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## SINGLE-SET VERSUS MULTIPLE-SET RESISTANCE TRAINING IN COLLEGE-AGED FEMALES

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### ABSTRACT

**Bickel SM, Shatzer JL, Van Meter SB.** Single-set versus Multiple-set Resistance Training in College-aged Females, *Journal of Undergraduate Kinesiology Research* 2007;3(1):1-8. **Purpose:** Resistance training is important for recreational purposes and also provides health benefits. The purpose of this study was to determine differences in muscular strength gains between single-set and multiple-set resistance training. **Methods:** Twenty female subjects, ages 19-22, participated in pre- and post-test sessions that included circumferences, skin folds, and 10-RM five lifts and a 6-wk training period consisting of five lifts, two days a week. **Results:** Comparisons of mean baseline (BL) to 6-wk changes showed no significant differences ( $p > .05$ ) in strength gains between the single set vs. multiple set groups: bench press 10-RM [+15.6 vs. +13.0,  $t(14)=1.028$ ,  $p=0.321$ ]; leg press 10-RM [+39.0 vs. +34.6,  $t(14)=.414$ ,  $p=0.685$ ]; seated row 10-RM [+10.7 vs. +7.8,  $t(14)=.927$ ,  $p=0.370$ ]; back squat 10-RM [+17.8 vs. +16.9,  $t(14)=.241$ ,  $p=0.813$ ]; shoulder press 10-RM [+8.8 vs. +7.3,  $t(14)=.667$ ,  $p=0.515$ ]. Within subjects, comparisons revealed significant improvements ( $p < .05$ ) in 10-RM values for all lifts in both single and multiple set groups. There were no significant ( $p > .05$ ) changes in anthropometric and body composition from pre- to post-testing in both groups. **Conclusion:** Single-set resistance training programs are as effective at improving strength as multiple-set resistance training programs.

**Key Words:** Strength training, training volume, training intensity, muscular strength gains, weight training, number of sets

### INTRODUCTION

Resistance training is becoming common across age groups as the primary way to gain muscular strength and it is beneficial in several areas (1). Resistance training is working a muscle or muscle group against a specific resistance to overload the musculoskeletal system and thereby increasing strength. As people age, bone density decreases but this can be slowed or prevented by engaging

in resistance training. Gaining strength and moving through complete ranges of motion helps prevent injury (1). Sport performance is usually enhanced with the increase of muscular strength.

There are many health and performance benefits that result from resistance training programs; however, it is unclear which method is the most effective to attain these benefits. Resistance training can be completed using machines, free weights, and thera-bands. Programs may also be manipulated by modifying the number of repetitions and sets. There is still a controversy over whether single set or multiple set resistance training is the most effective way to receive maximal strength gains.

In a literature review completed by Carpinelli and Otto (2), most studies that were reviewed reported no significant difference in muscular strength between 1 set and 2, 3, or 4 set resistance training. It was concluded that there was no dose-response relationship between set volume and strength gains. The training threshold is met through single set resistance training therefore multiple sets are not necessary. A study by Drinkwater and Lawton (3) also supported the findings that single set is as effective as multiple set resistance training. However, not all studies supported this same result. In a recent study by Schlumberger et al. (4), multiple set resistance training was superior to single set resistance training in improving one repetition maximum (1-RM) in females that had previous resistance training backgrounds in the past six months. A study completed by Bush et al. (5) supported these results while looking at untrained females. Again they found multiple set strength improvements surpassed the improvements by the single set resistance training in a 24 week training duration.

Clearly, there exists a controversy over whether single set or multiple set resistance training is the most beneficial to muscular strength gains. Untrained females were chosen because this population seemed to be the least studied. The purpose of this study was to determine differences in muscular strength gains between single set and multiple set resistance training. We hypothesize that the multiple set resistance training will produce more strength gains than the single set resistance training.

