Single versus multiple sets in long-term recreational weightlifters

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ABSTRACT

HASS, C. J., L. GARZARELLA, D. DE HOYOS, and M. L. POLLOCK. . *Med. Sci. Sports Exerc.*, Vol. 32, No. 1, pp. 235–242, 2000. **Purpose:** The purpose of this study was to determine the effects of increasing training volume from one set to three sets on muscular strength, muscular endurance, and body composition in adult recreational weight lifters. **Methods:** Forty-two adults (age 39.7 ± 6.2 yr; 6.2 ± 4.6 yr weight training experience) who had been performing one set using a nine-exercise resistance training circuit (RTC) for a minimum of 1 yr participated in this study. Subjects continued to perform one set (EX-1; $N = 21$) or performed three sets (EX-3; $N = 21$) of 8–12 repetitions to muscular failure 3 d·wk^{-1} for 13 wk using RTC. One repetition maximums (1-RM) were measured for leg extension (LE), leg curl (LC), chest press (CP), overhead press (OP), and biceps curl (BC). Muscular endurance was evaluated for the CP and LE as the number of repetitions to failure using 75% of pretraining 1-RM. Body composition was estimated using the sum of seven skinfold measures. **Results:** Both groups significantly improved muscular endurance and 1 RM strength (EX-1 by: 13.6% LE; 9.2% LC; 11.9% CP; 8.7% OP; 8.3% BC; and EX-3 by: 12.8% LE; 12.0% LC; 13.5% CP; 12.4% OP; 10.3% BC) ($P < 0.05$). Both groups significantly improved lean body mass ($P < 0.05$). No significant differences between groups were found for any of the test variables ($P > 0.05$). **Conclusion:** Both groups significantly improved muscular fitness and body composition as a result of the 13 wk of training. The results show that one-set programs are still effective even after a year of training and that increasing training volume over 13 wk does not lead to significantly greater improvements in fitness for adult recreational weight lifters. **Key Words:** RESISTANCE TRAINING VOLUME, RESISTANCE TRAINING, TRAINING VOLUME, STRENGTH

Resistance training has become one of the most popular forms of exercise for developing musculoskeletal fitness and overall health (9). Musculoskeletal fitness decreases the risk for orthopedic injury and delays the onset of frailty associated with aging (8,18). Resistance training reduces the risk of coronary heart disease (CHD), osteoporosis, and non-insulin-dependent diabetes and lowers the risk for obesity by elevating resting metabolism when part of a comprehensive exercise program (6,9,21). The physiological adaptations resulting from a well-designed resistance training program include increased strength, muscle hypertrophy, lean body mass, bone mass, connective tissue thickness, and improved physical function (27,28,30).

The beneficial effects conferred by resistance training depend on the manipulation of several factors, including the intensity and frequency of training, and the volume of exercise needed to meet the goals of the individual (9). The volume of exercise is a product of the number of sets completed of each exercise and the number of repetitions completed in each set. For adults interested in general health and fitness, the American College of Sports Medicine and the Surgeon General recommend a weight training regimen that requires a minimum of a single set per exercise for 8–12 repetitions (1,31). These recommendations are based on the time efficiency of single-set programs and the similar improvements in strength observed when comparing single and nonperiodized multiple-set programs (1).

However, Fleck and Kraemer (9) suggest that the use of single-set programs are most appropriate for individuals who are untrained or are just starting a resistance training program. These authors suggest that once initial fitness has been achieved, multiple sets become superior to a single set in acquiring optimal physiological adaptation. Presumably, the proposed greater improvements in performance conferred by multiple-set programs would surpass the time advantages of one-set training. There are few published studies examining the effects of training volume on muscular hypertrophy and strength in previously resistance trained adults. Kramer et al. (16) examined the effects of a single set of weight training exercise to failure and two multiple-set protocols (three sets of 10 repetitions (MS) and a multiple-sets program using varied set and repetition schemes (MSV)) on the 1-RM parallel squat in recreational weight lifters. The results indicated that the 1-RM parallel squat increased significantly in all groups and that the MS and the MSV increased strength significantly more than the single-set group. Conversely, Ostrowski et al. (19) reported that one set per exercise was as effective as two sets and four sets for improving muscular size, strength, and upper body

0195-9131/00/3201-0235/0
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Submitted for publication December 1998.
Accepted for publication June 1999.

