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Short-Term Performance Effects of Weight Training With Multiple Sets Not to Failure vs. a Single Set to Failure in Women

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ABSTRACT

The purpose of this investigation was to compare the effects of weight training using a single set to failure vs. multiple sets not to failure in young women. The subjects were 17 previously untrained, healthy, college-age women (age 18–20 years; 66.8 ± 12.3 kg). After initial testing, the subjects were randomly assigned to 1 of 2 groups: the single-set group (SS, $n = 9$) and a multiple-set–variation group (MSV, $n = 8$). Testing was conducted at the beginning and end of the study. There were no initial differences between the groups. Tests included the 1 repetition maximum parallel squat (1RMS) and countermovement vertical jump (CMVJ). Body mass was measured on a medical scale. Subjects trained 3 days per week for 8 weeks; all training sessions were monitored by investigators. After warm-up, the SS performed 1 set of 8–12 repetitions to muscular failure. If 12 or more repetitions could be performed, an additional 2.5–5.0 kg were added for the next training session. The MSV group performed 3 sets at a target weight (not-to-failure) and used loading variations producing heavy and light training days. All subjects in the MSV were instructed (and encouraged) to move the weight as explosively as possible. The variation in squat training intensity across 1 week allowed the MSV subjects to produce marked differences in velocity of movement in the squat. Data were analyzed using a repeated measures ANOVA. The alpha level was 0.05. Results showed that the 1RMS and CMVJ increased significantly over time ($p < 0.05$). The 1RMS improved 34.7% in the MSV and 24.2% in the SS. The CMVJ showed a significant interaction ($p = 0.047$). The CMVJ improved 11.2% in the MSV and 0.3% in the SS. Body mass did not change significantly over time or between groups. These results generally show a superior adaptation for the MSV group.

Key Words: exercise, volume, intensity

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Introduction

An obvious benefit of a well-planned weight-training program is an increase in isometric or dynamic maximum strength (21). Strength training can also beneficially alter speed-strength variables such as vertical-jump ability, particularly in untrained subjects. However, some controversy exists as to what type of training program most effectively increases maximum strength and its carryover to speed-strength activities. Much of this controversy concerns the number of sets per exercise necessary to maximize strength gains (3). The use of 1 set to muscular failure has been advocated for more than 20 years for both isolated and multijoint exercises on both free weights and machines (11). Proponents suggest that training with 1 set to muscular failure (8–12 repetitions) is adequate for maximizing muscular growth, strength gains, and various aspects of athletic performance (2, 3). Thus if increasing maximum strength is a primary goal of training, then the duration of a training session can be shortened, producing a more efficient training program (3).

Short-term multiple-set protocols have been shown to produce superior 1 repetition maximum (1RM) strength gains compared with single-set protocols in both trained (12, 13) and relatively untrained subjects (1, 25). However, other studies have not demonstrated a statistical difference between multiple-set and single-set protocols in untrained subjects over a short period using 1RMs (5, 10) or isometric measures (20).

A number of researchers suggest that a key component to continued long-term strength gains is variation in the exercise stimulus (6, 7 21–24). Additionally, some evidence suggests that variation in volume and intensity of training can be advantageous in producing optimal strength gains over a short term in relatively untrained subjects (25), previously trained subjects (26), and particularly in advanced strength trainers (8,

Table 1. Training protocol.

Monday/Friday: (a) squats*, (b) 1/4 squats*, (c) bench press*, (d) standing press, (e) crunches
Wednesday: (a) mid/thigh pull*, (b) shoulder shrugs, (c) straight-legged deadlift*, (d) upright row, (e) crunches

Target set and repetition scheme					
Week 1	Weeks 2–4	Week 5	Week 6	Week 7	Week 8
MSV 3 × 10	3 × 5	3 × 3	5 × 5	3 × 5	3 × 2
SS 1 × 8–12	1 × 8–12	1 × 8–12	1 × 8–12	1 × 8–12	1 × 8–12 to failure

* Major exercises, preceded by 2 warm-up sets.

12, 13). Only 1 study to date has investigated the effects of variation in volume and intensity in women (9); however, data interpretation is unclear because of a serious experimental design flaw that obviated appropriate variation in the periodized group.

The purpose of this study was to investigate the effects of using a single-set to muscular failure vs. a multiple-set protocol not to muscular failure with programmed variation over 8 weeks in young women.