## METHODS

### Subjects

Twenty college-aged female students that had not completed regular resistance training in the past 6 months, volunteered for the study. The characteristics of the subjects are presented in Table 1. Each subject was informed of any risks and benefits that could occur by participating in this study. Each signed an informed consent form before participating. The study was approved by The University Human Subjects Institutional Review Board. Subjects were recruited from the student body and were randomly assigned to either the single set or the multiple set groups.

**Table 1.** Participant baseline characteristics (mean  $\pm$  SD).

Measurement	Single-set (N=10)	Multiple-set (N=10)	Combined (N=20)
Age (yr)	20.1 $\pm$ 1.0	20.3 $\pm$ .9	20.2 $\pm$ 1.0
Body mass (kg)	69.4 $\pm$ 11.2	69.17 $\pm$ 8.9	69.3 $\pm$ 8.9
Height (cm)	168.1 $\pm$ 4.8	170.9 $\pm$ 6.4	169.5 $\pm$ 5.7

### Instrumentation

The testing and training periods were completed in the weight room and exercise physiology lab. The bench press, shoulder press, and lat row machines were all used to measure upper body strength

(Magnum Fitness Systems; Milwaukee, WI). The Hammer Strength Uni-Lateral leg press machine (Life Fitness; Schiller Park, IL), and smith squat machine (Deltech Fitness; Louisville, KY) were used for lower body strength. Lange skin fold calipers (Beta Technology Incorporated; Cambridge, MD), a Seca height and weight scale and measuring tapes (Creative Health Products; Plymouth, MI) were used to obtain pre- and post-training measures of body composition.

### **Procedures**

The study included a pretest session in the week before the training period, a 6 week training period, and a posttest session after the final training day. The subjects were randomly assigned to 1 of 2 groups following the pretest session, single-set or multiple-set group. Basic measurements of height, weight, waist/hip circumference, bicep and thigh circumference, and three-site skin fold measurements were also taken during the test sessions. A 10-RM was also completed during the test sessions. The height and weight measurements were completed with no shoes on and the subjects in basic workout attire.

A Gullick cloth tape measure was used to determine circumferences. Two measurements were taken at the waist, hip, bicep, and thigh sites in a rotational order and the average of the measurements was reported. The technique for the mid-thigh site was completed with the subject standing with one foot on a bench so the leg is bent at 90 degrees; the measurement is taken midway between the knee and hip. The waist site technique is completed with the subject standing, arms at sides and feet together. A measurement is taken at the narrowest part of the torso, while the subject keeps the abdomen relaxed. The technique for the hip site is taken when the subject is standing with feet together and the measurement is applied around the widest circumference of the buttocks. The measurement for the bicep is taken when the subject is standing with arms hanging freely at sides and the measurement is applied around the midpoint between the shoulder and elbow joints. All measurements were taken with the tape on the skin surface without compressing the subcutaneous tissue. There is a 2.5% - 4% error when using cloth tape measures for circumference measurements (6).

The Jackson and Pollock (6) three-site skin fold technique and equation was used to determine body density. We placed them in a formula designed for this three site technique to determine body density, and body density was converted to a body fat percentage using the Lohman (6) equation. The site for the triceps is a vertical fold on the midline between the shoulder and elbow of the posterior site of the arm when the arm is held freely. The site for the thigh is a vertical fold on the anterior midline between the knee and hip. The site for the suprailiac is a diagonal fold along the line of the iliac crest that is anterior and superior to the iliac crest. All of these measurements were taken on the right side of the body while the individual was standing. Two or three measurements of each site were taken in a rotational order. Two measurements were used if the values were within 2 mm of one another, otherwise we obtained a third measurement. The average measurements were used to obtain a value to be used for our data (6).