TABLE 1. Subject characteristics by group (values are mean ± SD).

Group	N	Age (yr)	Height (cm)	Mass (kg)
EX-1	21	40.1 ± 5.5	168.9 ± 8.4	72.4 ± 13.6
EX-3	21	39.2 ± 6.8	170.2 ± 8.8	68.0 ± 10.9

power in recreational weight lifters during a 10-wk total body training program.

Apparently, the optimal volume of resistance training for recreational weight lifters is undetermined. Further, the efficacy of one-set programs have not been evaluated in long-term lifters. The purpose of this study was to determine whether increasing training volume (from one to three sets) would elicit greater improvements in muscular strength, muscular endurance, and body composition in recreational weight lifters. We hypothesized that both weight trained groups would show similar improvements in muscular strength, endurance, and body composition. Further, it was hypothesized that no additional improvements would occur with the higher volume of training.

METHODS

Subjects recruited for this study were between the ages of 20 and 50 yr and were active members of Gainesville Health and Fitness Center (GHFC), in Gainesville, Florida. They were apparently healthy volunteers with no history of cardiovascular disease, orthopedic problems, or other medical conditions that would contraindicate exercise. All subjects were recreational weight lifters with an average of 6.2 ± 4.6 yr resistance training experience who had been performing one set of the nine exercise circuit for an average of 2.7 times a week for a minimum of 1 yr. The training goals of these individuals were improved health and muscular fitness. Descriptive characteristics of the subjects are presented by group in Table 1.

The methods and procedures used in this investigation were reviewed and approved by the Institutional Review Board of the University of Florida College of Medicine before data collection and are in accordance with the policies of the American College of Sports Medicine. Documented informed consent for testing and training was obtained from all the subjects.

Dynamic muscular strength testing. The one repetition maximum (1-RM) was used as a measure of dynamic concentric muscle strength of the legs, chest, shoulders, and biceps using the leg extension, leg curl, chest press, overhead press, and biceps curl machines (MedX Corp., Ocala, FL). All 1-RM testing was conducted on the same resistance training machines with identical subject/equipment positioning for both pre- and post-testing. To eliminate inter-observer variability only one trained investigator (CH) performed these procedures. Subjects underwent a period of warm-up and light stretching before the testing protocol. For each exercise, subjects warmed up with a light resistance (one or two plates for women and three to four plates for men) performing 10 repetitions. The subjects were then asked to lift their prestudy training weight as their first attempt. This weight was taken from the subject's workout logs that were collected before beginning the study. Thereafter, resistance was increased in incremental loads until failure occurred despite verbal encouragement to exert maximal effort. Failure was defined as a lift short of a full range of motion. The 1-RM was determined within three to five attempts. Dynamic muscular strength testing was performed on two separate days (day 1: leg extension, leg curl, and chest press; and day 2: overhead press and biceps curl) with a minimum of 48 h of rest (no physical activity) between testing visits.

Maximal isometric knee extension/flexion strength testing. Maximum isometric knee extension and knee flexion torque was measured bilaterally using a knee extension/flexion ergometer (MedX Corp., Ocala, FL). The methods used during testing have been previously published (26). Briefly, the subject's peak isometric knee extension torques were recorded at seven angles (maximum degrees, 96°, 78°, 60°, 42°, 24°, 6° of knee flexion) throughout their full ROM. Each isometric contraction was separated by a 10-s rest period while the next angle of measurement was set. Once isometric strength was measured at all seven positions, the subject rested for 5 min. The subject's maximal bilateral knee flexion strength was then assessed at the same angles and in the same order as those tested for knee extension. To eliminate inter-observer variability only one trained investigator (CH) performed these procedures.

Muscular endurance testing. Muscular endurance was measured for the chest press and leg extension. Subjects underwent a period of warm-up and light stretching before beginning the testing protocol. The subjects were then asked to lift a weight representing 75% of their pretraining 1-RM until they could not successfully perform an additional repetition.

