, suggesting that a single set of intensity-matched exercise was as effective as 4 sets were. It is possible that over the longer 6-week period, the accumulated volume and associated training stimulus were sufficient to elicit an effect similar to that elicited via the 4-SET condition. This finding supports those of previous studies (6,19), while contradicting others (8,9,11,18). Presumably, if, over periods >3 weeks, a single-set protocol elicits strength gains similar to that of a 4-set protocol, single-set modalities are preferred for reasons such as time efficiency and program adherence.

Although not statistically different among groups, despite similar instructions (i.e., provide maximal effort), repetitions completed during the first set of exercise are greatest under the 1-SET condition and become progressively less as total volume prescription increases. It is possible that slightly greater effort, and thus a somewhat different stimulus, is given if subsequent effort requirements are reduced (e.g., 4 sets as compared with 8 sets) or not required (e.g., 1 set). If this is the

case, psychological factors may need to be considered when prescribing volume.

The final 4-week period (T2 to T3) in which standardized whole-body programs were performed elicited no changes in squat strength under any of the 3 conditions. A couple of speculations can be derived from this. Firstly, the high volume performed under the 8-SET condition did not result in an overtraining effect, suggesting that such volumes and intensities may be prescribed over similar periods without concern for short-term performance attenuation. Second, the prescribed squat volume (3 sets of 4RM, twice per week) is insufficient to elicit strength gains over 4 weeks, or perhaps more accurately, insufficient to do so when preceded by training prescriptions such as those implemented in this study.

The volume of work necessary to optimize strength development is a complex problem confounded by many variables. Training variables often manipulated in conjunction with volume include type of contraction (e.g., isometric, concentric-eccentric, multijoint, and closed or open kinetic chain), intensity, cadence and rest interval(s) between multiple sets and sessions. It is also possible that interindividual variability could further confound any attempt to draw conclusions as to appropriate volume prescription. Categorical variables that could confound conclusions include the following: training status, training age, chronological age, genetics (i.e., fiber-type composition), anthropometry, gender, and relative and absolute strength. Because volume is one of the many variables commonly manipulated in conjunction with others, definitive conclusions are elusive. It is likely that volume prescription is a population-specific variable (e.g., based on the above-noted categorical factors) to be considered in conjunction with a number of training variables. The elucidation of optimal training volumes is a daunting but necessary task.

Practical Applications

It is very unlikely that there is a "one size fits all" volume prescription. Statements indicating that a certain volume is preferred, such as "multiple sets are superior to single sets" or "moderate volumes may be preferred to either light or heavy volumes," are problematic. Such statements run the risk of being misinterpreted and misused. Unfortunately, volume is likely a variable that requires constant consideration. Dependent on goal(s), volume prescription should be considered in conjunction with a multitude of other variables (e.g., intensity, time under tension, rest intervals). Further confounding volume prescription is the above-described interindividual variability. The optimal volume to achieve a given goal may be very different based on a myriad of categorical variables. Volume should be considered in a case-specific manner with the trainee(s) in mind.

The prescription of high volumes also raises questions about feasibility and practicality. Training programs aimed at developing multiple muscle groups prescribing high volumes (e.g., 8 sets) for each exercise, or muscle group, require considerably more time than do single-set volume prescription. It is recommended that programs prescribing high volumes be constructed in a body part split manner, enabling effective manipulation of volume and frequency. Also, depending on factors such as training age and status, high volumes may be inadvisable. The participants in this study had considerable training experience (i.e., average 6.6 years), and, over the volume-manipulated period, performed no lower-body exercise other than the prescribed sets of barbell back squat. If multiple lower-body exercises are prescribed at similarly high volumes, care should be taken to monitor possible overtraining effects. Further, issues associated with overtraining deserve consideration if prolonged prescription of high volumes is deemed warranted. Although performance attenuation was not observed in this study, the high volume portion of the experimental period was only 6 weeks. It may be that high volume schemes should be used in a cyclical manner with programs that are less physiologically demanding.

As discussed, the number of repetitions completed in the first set of each of the 3 protocols decreased as total session volume prescription increased. That is, with respect to first set repetitions, 1-SET > 4-SET > 8-SET. If trainees performing large session volumes "hold back" in early sets to perform better in later sets, practitioners may wish to be cognizant of this. Consideration of psychological factors may be warranted when prescribing volume.

The outcomes observed in the present research suggest some interesting possibilities with respect to training duration. It would appear that given prescription of moderate to high volumes (e.g., 40–80 repetitions) at 80% of 1RM, strength gains can be elicited in trained populations in a relatively short period of time (e.g., 3 weeks). The fact that both the 4-SET and 8-SET conditions elicited strength increases in 3 weeks (T0–T1), whereas the 1-SET condition did not, suggests that volume played a role. The notion that volume is critical for such short-term gains is supported by the lack of change in strength under any of the 3 conditions in the period after volume manipulation (T2–T3). Albeit the 6-week period preceding the final 4 weeks was very different dependent on group, it would appear that a volume of 12 repetitions (3 sets of 4RM) at an intensity of approximately 90% of 1RM (1) was insufficient to elicit advancements in strength regardless of preprogram activity. Practitioners are advised to consider maximal effort, moderate to high volumes at, or around, 80% of 1RM to achieve short-term strength development.

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