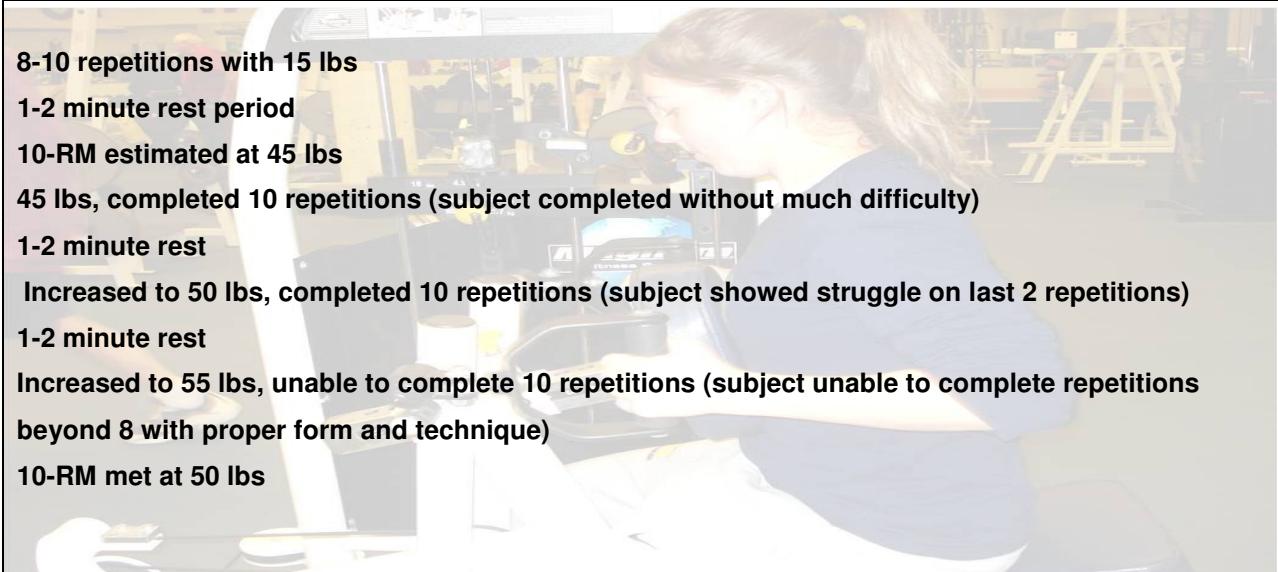
Baseline strength testing included a 10-RM assessment for bench press, leg press, seated row, back squat, and shoulder press, in that order. The 10-RM testing was conducted using the methods described by others (7). All tests were preceded by a 5-10 minute warm up session either on the treadmill or cycle and concluded with a 5-10 minute cool down on either the treadmill or cycle. The subjects were allowed to select their own intensity; however, a low to moderate intensity was suggested.

#### 10-RM Protocols:

- 8-10 repetition warm up with a light weight load
- 1-2 minute rest period

- Estimated 10-RM, either from our own RM or their own estimates
- Chose starting weight, completed 10 repetitions
- 1-2 minute rest
- Increased the weight load if subject was able to complete
- Complete 10 repetitions, rest, increase weight, and continue process
- 10-RM successful when unable to complete 10 repetitions of next weight increment

**Table 2.** Example for 10-RM

<p><b>8-10 repetitions with 15 lbs</b>  <b>1-2 minute rest period</b>  <b>10-RM estimated at 45 lbs</b>  <b>45 lbs, completed 10 repetitions (subject completed without much difficulty)</b>  <b>1-2 minute rest</b>  <b>Increased to 50 lbs, completed 10 repetitions (subject showed struggle on last 2 repetitions)</b>  <b>1-2 minute rest</b>  <b>Increased to 55 lbs, unable to complete 10 repetitions (subject unable to complete repetitions beyond 8 with proper form and technique)</b>  <b>10-RM met at 50 lbs</b></p>	
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The weight was increased by 5 lbs if the subject was able to complete the first set. If unable to complete the first set, the weight was decreased to a more suitable amount. All of these sets/repetitions were completed with proper technique and form and the routine was repeated for each exercise through all five. These procedures were similar during post-training.