Body composition analysis. Subjects were instructed to refrain from strenuous exercise for 24 h before testing, from eating for 2 h before testing, and from using caffeinated beverages, tobacco, or alcohol for 4 h before testing. Female participants were not tested during or within 3 d of their menstrual cycle. To eliminate inter-observer variability only one highly trained investigator (LG) performed these procedures. Anthropometric measurements included height to the nearest 0.1 cm (Harpenden Stadiometer, model 602; Holtain Ltd., Holtain, U.K.) and weight to the nearest 0.1 kg (Detecto Scale, model number 8430; Webb City, MO). Measurements of skinfold diameter were taken at the following sites: chest, axilla, triceps, subscapular, abdomen, suprailiac, and anterior thigh to the nearest 0.5 mm, using a Lange caliper (Cambridge Scientific Industries, Cambridge, MD). Additionally, chest, waist, gluteal, thigh, flexed biceps, and relaxed biceps circumferences were measured to the nearest 0.1 cm, using a Lufkin spring-retractable steel tape (Lufkin, London, England). All anthropometric measurements were taken in accordance to the methods of Pollock and Wilmore (21). Body density was then determined using the equation of Jackson and Pollock (13) for men and Jackson et al. (14) for women. Relative body fat was calculated using the Siri equation (24).

Training program. Following the initial evaluations, subjects were randomly stratified into one of two training groups. Subjects were stratified by sex, age, leg extension strength, and amount of endurance training. Each subject's daily physical activity level was determined using the FIT equation by self-assessment of exercise frequency (F), intensity (I), and minutes of activity (T). Subjects were instructed to maintain the same level of physical activity throughout the study. Subject enrollment was structured so a minimum of 20 subjects would be in each group. The training groups completed either one set (continued to train using one set, EX-1, $N = 21$) or three sets (EX-3, $N = 21$) (one or three times through the nine machine circuit, respectively).of the following exercises: leg extension, leg curl, pullover, arm cross, chest press, lateral raise, overhead press, biceps curl, and triceps extension using dynamic variable resistance exercise training machines (MedX Corp.). Each set of exercise required performing 8–12 repetitions to volitional fatigue. Initial load for dynamic training was set at 75% of 1-RM strength determined during the initial testing for the chest press and leg extension and 70% of 1-RM for the overhead press, leg curl, and biceps curl. Initial training loads for the pullover, lateral raise, and triceps extension were increased 10% from each subject's previous training weight. Strict form was required for the repetitions to be accepted. Subjects were instructed to perform each repetition with a 2-s concentric phase followed by a 4-s eccentric phase. Subjects were allowed to rest up to a minute between exercises. EX-3 was allowed to rest 3–5 min between circuits. The training load was increased by 5–10% for the next workout when subjects were able to perform 12 repetitions or more of the particular exercise. Training load, number of repetitions performed, and the Borg rating of perceived exertion (RPE) (3) were recorded after each exercise to document progression of training intensity and perceived effort. Each training session was conducted and monitored by the investigators. Subjects were encouraged to exert maximal effort on all sets. During the seventh week of training maximal concentric strength was determined for the chest press and leg extension using the aforementioned procedures. Following 13 wk of training, maximal concentric strength, isometric strength, muscular endurance, and anthropometric measurements were made on both groups using the previously described methodology.

Statistical analysis. Descriptive statistics (Mean ± SD) for age, height, and weight were calculated for both training groups. Measures of central tendency and variability were calculated for pre-, mid-, and post- training maximum concentric and isometric strength and muscular endurance. Measures of central tendency and variability were also calculated for the pre- and post-training body composition and circumference variables. An analysis of variance (ANOVA) was performed to determine whether differences existed between the group's pretraining dynamic and isometric strength, muscular endurance, and body composition values in which none were found ($P > 0.05$). Pre- and post-training variables were compared using repeated measures ANOVA.

Training load, RPE, and the number of repetitions performed during each exercise and each set during the second workout of weeks 1, 4, 7, 10, and 13 were compared to analyze the progression of training. A repeated measures ANOVA was performed to determine: any differences between training groups for training load, RPE, and number of repetitions leg extension, leg curl, chest press, overhead press and biceps curl; any differences within groups between weeks 1, 4, 7, 10, and 13; and any differences between set 1, set 2, and set 3, for the group that trained using three sets.

All statistical procedures were performed using the Statistical Analysis System (22) general linear model procedure. Statistical significance was accepted at $P < 0.05$. Significant results were followed by Tukey *post-hoc* comparisons to identify where differences occurred.

