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Three Sets of Weight Training Superior to 1 Set With Equal Intensity for Eliciting Strength

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ABSTRACT

The purpose of this study was to compare single and multiple sets of weight training for strength gains in recreationally trained individuals. Sixteen men (age = 21 ± 2.0) were randomly assigned to 1 set (S-1; $n = 8$) or 3 set (S-3; $n = 8$) groups and trained 3 days per week for 12 weeks. One repetition maximum (1RM) was recorded for bench press and leg press at pre-, mid-, and posttest. Subjects trained according to daily undulating periodization (DUP), involving the bench press and leg press exercises between 4RM and 8RM. Training intensity was equated for both groups. Analysis of variance with repeated measures revealed statistically significant differences favoring S-3 in the leg press ($p < 0.05$, effect size [ES] = 6.5) and differences approaching significance in the bench press ($p = 0.07$, ES = 2.3). The results demonstrate that for recreationally trained individuals using DUP training, 3 sets of training are superior to 1 set for eliciting maximal strength gains.

Key Words: volume, resistance training, daily undulating periodization, nonlinear periodization, multiple sets

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Introduction

Research (2, 3, 8, 9, 13) has demonstrated that multiple sets elicit greater strength gains than single set training. But some researchers (16, 22) have suggested that single set protocols produce equal results and that additional sets are unnecessary. The need to determine the dose-response relationship between volume and strength gains is logical and important for strength professionals. If 3 sets fail to elicit greater gains in strength than a single set, then weight trainers can save significant amounts of time and effort by performing only 1 set. But questions on the efficacy of single set training in eliciting maximal strength gains still remain. Does single set training actually result in similar amounts of strength gains as multiple set training?

Extensive research has been conducted comparing single and triple sets of training, with contradictory results. After an analysis of studies comparing single set and triple set training, several possible confounding variables should be considered. First, pretest strength measures were not always taken on multiple occasions to establish the reliability of baseline data (2–4, 6, 7, 11, 14, 17, 19, 22). Without establishing the reliability of the baseline measure, the changes measured after training may not represent true strength increases.

Second, some studies (2, 11, 17, 19, 21) make no mention of the amount of rest given to the multiple set subjects between sets, whereas in other studies (4, 6, 8, 10) up to 30 minutes rest between sets was allowed. The use of multiple circuit training may not be comparable with multiple set training because of rest intervals between sets. Allowing too much rest between sets may limit the added stress of a multiple set training program by allowing the muscle fibers recruited and exhausted in the previous set to recover and be recruited again rather than making use of new fibers. This may limit the added adaptations to multiple set training.

It has also been common for single vs. multiple set studies (4, 7, 9, 10, 11, 13, 14, 17, 19, 21) to fail to equate training intensity between the training groups. If the goal is to examine the effect of different volumes on strength increases, then all other training variables must be held constant to attribute any differences in strength increase to the difference in volume.

Each of these issues could affect the degree of strength increases elicited by the training programs and therefore must be controlled to avoid a confounding influence. This study attempted to address each of these issues during a comparison of single and triple set training programs for increasing strength. We hy-

Table 1. Subject characteristics: means (*SD*).

Group	Age (y)	Height (cm)	Weight (kg)	Body fat (%)	Lean body (%)
S-1, $n = 8$	22 (1)	180.9 (2.4)	83.0 (6.4)	19.7 (3.7)	80.4 (3.7)
S-3, $n = 8$	20 (1)	181.5 (2.8)	97.0 (12.0)	19.5 (2.9)	78.6 (4.1)

pothesized that maintaining more stringent methodological control and limiting rest periods for multiple subjects would result in greater gains in strength in those subjects training with greater volume.

Methods

Experimental Approach to the Problem

The current study was conducted to compare single and multiple sets (3) of training for strength after ensuring reliability of baseline strength measures and limiting the multiple set training group to only 1–2 minutes rest between sets. Training intensity was equated, and physical activity outside the training program as well as the use of ergogenic aids among subjects was controlled.