The resistance training program was carried out two times a week for six weeks. The subjects began with a 5-10 minute warm up on a treadmill or cycle and concluded with a 5-10 minute cool down on a treadmill or cycle, again at a low to moderate intensity of the subject's choice. The single-set group completed 1 set of 8-10 repetitions on the bench press, leg press, seated row, back squat and shoulder press in that order. The multiple-set group completed 3 sets of 8-10 repetitions on the bench press, leg press, seated row, back squat and shoulder press in that order. The rest intervals between sets, multiple-set group only, were between 1-2 minutes. For both groups, there was a rest interval of 1-2 minutes between exercises. After completing 10 repetitions of the current weight used in the training period, the subjects increased their weight load by 5 lbs. Subjects were weighed in prior to and following the workout to monitor hydration levels to ensure the subjects were receiving adequate amounts of water during the workout. Each subject was given a log to document their progress throughout the training period.

### Statistical Analyses

All analyses were performed using Statistical Package for the Social Sciences, Version 14.0 (SPSS, Inc, Chicago, IL). Independent *t*-tests were performed to compare BL to 6-wk changes in all 10-RM strength parameters between the single-set and multi-set groups. Paired *t*-tests were used to

compare strength changes within each group in all lifts. The probability of making a Type I error was set at  $p < .05$  for all statistical analyses.

The independent variable in this study was the different amount of sets, single or multiple sets. The dependant variable in this study was the amount of strength changes in each individual.

## RESULTS

Results are presented for the 16 of 20 subjects (80%) who completed the study. The reasons for failing to complete the exercise training study were: lack of ability due to injury (1 subject), training for a prolonged period of time (3 subjects). The baseline characteristics for subjects who completed the study are shown in Table 1.

Comparisons of mean BL to 6-wk changes showed no significant differences ( $p > .05$ ) in strength gains between the single set vs. multiple set groups: bench press 10-RM [+15.6 vs. +13.0,  $t(14)=1.028$ ,  $p=0.321$ ]; leg press 10-RM [+39.0 vs. +34.6,  $t(14)=.414$ ,  $p=0.685$ ]; seated row 10-RM [+10.7 vs. +7.8,  $t(14)=.927$ ,  $p=0.370$ ]; back squat 10-RM [+17.8 vs. +16.9,  $t(14)=.241$ ,  $p=0.813$ ]; shoulder press 10-RM [+8.8 vs. +7.3,  $t(14)=.667$ ,  $p=0.515$ ]. The mean values and standard deviations (SD) for all strength performance outcomes before and after the resistance training intervention are presented in Table 3. The paired  $t$ -test revealed significant improvements ( $p < .05$ ) in 10-RM values for all lifts in both single and multiple set groups. There were no significant ( $p > .05$ ) changes in anthropometric and body composition from pre- to post-testing in both groups.