Methods

The subjects were 17 previously untrained, healthy, college-age women (age 18–20 years). After initial testing, the subjects were randomly assigned to 1 of 2 groups: the single-set group (SS, $n = 9$) and a multiple-set–variation group (MSV, $n = 8$). Two subjects dropped out of the MSV because of causes unrelated to the study. Subjects trained for 8 weeks; all training sessions were monitored by investigators. Subjects were allowed to progress at their own rate and agreed not to deviate from the assigned training protocols. Subjects were familiarized with the required exercises the week prior to initiation of the study. Both groups exercised 3 days per week (Table 1) for 8 weeks. The SS used 1 light warm-up set (approximately 45% of 1RM) and then performed 1 set of 8–12 repetitions to muscular failure. If 12 or more repetitions could be performed, an additional 2.5–5.0 kg were added for the next training session. The MSV group performed 3 sets at a target weight, which were preceded by light (approximately 45% of the target) and moderate (approximately 75% of the target) warm-up sets. MSV used RM values for the major exercises on Monday; loading (target weight) was reduced by 20% on Friday, producing heavy and light training days. On Wednesday, the MSV used RM values for all exercises. All MSV subjects were instructed (and encouraged) to move the weight as explosively as possible and to drive up on the balls of their feet in completing the squat. The variation in squat training intensity across a week allowed the MSV subjects to produce marked differences in velocity of movement in the squat. All training sessions were monitored and supervised by investigators. The training protocols are shown in Table 1.

Testing was conducted at the beginning and end of the study. There were no initial differences between groups. Tests included the 1RM parallel squat (1RMS) and countermovement vertical jump (CMVJ) (8, 21). In our laboratory, test-retest reliability for the 1RM squat has consistently been $r = 0.92$ or greater; CMVJ reliability has been consistently $r = 0.9$ or greater. Body mass was measured on a medical scale. Data were analyzed using a repeated measures (GXT) ANOVA. The alpha level was 0.05.

Results

The 1RMS and CMVJ increased significantly over time ($p \leq 0.05$). The 1RMS improved 34.7% in the MSV and 24.2% in the SS. The CMVJ showed a significant interaction ($p = 0.047$). The CMVJ improved 11.2% in the MSV and 0.3% in the SS. Body mass did not change significantly over time or between groups (Table 2). Body mass and performance variables are shown in Figure 1.

Discussion

The results suggest that short-term weight training using MSV produced more favorable improvements in performance compared with SS in initially untrained women. It has been known for some time that almost any reasonable resistance-training program can result in significant strength gains in untrained men and women. Initial strength gains over the first 3–6 months are primarily due to neural alterations, with later gains being more related to hypertrophic mechanisms (21, 24). Many, if not all, physiologic mechanisms acutely respond and chronically adapt to stimuli in a dose response fashion (21, 24). Although the optimal number of sets necessary to maximally increase different performance variables is unclear, this same dose response factor is likely a characteristic of resistance training. Thus over a reasonable training period it may be expected that an increase in the number of sets (i.e., multiple stimuli) to a point would produce superior

Table 2. Alterations in body mass and performance (M ± *SD*).

	Body mass (kg)	1RMs* (kg)	Change (%)	CMVJ† (cm)	Change (%)
MS					
Before	70.9 ± 12.1	53.3 ± 15.5	—	30.3 ± 1.5	—
After	72.3 ± 12.9	69.2 ± 11.5	34.7	33.7 ± 2.4	11.2
SS					
Before	62.8 ± 9.2	48.1 ± 10.5	—	33.3 ± 4.8	—
After	63.6 ± 8.8	57.9 ± 8.1	24.2	33.4 ± 5.2	0.3

* Significant increase over time.
† Significant interaction; MSV > SS.

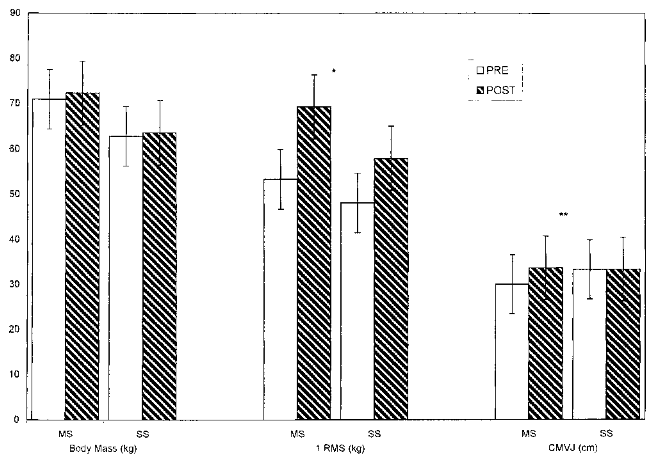

Figure 1. Changes in body mass and performance variables. Body mass = ns; *1RMS = significant time effect ($p = 0.023$); **CMVJ = significant time effect ($p = 0.036$), significant interaction ($p = 0.047$) MSV > SS.

results compared with a single-set protocol. Differences in performance found in comparisons of training protocols may be explained by differences in physiological responses (4, 18) and adaptations to multiple sets compared to single sets.