Subjects

Eighteen men were recruited from college weight-training classes to participate in the 12-week training program, and they ranged in age from 19 to 23 years. Subjects were apparently healthy and reported no condition that would contraindicate participation in a weight-training program. All subjects were classified as recreationally experienced weight trainers, with a minimum of 2 years training experience (at least 2 days per week) immediately before commencement of the study. Their descriptive characteristics are presented in Table 1.

All subjects volunteered to participate in this study, which was evaluated and approved by an Institutional Review Board. Each subject completed a written informed consent before commencement of the study. Subjects were informed that missing more than 3 training sessions or failing to strictly comply with the training program would result in disqualification from the study. Two subjects reported the use of creatine monohydrate and were excluded from the study. Thus, 16 subjects were determined to be eligible to participate in this study.

Testing and Procedures

The subjects completed a questionnaire and interview regarding habitual activity and the use of ergogenic aids. This was done to ensure that all subjects were participating in similar amounts and types of activities apart from the training program and to ensure that subjects using ergogenic aids were excluded from the study. Habitual physical activity patterns were similar among all subjects mainly characterized by moderate amounts (30–45 minutes per session; 2–3 sessions per week) of aerobic-type activities, such as jogging, cycling, or recreational sports participation.

The subjects received 6 instructional sessions before the first testing session during which they were instructed in proper lifting technique and testing procedures. They were also able to become familiar with the equipment and procedures. Subjects then participated in 3 testing sessions. Three trials were completed for each exercise on separate days, each separated by at least 48 hours. Strength testing consisted of 1 repetition maximum (1RM) testing on both the barbell bench press (free weights) and leg press (Cybex incline leg press machine). Testing was carried out according to the National Strength and Conditioning Association guidelines for strength testing (15). All 1RM testing was overseen by the same trained investigator and conducted on the same equipment with identical subject/equipment positioning. Subjects were required to warm up and perform light stretching before performing approximately 10 repetitions with a relatively light resistance. The resistance was then increased to an amount estimated to be less than the subject's 1RM. The resistance was progressively increased in incremental loads after each successful attempt until failure. All 1RM values were determined in 3–5 attempts. Strength testing was repeated in week 6 and after week 12.

The 3 trials were analyzed for reliability to ensure a proper baseline measure. Trials 2 and 3 were highly correlated ($R = 0.99$), but trial 1 was found to be significantly different from trials 2 and 3 ($p > 0.05$). Therefore, the highest amount from trials 2 and 3 was selected as the baseline measure.

Before 1 of the 3 testing sessions, body composition was measured by whole-body plethysmography (Bod Pod, Life-Measurement Instruments, Concord, CA) and converted into percent fat values using the Siri equation (12). The initial measured thoracic volume was entered for the posttest to ensure reliability. Subjects were required to wear a lycra swim cap and tight fitting lycra/spandex bike shorts, or swimming briefs, for each trial. Bod Pod testing was performed by 1 trained technician.

Repeated circumference measures were taken using a Gulick tape measure. Standardized procedures for circumference measures were taken at the chest and at midthigh (1). Body composition and circumference measures were repeated after week 12.

Table 2. Results: means (*SD*).

Strength	Pre	Mid	Post	% Change pre-mid	% Change mid-post	% Change pre-post
Leg Press (kg)						
S-1	269.04 (16.8)	319.0 (64.8)	337.2 (69.0)	19 (4)*	6 (2)*	26 (5)*
S-3	225.85 (25.0)	294.3 (82.8)	343.5 (89.9)	32 (5)*	18 (4)*	56 (8)*
Bench press (kg)						
S-1	64.21 (8.9)	74.7 (27.9)	76.7 (28.0)	18 (3)	3 (2)*	20 (3)
S-3	66.76 (7.3)	75.3 (21.9)	85.5 (20.8)	13 (2)	16 (5)*	33 (8)

Body composition (Bod Pod)	Pre	Post	Change
Body fat (%)			
S-1	19.7 (3.7)	19.0 (3.3)	−0.63 (0.8)%
S-3	19.5 (2.9)	18.1 (3.1)	−1.38 (4.1)%
Lean body mass(%)			
S-1	80.5 (3.7)	81.35 (3.5)	0.9 (0.7)%
S-3	78.7 (4.1)	79.98 (4.3)	1.3 (0.6)%
Chest circumference (cm)			
S-1	123.8 (3.8)	125.7 (3.8)	1.9 (0.7)
S-3	127.1 (4.5)	129.9 (4.1)	2.8 (0.7)
Thigh circumference (cm)			
S-1	51.0 (3.2)	50.6 (2.6)	−0.5 (1.4)
S-3	53.9 (1.1)	54.6 (2.0)	0.7 (1.2)

* Signifies significant differences between groups ($p < 0.05$).