**Table 3.** Anthropometric and 10-RM values pre- and post-program (mean  $\pm$  SD).

Outcome	Single-set (N=7)		Multiple-set (N=9)		Combined (N=16)	
	PRE	POST	PRE	POST	PRE	POST
Bicep circumference (cm)	27.2 $\pm$ 2.8	26.8 $\pm$ 2.9	27.0 $\pm$ 1.5	27.1 $\pm$ 1.5	27.1 $\pm$ 2.2	27.0 $\pm$ 2.2
Thigh circumference (cm)	47.0 $\pm$ 4.0	46.6 $\pm$ 3.9	50.6 $\pm$ 3.6	50.5 $\pm$ 3.0	48.8 $\pm$ 4.2	48.8 $\pm$ 3.8
Waist circumference (cm)	76.9 $\pm$ 10.2	74.4 $\pm$ 7.7	74.6 $\pm$ 7.5	73.3 $\pm$ 4.9	75.8 $\pm$ 8.8	73.8 $\pm$ 6.1
Hip circumference (cm)	103.2 $\pm$ 7.7	100.3 $\pm$ 8.0	101.6 $\pm$ 3.8	101.9 $\pm$ 2.7	102.4 $\pm$ 5.9	101.2 $\pm$ 5.5
Waist/Hip ratio (cm)	.74 $\pm$ .04	.74 $\pm$ .02	.73 $\pm$ .05	.72 $\pm$ .03	.74 $\pm$ .05	.73 $\pm$ .03
Triceps skin fold (mm)	20.8 $\pm$ 4.6	20.5 $\pm$ 2.8	17.3 $\pm$ 3.8	17.8 $\pm$ 3.3	19.0 $\pm$ 4.5	19.0 $\pm$ 3.3
Surprailiac skin fold (mm)	19.5 $\pm$ 4.9	19.6 $\pm$ 4.3	17.5 $\pm$ 3.6	18.3 $\pm$ 2.7	18.5 $\pm$ 4.3	18.9 $\pm$ 3.4
Thigh skin fold (mm)	26.6 $\pm$ 5.0	26.1 $\pm$ 4.5	25.0 $\pm$ 4.0	25.4 $\pm$ 3.4	25.8 $\pm$ 4.5	25.8 $\pm$ 3.8
Body Fat (%)	24.0 $\pm$ 3.7	24.2 $\pm$ 3.3	22.3 $\pm$ 3.4	23.0 $\pm$ 2.3	23.2 $\pm$ 3.6	23.5 $\pm$ 2.7
Bench Press (kg)	30.9 $\pm$ 4.3	*46.4 $\pm$ 7.9	37.7 $\pm$ 7.9	*49.9 $\pm$ 7.4	34.3 $\pm$ 7.1	48.4 $\pm$ 7.5
Leg Press (kg)	102.7 $\pm$ 11.6	*146.8 $\pm$ 25.6	109.1 $\pm$ 23.3	*141.2 $\pm$ 24.4	105.9 $\pm$ 18.2	143.6 $\pm$ 24.2
Seated Row (kg)	24.3 $\pm$ 3.2	*34.7 $\pm$ 6.7	26.8 $\pm$ 6.8	*34.6 $\pm$ 6.3	25.6 $\pm$ 5.4	34.7 $\pm$ 6.3
Back Squat (kg)	42.8 $\pm$ 7.6	*63.0 $\pm$ 10.9	50.0 $\pm$ 12.9	*68.7 $\pm$ 13.0	46.4 $\pm$ 11.0	66.2 $\pm$ 12.1
Shoulder Press (kg)	24.1 $\pm$ 5.0	*35.4 $\pm$ 5.8	28.2 $\pm$ 5.6	*35.6 $\pm$ 5.3	26.1 $\pm$ 5.6	35.5 $\pm$ 5.4

\* denotes significant ( $p < .05$ ) difference within subjects pre- to post-training

## **DISCUSSION**

The findings of the present study did not support the hypothesis that multiple-set would be superior to single-set in strength gains. Our research demonstrated that there was no significant difference in strength gains between the two groups.

The results are supported by a study done by Hass, et al. (8). The researchers found there was no significant difference in strength gains between single-set and multiple-set resistance training. However, the results demonstrated significant strength gains from pre- to post- training in each group. The current study concurs with these results. Another approach to the controversy is presented by a study done by Galvao and Taaffe (9). The researchers found that both single-set and multiple-set resistance training showed benefits; however, one should consider goals and training status before setting up a program. The researchers also suggested completing a combination of single-set and multiple-set resistance training program. This type of program would promote adherence due to variety. Boros and others (10) demonstrated that multiple-set provided more strength gains than single-set resistance training. However, these subjects did not show any changes in body mass in either group. Though the current study contradicts these results in terms of strength gains, the current results are in agreement with Boros and others regarding body mass. Neither group showed any significant changes in body mass in the current study.