When comparing training protocols, several recent studies have shown that it can take several weeks to several months to produce significant differences in maximum strength measures in relatively untrained subjects (12, 13, 25). However, significant differences can occur in only a few weeks in other variables such as high-intensity exercise endurance (15) and power-related variables (14, 15). Indeed, in the present study, the 10% greater improvement in the 1RMS for the MSV did not show a statistically significant difference; however, there was a significant difference between groups for the gain in CMVJ. This observation is similar in nature to that observed by Marx et al. (14). In this 24-week study (14), 1RM strength measures improved to a greater extent but did not reach statistical significance over the first 12 weeks, and there were significant differences in peak power as measured by cycle ergometry. Differences in both maximum strength and power favoring the multiset group were noted during the second 12-week period (weeks 12–24). In a follow-up study, Marx et al. (15) observed similar adaptations. These data suggest that the degree of adaptation and the chronological structure for maximum strength and power-related variables are different as a result of different training programs.

It is interesting to note that the MSV group showed a 10% greater improvement in the 1RMS and a similar percentage improvement in the CMVJ, *suggesting* a relationship between the gain in leg and hip strength and CMVJ ability. Similar percentage gains were noted when body mass was accounted for in the squat (1RMS × kg^{-1}). An indication of a similar relationship between gain in 1RMS and CMVJ was not noted in the SS group.

Part of the greater improvement in the performance variables in the MSV compared to the SS is likely due to several levels and types of variation (21–24). These differences include variation in training volume and intensity, as well as differences in speed of movement. Both cross-sectional data (16) and longitudinal data (8) indicate that a combination of heavy (high force/slow speed) and lighter (high power) movements can result in superior power and speed production. In the present study, variation in movement speed from day to day (MSV) offered a type of combination training (high force plus higher velocity/power movements), which may explain the superior results in a dynamic explosive movement (CMVJ) compared with using only slower movements in training (SS).

Practical Applications

These results suggest that training protocols using multiple sets and variation in volume, training intensity, and exercise speed can enhance performance to a greater extent than a single-set to failure protocol. Importantly, this effect occurred over a short term (8 weeks) using previously untrained women.

It has been suggested that single-set protocols offer a sufficient stimulus to improve maximum strength and other performance measures, regardless of the trained state or time frame (3). However, the present study, using untrained women, as well as previous observations using untrained men (17, 25) indicates that multiple-set protocols can produce superior results compared with single-set protocols in a variety of performance measures. Previous studies also suggest that multiple sets can produce superior gains in a wide variety of performance variables in moderately trained and well-trained subject populations (12–15). Although the exact time frame of producing significantly different adaptations in various performance variables is currently unclear, these studies do suggest that superior adaptations can occur using multiple sets and appropriate variation. These data indicate that multiple-set protocols, particularly those using variation at several levels (21–24), should be used with both trained and untrained populations.

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Short-term training (< 9 wk) leading to repetition failure produces greater improvements in strength when compared with a non-failure training approach (Drinkwater et al., 2005; Rooney et al., 1994). However, other studies have reported that training to failure results in a small effect and may not be necessary for optimal strength gains, because the incurred fatigue reduces the force and velocity a muscle can generate (Folland, Irish, Roberts, Tarr, & Jones, 2002; Legaz-Arrese et al., 2007; Sanborn et al., 2000).Â programs based on the maintenance of mechanical power), and only using those repetitions that maintain maximum power, would be useful to increase the overall power demands in tennis players (M. Izquierdo et al., 2006; Legaz-Arrese et al., 2007 The single-set group's program consisted of only 1 set of 6â€“9 repetitions until failure, whereas the multiple-set group trained with 3 sets of 6â€“9 repetitions until failure (rest interval between sets, 2 minutes). Two times before and 3 days after termination of the training program, subjects were tested for their 1 repetition maximum strength on the bilateral leg extension and the seated bench press machine. Data were analyzed using a repeated-measures analysis of variance, ScheffÃ© tests, t-tests, and calculation of effect sizes.Â Calculation of effect sizes and percentage gains revealed higher strength gains in the multiple-set group. No significant differences were found in the control group. The single-set group's program consisted of only 1 set of 6-9 repetitions until failure, whereas the multiple-set group trained with 3 sets of 6-9 repetitions until failure (rest interval between sets, 2 minutes). Two times before and 3 days after termination of the training program, subjects were tested for their 1 repetition maximum strength on the bilateral leg extension and the seated bench press machine. Data were analyzed using a repeated-measures analysis of variance, ScheffÃ© tests, t-tests, and calculation of effect sizes. Both training groups made significant strength improvement