Training Program

After testing, subjects were randomly assigned to either a 1 set (S-1, $n = 8$) or 3 sets (S-3, $n = 8$) group. No significant differences existed ($p > 0.05$) in any measure between groups at baseline. Groups trained according to daily undulating periodization (DUP) that entails daily changes in volume and intensity as suggested by Rhea et al. (18). Subjects trained 3 days per week, with each session lasting about 1 hour. The first session of each week consisted of 8–10 RM, the second session consisted of 6–8 RM, and the third session consisted of 4–6 RM. Subjects were required to adjust the amount of weight used for each exercise to ensure failure between the specified RM values. Each session was separated by 48 hours. This cycle was repeated for 12 weeks, with 1 week of active rest (participation in physical activity with the exception of weight training) between weeks 5 and 6.

Both groups trained according to similar training procedures (differing only in the number of sets performed) for both the leg press and bench press. After a 10-minute warm-up consisting of light jogging or cycling and flexibility exercises, subjects performed a warm-up set with a very light resistance for approximately 10 repetitions. Resistance was then increased to an amount appropriate for the specified RM for the day. The daily RM value was identical for both groups. The S-3 group was limited to 1–2 minutes rest between sets.

Because the S-1 group completed the prescribed exercises in less time than the S-3 group, they were assigned to perform 1 set (8–12 repetitions) of exercises unrelated to the bench press and leg press. These exercises included biceps curl, lat pull-down, abdominal crunches, back extensions, and seated rows. Any remaining time was used for flexibility exercises. Time permitting, the S-3 group also performed these same exercises for only 1 set. Subjects were instructed to continue their normal habitual physical activities, but weight training not prescribed by the training program was not allowed.

Statistical Analyses

These data were analyzed using an analysis of variance with repeated measures, and, where appropriate, Tukey's post hoc tests were used to determine differences among groups and across time. The level of significance in this study was set at $p \leq 0.05$.

Results

Table 2 shows changes in measures at pre-, mid-, and posttraining. Significant increases in strength were measured for both groups pre-post ($p < 0.05$) in both the bench press and leg press. Strength increases for the leg press pre-post were measured and calculated to be 26 and 56% for S-1 and S-3, respectively. For the bench press this increase was 20 and 33%, respectively. Differences in percent increases for the leg press were found to be statistically greater ($p < 0.05$), favoring S-3. Bench press percentages were not found to significant at 0.05; however, the difference closely approached this level ($p = 0.07$).

Effect sizes (ES), using means and pooled standard deviations (*SD*s) with S-1 as the control group, were calculated to be 2.3 for the bench press and 6.5 for the leg press. These were found to be significantly different from zero ($p < 0.001$). Statistical power was estimated to be 0.99.

Neither group significantly changed ($p > 0.05$) any of the body composition nor circumference measures after the training program.

Discussion

Both S-1 and S-3 groups significantly improved strength after the training program. But the results of this study demonstrate that performing 3 sets of weight-training exercises elicits more strength gains than training with 1 set (30 and 13% greater gains in the leg press and bench press, respectively). The differences in ES demonstrate that the magnitude of the effect of 3 sets of training on strength increases is about 2 *SD*s higher for the bench press and about 6 *SD*s higher in the leg press and were found to reject the null hypothesis. The ability to identify these differences may have been a result of control of variables that might influence strength gains. In this study, the only difference between S-1 and S-3 groups was the training volume.