RESULTS

Subjects. Forty-two ($N = 12$ men, $N = 30$ females) of the original 49 subjects recruited completed the study. Of the seven who did not complete the study, five were removed by the investigators for failure to adhere to the 3 $d \cdot wk^{-1}$ training protocol. Subjects had to complete a minimum of 85% of the training sessions to be included in the study. Two subjects experienced tendinitis in their shoulder and knee joints. After medical evaluation and physician clearance both subjects chose to withdraw from the study. All seven subjects who did not complete the study were in the EX-3 group. Characteristics of those who completed the study are listed by group and gender in Table 1. There were no significant differences between groups for age, height, or weight ($P > 0.05$). Statistical analysis revealed that both genders progressed similarly, thus results are presented with males and females together.

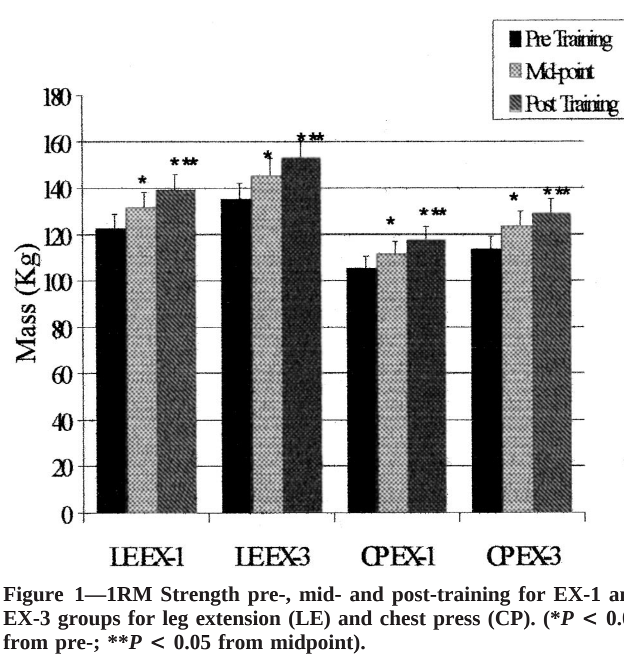

Figure 1—1RM Strength pre-, mid- and post-training for EX-1 and EX-3 groups for leg extension (LE) and chest press (CP). (*$P < 0.05$ from pre-; **$P < 0.05$ from midpoint).

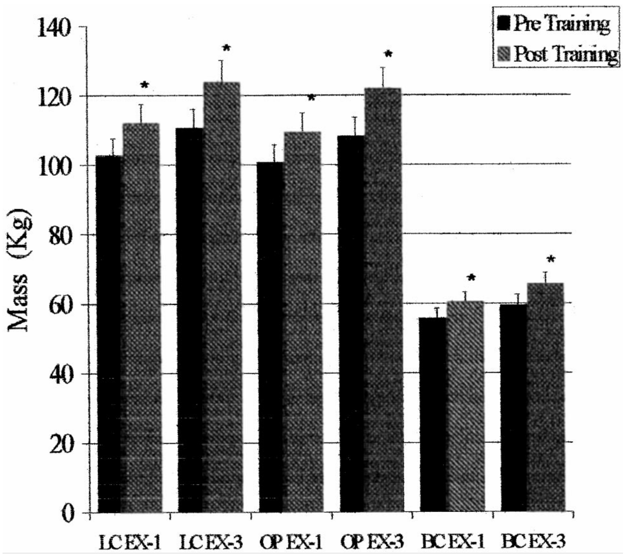

Figure 2—1RM Strength pre- and post-training for EX-1 and EX-3 groups for leg curl (LC) overhead press (OP) and biceps curl (BC). (*$P < 0.05$ from pre).

Dynamic muscular strength. Figure 1 shows the pre-, mid-, and post-testing means (± SEM) for 1-RM strength for the leg extension and chest press. Pre- and post-training 1-RM strength for the leg curl, overhead press, and biceps curl are presented graphically in Figure 2. Significant increases in 1-RM strength were observed at post-testing for both groups in all five exercises ($P < 0.05$). Furthermore, both groups significantly increased 1-RM strength in the chest press and leg extension from pre- to mid- and from mid- to post-testing ($P < 0.05$) (Figs. 1 and 2). The EX-1 group increased leg extension strength by 7.4% from pre-training to week 7 and 6.2% from week 7 to post-testing. The EX-3 group improved leg extension strength by 7.4% from pre-training to week 7 and 5.4% from week 7 to post-testing. In the chest press, the EX-1 group improved 1 RM strength by 6.1% and 5.4% from pre-training to week 7 and week 7 to post-testing, whereas the EX-3 group increased by 8.9% and 4.6%. There were no significant differences ($P > 0.05$) in increased muscular strength between the EX-1 or EX-3 group for any of the five exercises at any time point.

