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Effects of Order of Resistance Training Exercises on Strength Gains in Untrained Females

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ABSTRACT

Janelle Schilter, Maggie Henjum, Brittani Funk, Chelsey Olson. Effects of Order of Resistance Training Exercises on Strength Gains in Untrained Females. *Journal of Undergraduate Kinesiology Research* 2007; 3(1):44-51. **Purpose:** A six week resistance training program was completed to determine the importance of order of exercise. The purpose of this study was to discover whether resistance exercise order plays a role in strength development among untrained college-aged women **Methods:** Untrained college-aged women were used in this study. There were 27 subjects split into three groups; multi-joint then single-joint, single-joint then multi-joint, and lastly, alternating single and multi-joint exercises. A 10 RM was used to determine the starting weight of each subject. Subjects were progressed by 5% upper body and 10% lower body each week. This method was used to determine differences in strength gains at the end of the training program. **Results:** After six weeks of resistance training, the results indicated that there were no significant ($p>.05$) strength gains with any particular order. Within groups A and B, significant strength ($p<.05$) gains were seen in all of the 8 resistance exercises. Group C only saw strength gains in 6 of the 8 exercises. **Conclusion:** Although there were no differences between groups on significance to the order of resistance training exercises, there were strength gains within each group. Overall, any order of resistance training exercises will improve one's strength over a chronic resistance training program.

Key Words: sequence, untrained women, chronic training program, single-joint, multi-joint

INTRODUCTION

Recently, the popularity of resistance training has increased (1). Resistance training encompasses eight training variables, which include: muscle action used, resistance used, volume, exercises selected and workout structure, sequence of exercise performance, rest intervals between sets, repetition velocity, and training frequency (2). Increasing one or a number of these training variables will allow one to see increases in strength over time. Resistance training is used to increase muscular strength, power, endurance, and hypertrophy in athletes, and it also benefits the

general population by maintaining or improving one's health status. Although there is research that demonstrates the benefits of resistance training, the overall design of a resistance training program is controversial (3). The controversy about resistance training involves the order of resistance training exercises, multi-joint versus single-joint exercises, major muscle groups versus small muscle groups, and the number of sets per exercise.

The question that remains to be answered is: do these different sequences have an effect on strength gains, and which order is most effective and impactful to gain strength? It is important to resolve this question because hypertrophy can be achieved, but the most effective way has not been determined. In a study completed by Simao, it was shown that exercises involving larger muscle groups should be completed at the beginning of a resistance training session, because it allows an individual to lift a larger amount of weight due to not being fatigued. The sequence of resistance training exercises has an effect on the force produced by an exercise; the force production is increased when utilizing large muscle groups first (4). The delay of fatigue from following this protocol may enable one to gain more strength over the long-term. Studies have shown individuals aiming to maximize their strength gains should perform multi-joint, large muscle group exercises prior to single-joint, smaller muscle group exercises. As stated in Spreuwenberg's study, when the leg press is performed following a leg extension, subjects were unable to achieve as many repetitions as those who completed the leg press first. This demonstrated in an acute training session when utilizing multi-joint exercises prior to single joint exercises, the fatigue level will be delayed (5). On the other hand, very little research has been done on chronic resistance training programs; the question of whether these findings will hold true over a six week training program is what remains to be discovered.

In previous studies completed, college-aged women were the most under studied group, which influenced the decision to research this particular population. As one ages, bone density naturally decreases; it is extremely important for college-aged females to increase bone mass prior to this natural decline in bone density. Individuals who participate in resistance training and weight bearing activities will see an improvement or maintenance in bone density over time. Maintenance of strength is important for normal healthy living. Approximately 70% of women by the age of 80 are unable to do heavy housework. The inability to carry out activities of daily living as one ages is likely due to the loss of muscular strength (6).

Therefore the purpose of this study was to discover whether resistance exercise order plays a role in strength development among untrained college-aged women. The independent variable of the study is the order of resistance training exercises, and the dependent variable is the strength gains. The three variations of the independent variable are starting with single-joint and ending with multi-joint (A), starting with multi-joint and ending with single-joint (B), and alternating between single-joint and multi-joint (C). It is hypothesized that by doing multi-joint groups before single-joint groups (B), in a resistance training exercise program; one will obtain larger strength gains over the course of the six week study.

METHODS

Subjects

The subjects in this study were twenty-six college aged women. They were recruited from the student body at the University of Eau Claire and the surrounding community. Female college population was selected because of the lack of research and college-aged participants were the most accessible subjects for this study. These participants have never resistance trained or have ended training within the past six months. Subjects were asked to maintain any current aerobic routine throughout the six week program. The mean age, weight, height, and body mass index are reported in the table below. All of the subjects understood the terms of the study and signed a consent form agreeing to the procedures. This study was approved by the University Subjects Institutional Review Board.

Table 1. Descriptive data of the participants that completed the study.