The current study is the first to compare single and multiple sets of training in recreationally experienced male weight trainers using DUP training. Kraemer et al. (9) compared a multiset, DUP-type program with a nonperiodized, single set program in female collegiate tennis players (apparently untrained in weight training). The multiset, DUP program resulted in significantly greater gains in strength across a 9-month program; however, the changes in that study are not directly comparable with the current study because of different subject populations and the length and type of training programs used.

Several theories may explain why multiple sets of weight training elicit greater strength gains than single set programs. Selye's general adaptation syndrome (GAS) (20) asserts that a bodily system will adapt with increased function when faced with a stress to which it is not accustomed. Selye describes 3 stages that the system may experience in such a process. First, the alarm phase in which the system is introduced a new stimulus. Second, the resistance phase is characterized by adaptations occurring in the system to meet the demands of the stimulus. Third, if the stimulus is too strong or presented too long, the exhaustion phase is reached where adaptations plateau.

Weight training serves as a stressor to the neuromuscular system. Selye's theory suggests that when an individual begins a weight-training program, an unaccustomed stress is presented to the neuromuscular system and the alarm phase begins. Once the system has been overloaded, it then adapts (resistance phase) to meet the stress, and if the stress is left unchanged for an extended time or is too strong, adaptation will cease (exhaustion phase) once the demands can be met.

An important variable for eliciting an overload effect in multiple set training programs is the amount of rest allowed between sets. Zatsiorsky (23) proposed the Corridor Theory of strength training, which states that motor units both recruited and exhausted are the only motor units that will experience physiological change. These motor units will show maximal increases in strength over time but only if they are both recruited and exhausted. If too much time is allowed between sets, the exhausted motor units may recover and be used in the next set, thus training the same set of motor units over and over. If time between sets is not sufficient for the units to recover from exhaustion, then different sets of motor units will be recruited and overloaded for the next set. This scenario may overload multiple sets of motor units and elicit greater adaptations than the 1 set protocol. The current study held rest to no more than 2 minutes between sets. This may have resulted in a greater number of muscle fibers being overloaded and may have been the factor that elicited greater strength improvements in the multiple sets group.

These theories may apply to the issue of volume and strength increases, in that differences in training volume represent different degrees of stress presented to the neuromuscular system. Because of the increases in strength that have been measured with both single and multiple set training, it is apparent that they both represent a stress sufficient to elicit neuromuscular adaptations. The issue then becomes, which represents the optimal amount of stress (volume) to elicit maximal strength adaptations? This can be determined by analyzing the dose-response relationship between volume and strength gains.

In this study, multiple sets of training yielded 30 and 13% greater gains in strength for the leg press and bench press, respectively. Mean percent increases were calculated from the research comparing single and triple sets of training, including the current study (2, 4, 6–10, 14, 17, 19, 21, 22). Strength increases do occur with the first set of training (mean increase of 14%); however, multiple sets do result in greater gains (mean increase of 18%). Strength increases appear to follow the principle of diminishing returns (5). With increase in training volume, the magnitude of adaptations may slow or diminish. The extra gains take more effort and volume to achieve but do exist.

Because multiple sets elicits greater strength gains, it is apparent that multiple sets do put a greater stress on the neuromuscular system and that the system is able to adapt to that stress. If single set training represented the optimal amount of stress and multiple sets represented a stress that was too strong, Selye's GAS would suggest that strength gains would plateau after the first set. This, however, does not appear to be the case. The optimal amount of stress continues to remain speculative. Without more research comparing single set training with 2, 3, 4, and more sets, it is difficult to identify exactly where that plateau occurs. At this point it is sufficient to state that multiple sets are required to elicit maximal strength gains.

Practical Applications

Both 1 set (to failure) and 3 sets of weight training can result in statistically significant gains in muscular strength. But 3 sets have demonstrated greater gains in strength than a single set in recreationally trained men. Therefore, strength coaches, trainers, and weight-training professionals should be aware of the differences between the 2 programs and be able to prescribe proper amounts of volume based on training goals. Some individuals may not need maximal strength increases to meet their needs or goals. In these cases, 1 set to failure may be sufficient. But in populations where maximal strength gains are desired, 3 sets of weight training is superior to 1 set of weight training.

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