1-RM strength was also normalized by lean body mass. Both groups improved significantly across time in the 1-RM values/lean body mass for all five exercises ($P < 0.05$) (Table 2). Significant differences were observed between groups at post-testing for the leg curl. This significant difference favored the EX-3 group as they improved strength significantly more than the EX-1 group (4.5% greater improvement). Both groups improved significantly and similarly across all three time points for the leg extension ($P < 0.05$). Both groups improved significantly from pre-post for the chest press ($P < 0.05$). The EX-1 group showed significant improvement across all three time periods (pre-post, pre-mid, and mid-post) ($P < 0.05$). However, the EX-3 group failed to improve chest press strength significantly from midpoint to post-testing ($P > 0.05$).

Muscle endurance. Muscle endurance increased significantly for chest press and leg extension in both groups following 13 wk of training (Fig. 3). The EX-1 group increased endurance for chest press and leg extension by 48.15% and 49.5%, respectively. The EX-3 group increased endurance by 58.4% and 66.7% for chest press and leg extension, respectively. However, there were no significant differences between groups ($P > 0.05$).

Isometric strength. Means and SD for pretest and post-test torque values for knee extension and knee flexion at each angle tested are listed in Tables 3 and 4. Both groups improved isometric torque significantly in extension and flexion from pre- to post-testing but not at every angle. The EX-1 group significantly increased bilateral knee extension torque production over time at 6°, 42°, and 60° of knee flexion. The EX-3 group increased torque in extension at 42°, 60°, 78°, 96°, and at their maximum degree of knee flexion. No significant differences were found between groups ($P > 0.05$). The EX-1 group increased torque production for knee flexion at 42° and 96° of knee flexion, whereas the EX-3 group significantly increased torque production at all seven angles ($P < 0.05$). No significant differences were found between groups ($P > 0.05$).

Body composition. No significant differences were observed between groups in any of the segmental circumference measurements ($P > 0.05$). The EX-3 group did experience a significant increase in both their chest and flexed biceps circumferences following the 13 wk of training ($P > 0.05$). Body composition data obtained by skinfold measurements revealed that the EX-1 group experienced a significant reduction in their anterior thigh skinfold and a significant increase in their lean body mass ($P < 0.05$). The EX-3 group experienced a significant reduction in the sum of seven skinfold values, percent body fat, and a significant increase in the amount of lean body mass ($P < 0.05$). No significant differences were found between groups ($P > 0.05$).

DISCUSSION

The purpose of this study was to determine whether increasing training volume (from one to three sets) would

TABLE 2. One repetition maximum strength (kg)/lean body mass (kg) at pre-, mid-, and post-training by group (values are mean ± SD).

Exercise	*N*	Pre	Mid	Post
Leg extension				
EX-1	18	2.4 ± 0.4	2.6 ± 0.4*	2.7 ± 0.4* **
EX-3	21	2.6 ± 0.4	2.8 ± 0.4*	2.9 ± 0.4* **
Leg curl				
EX-1	20	2.0 ± 0.3		2.1 ± 0.2*
EX-3	21	2.1 ± 0.2		2.3 ± 0.2*†
Chest press				
EX-1	21	1.9 ± 0.6	2.0 ± 0.5*	2.1 ± 0.5* **
EX-3	21	2.1 ± 0.7	2.3 ± 0.7*	2.3 ± 0.6*
Overhead press				
EX-1	20	1.9 ± 0.4		2.0 ± 0.4*
EX-3	21	2.0 ± 0.6		2.3 ± 0.6*
Biceps curl				
EX-1	21	1.0 ± 0.3		1.1 ± 0.3*
EX-3	21	1.1 ± 0.3		1.2 ± 0.3*

* Significant difference ($P \leq 0.05$) from pre.
** Significant difference ($P \leq 0.05$) from midpoint.
† Significant difference ($P \leq 0.05$) from the group that trained using one set.