In studies that found multiple-set resistance training as superior to single-set, researchers are presenting a dose-response relationship between number of sets and strength gains. However, the current results demonstrate that there is no dose-response relationship between number of sets and strength gains as long as the training threshold is met. The training threshold is the point at which a physiological effect begins to take place. This threshold is shown to be met through single-set resistance training.

When an untrained individual starts a resistance training program, it is almost certain that they will see strength gains. However, as the training period gets longer, the rate that the gains occur will decrease. This initial increase in strength is primarily due to two things: learning effects and neural adaptations. As the participant becomes more familiar with the testing procedures and the lifts themselves, greater strength increases occur because of a greater comfort level and confidence in lifting abilities. The neural adaptations occur especially in the first one to two months of starting a resistance training program. A person who was sedentary prior to the program will not experience muscle fiber hypertrophy but the neural factors have to adjust to the new program in some way in order to accommodate the new strength. With these neural adaptations occurring, less muscle is actually used in order to complete the lifts, therefore a greater load is lifted using a smaller amount of muscle. This results in an increase in strength very quickly. However, as previously stated, this amount of strength gains will not last because the nervous system eventually adapts completely, which places the strain back onto the muscles completely. (7)

As mentioned, initial strength gains are due to neural adaptations which can be achieved through single-set resistance training. Neural adaptations are no longer the primary source of strength gains in longer term resistance training; instead, an increase in resting serum testosterone and IGF-I and a decrease in resting serum cortisol concentrations provide an improved anabolic environment in longer training periods. Therefore, the increase in these hormones circulating during the recovery stage of resistance training is increased with the number of sets performed. Therefore, multiple-set resistance training would increase the amount of hormones more than single-set resistance training. These hormones provide larger strength gains which would indicate multiple-set resistance training being superior to single-set resistance training after initial strength gains are achieved. (9)



The results support the current American College of Sports Medicine (ACSM) guidelines for resistance training. The guidelines suggest one set of 8-12 repetitions at least two days a week. The current study was completed using one set of 8-12 repetitions, two days a week and showed significant strength gains over the 6-wk training period. Therefore, the results support the recommendations made by ACSM for apparently healthy adults. (6)

### **Limitations**

The length of the training period during the current study is a major limitation. Due to the time constraints, the training period was limited to six weeks though a 12-wk training program would have been preferred. Another limitation is the population of untrained females. The results can only be generalized to other females that are untrained and of college age. Dietary habits were not discussed with the subjects; therefore, the results could have been impacted by dietary intake or general health habits.

### **Assumptions**

One of the major assumptions during the study was that the subjects were providing a maximal effort during both the testing and training periods. Another major assumption was that the subjects were only participating in the study and were not performing any resistance training outside of the guidelines. The last assumption was that the subjects were completing their training in the same order, not alternating their routine through order of exercises.

### **Future Research**

More research is clearly needed on this topic. Future studies should be longer in duration, striving for at least 12 weeks in length. Many studies have been eight weeks or less which doesn't allow enough time to see significant improvements in strength. Also, more diverse subject demographics should be considered. Currently, the most popular group studied has been college-aged males. Therefore, older populations and female groups should be studied more. Also, a future study should consider initial single-set resistance training and multiple-set resistance training after an initial level of strength has been achieved. This topic is an important area to consider and it is imperative to continue to research this area due to the controversy still remaining between whether single-set or multiple-set resistance training is superior in strength gains.

### **CONCLUSIONS**

This study demonstrated that single-set resistance training was as efficient as multiple-set resistance training. These findings are valuable when considering resistance training for health benefits. Single-set resistance training programs can be prescribed that allow for shorter workout sessions. This could promote adherence to training programs more than longer, multiple-set resistance training programs would. The results are most applicable towards untrained, college-aged females. However, health professionals, coaches, and athletes could all use these results when prescribing a workout routine.

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