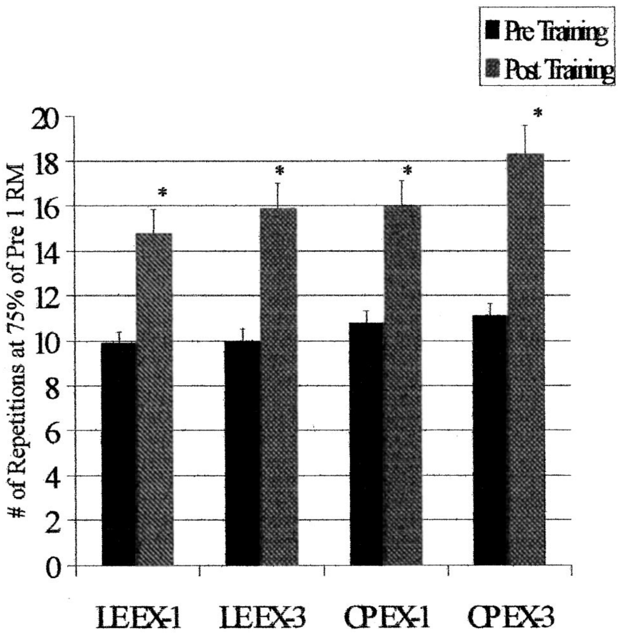

Figure 3—Muscle endurance for EX-1 and EX-3 groups for leg extension (LE) and chest press (CP). (*P < 0.05 from pre).

elicit greater improvements in muscular strength, muscular endurance, and body composition in recreational weight lifters (average 6.2 ± 4.6 yr weight training experience). It was hypothesized that both the EX-1 and EX-3 groups would experience improvements in muscular strength, endurance, and body composition. Further, it was hypothesized that no additional improvements in muscular strength, muscular endurance, or body composition would occur with the additional volume of training. The present data support our hypothesis. Both groups experienced substantial and similar improvements in muscle strength, muscular endurance, and body composition. Our data indicate that additional sets do not significantly improve the physiological adaptations to resistance training within the first 13 wk of training in recreational weight lifters participating in a well-rounded exercise program compared with one-set training.

Manipulating training volume: single- versus multiple-set regimens. The recommended volume of resistance training has been studied for nearly 40 yr. Carpinelli and Otto (5) and Feigenbaum and Pollock (6,7) in recent reviews outlined the results of studies investigating single- versus nonperiodized multiple-set resistance training programs in nonathletic populations. Only two studies showed a significantly greater increase in strength comparing three- versus one-set regimens. Close inspection of the Berger study (2) reveals that after the 12 wk of training the difference in strength increase among the one-, two-, and three-set groups was less than 4 pounds. No studies have shown a significant difference in strength development when comparing one versus two sets of exercise. These studies clearly indicate that single-set training promotes significant improvements in strength of both the upper and lower extremities and postural muscles and that these improvements are comparable with those attained from a higher volume of training. The majority of these studies were 8–12 wk in duration using previously sedentary adults and used single isolation exercises. Whether more compound multijoint movements respond similarly to low volume and high volume training warrants further investigation.

In previously sedentary individuals, improvements in muscle strength are readily attained and are mediated by neural adaptations as well as, a gradual increase in muscle hypertrophy (23). After the initial stages of a training program, little is known about the effect that different training volumes have on muscular strength, endurance, and body composition. There is a shortage of well-controlled studies comparing single- versus multiple-set nonperiodized resistance training programs in individuals with weight training experience. The results of the present study are in accordance with those of Ostrowski et al. (19) who reported that one set per exercise was as effective as two sets and four sets for improving muscular size, strength, and upper body power in recreational weight lifters with 1–4 yr of weight training experience. Conversely, Kramer et al. (16) showed that training with multiple sets not performed to failure was superior to a single set to failure for increasing the 1-RM squat. Several important differences between the present study and the study of Kramer et al.(16) must be pointed out before comparing the results of these studies. The subjects in the present study were adult males and females who were actively participating in a well-rounded exercise program including aerobic training. These individuals had been performing one set to failure consistently (for an average of 2.7 times per week) for a minimum of 1 yr before entering the study with an average of 6.2 yr of weight training experience. In this study, the additional volume of training did not improve muscular strength, endurance, or body composition to a greater extent than did training using one set. Subjects in the study of Kramer et al. (16) were considered moderately trained if they were able to squat at least their body mass and were not participating in any other exercise activity. The squat itself is a complex skill movement that is

TABLE 3. Pre- and post-training isometric torque values (means ± SD in Nm) by group and angle for knee extension.

	Degrees of Knee Flexion						
	6°	24°	42°	60°	78°	96°	Max°
One Set							
Pre	99.3 ± 28.9	176.0 ± 50.0	250.7 ± 70.6	314.2 ± 105.6	361.2 ± 113.4	308.4 ± 105.0	268.6 ± 91.7
Post	105.0 ± 30.5*	187.0 ± 35.9	272.3 ± 89.5*	353.8 ± 126.8*	383.7 ± 127.2	316.1 ± 104.4	269.4 ± 89.2
Three Sets							
Pre	97.6 ± 33.1	174.5 ± 51.9	257.6 ± 75.8	336.4 ± 97.2	377.9 ± 127.2	301.3 ± 101.7	263.1 ± 83.5
Post	98.7 ± 35.9	183.3 ± 55.6	276.2 ± 85.8*	367.6 ± 122.7*	410.2 ± 125.6*	330.7 ± 98.7*	281.1 ± 75.3*

* $P < 0.05$ from Pre

TABLE 4. Pre- and post-training isometric torque values (means ± SD in Nm) by group and angle for knee flexion.

	Degrees of Knee Flexion						
	6°	24°	42°	60°	78°	96°	Max°
One set							
Pre	149.2 ± 49.5	172.9 ± 63.3	175.3 ± 62.0	170.3 ± 56.5	155.1 ± 52.3	121.1 ± 41.0	87.5 ± 28.3
Post	151.5 ± 54.1	178.4 ± 61.7	187.8 ± 61.0*	183.5 ± 57.0	166.2 ± 51.4*	135.6 ± 46.4*	100.2 ± 40.3
Three sets							
Pre	145.4 ± 46.8	168.7 ± 51.1	172.9 ± 50.0	164.3 ± 43.0	148.3 ± 36.3	122.7 ± 33.8	89.6 ± 26.0
Post	163.9 ± 57.4	188.1 ± 66.2*	192.7 ± 58.4*	186.3 ± 48.5*	173.0 ± 39.1*	146.0 ± 34.6*	111.7 ± 33.6*

* $P < 0.05$ from Pre.

often used as an index of lower body strength. Activities that involve greater skill and coordination may require a greater frequency of the stimulus (greater sets) and promote greater physiological adaptations, i.e., strength gains. The large increase in strength could therefore be attributed to increased neural adaptation and may be related to training intensity (% of 1 RM) (16) as well as the training volume.

Studies have also compared single-set programs to multiple-set periodized programs (16,29) in noncompetitive populations. In these studies, multiple-set periodized programs have been compared with training with one set to failure within 8–12 repetitions. After 7 wk of training, Stowers et al. (29) found that there was no difference in the strength gains measured via the 1 RM bench press among the multiple set to exhaustion, single set to exhaustion, and the periodization groups. At the end of the training period no significant differences were found between the one set to exhaustion and multiple set to exhaustion groups on the 1 RM squat. However, they did find significantly greater improvements in the 1 RM squat in the periodization group compared with those attained by single and multiple sets to exhaustion. The results of the study of Kramer et al. (16) further support these findings in the squat exercise. Kraemer (15) published a series of studies comparing single-set programs to multiple set and periodized programs in collegiate football players. The results indicated that trained football players achieved greater improvements from multiple-set programs that provide variation. Kraemer suggested that though intensity plays a major role, the volume of training may also have interacted to produce the larger increases in strength. Thus, it appears that the inclusion of higher intensity training (80–90% of 1-RM loads for few repetitions) and the variation of intensity and volume will result in greater strength gains than training with moderate weights for 8–12 repetitions (9) to exhaustion.

Dynamic muscular strength increases. The present study used middle-aged men and women who had an average of 6.2 yr of weight training experience. These subjects experienced an 8–14% increase in concentric strength following the 13-wk training program. However, the magnitudes of the strength gains in the present study are less than those observed elsewhere. A probable explanation for these discrepancies is the initial fitness level of the subjects used in these studies. Most resistance training studies use previously sedentary adults. Fleck and Kraemer (9), in review of 13 studies representing various forms of isotonic training, reported an average increase in bench press strength of 23.3% and an average increase in leg strength of 26.6%. Furthermore, the ACSM (1) reports an average improvement in strength of 25–30% for sedentary young and middle-aged men and women during the first 6 months of training. Although studies have shown continued increases in strength with added weeks of training up to 2 yr (17), the magnitude of gains is less and tends to plateau after 3–6 months (9,17). Ostrowski et al. (19) reported a 2–7% increase in maximal strength following 10 wk of training in subjects with 1 to 4 yr weight training experience. Similarly, Hakkinen reported a modest 3.5% increase in maximal torque production following a year of training in elite weight lifters (11). These findings demonstrate the limited potential for strength development in experienced weight lifters and suggest that the magnitude and time course of neuromuscular adaptations during their training may differ from those reported for previously untrained individuals (12). Conversely, Kramer et al. (16) found up to 25% increases in squat strength in individuals who were classified as moderately trained if they could squat their body weight.

Strength measurements were taken at pre-, mid-, and post-training for the leg extension and chest press to observe changes in strength as a function of time over the 13 wk. The data indicate similar progressions in strength between the two groups from pre-training to midpoint and midpoint to post-training. Whether a longer training program would support the notion that one has to train with multiple sets for a much longer time before differences in training programs become significant warrants further investigation.

Isometric strength. In this study the average improvements in knee extension strength for the EX-1 and EX-3 groups were 6.3% and 6.8%, respectively. These improvements are less than those reported elsewhere (4,10). Starkey et al. (26) reported an 11% and a 10% average increase in isometric knee extension strength for those who trained for 14 wk using one set or three sets. Few studies have investigated the development of knee flexor strength and used a testing method consistent with the methods in this study. The 14.5% improvement reported by Smith and Melton (25) is similar to our findings of 7.7% and 15.6% for the EX-1 and EX-3 groups, respectively. Starkey et al. (26) observed an 18% peak strength increase in knee flexion isometric torque production over a 14-wk period.

Muscular endurance. Lower intensity loads performed for a higher number of repetitions develop local muscular endurance (9). In the present study training intensity was standardized to an 8–12 repetition maximum load. Training within this RM range will develop a mixture of strength and local muscular endurance (9). Over the 13 wk the subjects in the present study were able to significantly improve both their upper body and lower body endurance. The EX-1 group increased their leg extension endurance by 48.2%, whereas the EX-3 group increased endurance by 58.4%. Both the EX-1 and EX-3 groups had a significant increase in chest press endurance (49.5% and 66.7%, respectively). These data indicate a specificity effect in which training at 8–12 RM leads to greater increases in endurance than increases in 1 RM strength. Greater muscular endurance as well as improved muscular strength is important in the adult fitness realm as it may improve performance during activities of daily living and other recreational activities.

SUMMARY AND CONCLUSIONS

In summary, this 13-wk training study compared the effects of increasing training volume from one set to three sets on improvements in muscular strength, endurance, and body composition in recreational weight lifters who were also participating in a well rounded exercise program including aerobic training. Subjects trained three times per week using one or three sets for 8–12 repetitions to volitional fatigue. Muscular strength and endurance, segmental circumferences, skinfold thickness, percent fat, lean body mass, and fat mass were measured before and after the 13-wk training period. Both training groups progressed similarly during the training and exerted equivalent efforts based on RPE. After 13 wk of training, both groups had significantly improved their muscular strength, muscular endurance, and body composition. However, there were no significant differences between groups in the improvement of muscular strength or muscular endurance. Furthermore, both groups experienced similar improvements in body composition. The data show that performing additional sets of high intensity resistance exercise does not lead to significantly greater improvements in muscular strength, muscular endurance, or body composition than training using a single set in adult recreational weight lifters. The results of this study are similar to those of previous studies using initially untrained subjects demonstrating that single-set programs are an effective alternative to higher volumes of nonperiodized training.

The amount of time required to complete a single-set resistance training program is much less than the time required to complete a program requiring multiple sets (6). In this study, subjects in the EX-3 group reported that the time required to complete their workout was approximately 1 h compared to the 25 min reported by the EX-1 group. Programs lasting 1 h per session have been associated with higher dropout rates (20). The 25% dropout rate observed in the three-set group in this study further supports this claim. Considering the lack of difference observed between one set and multiple-set nonperiodized training, a single set of 8–12 repetitions represents an efficient method of developing muscular strength, endurance, and body composition regardless of the fitness level of the individual. This is important for individuals who desire the health and fitness benefits associated with a well-rounded physical fitness program but may not have the time to devote to multiple-set resistance training programs.

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