Conditions	Group A N=8	Group B N=5	Group C N=5	All Participants N=18
Age (years)	19.5 ± 0.5	19.0 ± 1.0	20.8 ± 1.3	19.7 ± 1.1
Mass (kg)	64.9 ± 9.7	68.8 ± 11.3	57.3 ± 6.1	63.9 ± 9.9
Height (m)	1.7 ± 0.1	1.7 ± 0.0	1.6 ± 0.1	1.7 ± 0.1
BMI (kg/m^2)	23.3 ± 2.9	25.1 ± 3.5	21.6 ± 2.3	23.3 ± 3.1

Instrumentation

For the initial evaluation with the participants, various measurements were taken such as height, weight, BMI, and age. The administration of the initial evaluation was performed in the University of Wisconsin – Eau Claire Exercise Physiology Laboratory. Height was measured in centimeters and inches using the Seca stadiometer. To find the subject's weight a standard Detecto scale was used. To calculate BMI the equation of weight (kg) divided by the subject's height squared (m^2) was used. With these measurements the subjects were placed into the correct percentile range compared to their ages, for standardizing purposes. For the resistance training program, the subjects all used the same weights and machines which were as follows:

- Free weight fly performed with Dura-Bell Hampton free weights (Chicago, IL) on a power systems resist-a-ball stability ball
- Free weight lateral raise with Dura-Bell Hampton free weights (Chicago, IL)
- Free weight bench press with Dura-Bell Hampton free weights (Chicago, IL) on a power systems stability ball
- Free weight overhead press with Dura-Bell Hampton free weights (Chicago, IL)
- Leg curl with a magnum fitness systems leg curl retro series
- Leg extension on a magnum fitness systems cross cable (serial # 96259)
- Free weight lunge with Dura-Bell Hampton free weights (Chicago, IL)
- Split squat on a Smith machine manufactured by Deltech Fitness (Louisville, KY)

Procedures

Each subject visited the Mcphee Weight Room two times a week for about an hour each session. On this first day, the subject's age, body mass (kg), height (m), and body mass index (kg/m^2) were collected and recorded. Pre-testing was completed on the first day, with a ten-repetition maximum test. The ten-repetition maximum test was performed by each subject to determine maximum strength prior to beginning the resistance training program.

Baseline Testing:

The baseline 10 repetition maximum test was used as follows:

- Begin with a warm-up weight to do 15-20 repetitions
- Following this set of repetitions- subject rest for 1-minute
- Determining fatigue level from the first set of repetitions
- Determined the increase in weight for the next set
- Second set- subject completes 10 repetitions
- If the subject felt she could complete more than 10 repetitions with the weight of the second set, she took at 2-3 minute rest.
- From her second set fatigue level- weight increased to achieve her 10 repetition max for her next set is determined.

Training Intervention:

From this ten-repetition max test, the subject's starting weight for resistance training was obtained. During the initial testing, each subject was taught proper form for four single-joint exercises and four multi-joint exercises. It was emphasized that lifting through a full range of motion is most beneficial for strength gains (7). A manual log was used to track the actual weight lifted during the program. On the log sheets, the prescribed weight, number of sets, and repetitions were typed out for each subject. On weeks 1 through 3 each participant was prescribed one set of 10 repetitions per exercise. On the fourth week, the sets were adjusted to two sets for the remainder of the study. Between each set the subjects were advised to take a 30 second to one minute rest break for recovery.

The 27 participants were randomly assigned to one of the following groups of A, B, or C (Figure 1.) Group A consisted of a prescribed exercise order of single-joint upper body, single-joint lower body, multi-joint upper body, then multi-joint lower body. Group B followed an exercise order of multi-joint upper body, multi-joint lower body, single-joint upper body, and then single-joint lower body. Group C consisted of an exercise order of multi-joint upper body, single-joint upper body, multi-joint lower body, and then single-joint lower body. All three groups completed a resistance training program that entailed two sessions per week, over a course of six weeks and had at least a 48-hour rest period between each resistance training session. This rest period was to ensure muscle recovery from the previous training session. Each participant was told to continue with any current aerobic exercise throughout the entire six weeks.

Each session, the subjects started with a five minute warm-up walking on a treadmill, bike, or elliptical at a low to moderate intensity of 40-60% heart rate reserve (HRR). To monitor the intensity subjects held onto heart rate sensors. Heart rate max (HRmax) was found by computing 220-age. Heart rate reserve was calculated by taking ((220-age).40) + resting heart rate, this showed the heart rate that each individual had to exceed. This was used to loosen up the muscles, for a reduction in muscle strains and to get subjects' heart rates in the expected range. During the first week of the program, the subjects started with the weight they achieved for ten-repetition max. Each week following, the subjects increased weight for upper body exercises by 5%, and the weight for lower body exercises increased by 10%. After the third week, the subjects added an additional set for each exercise.

Weight Lifting Program (Group A)	Weight Lifting Program (Group B)	Weight Lifting Program (Group C)
Single-Joint Upper Body	**Multi-Joint Upper Body**	**Multi-Joint Upper Body**
- Free weight Fly (on stability ball)	- Free weight bench press (on stability ball)	- Free weight bench press (on stability ball)
- Free weight Lateral Raise	- Free weight Overhead Press	- Free weight Overhead Press
Single-Joint Lower Body	**Multi-Joint Lower Body**	**Single-Joint Upper Body**
- Leg Curl (machine)	- Lunge	- Free weight Fly (on stability ball)
- Leg Extension (cables)	- Smith machine Split Squat	- Free weight Lateral Raise
Multi-Joint Upper Body	**Single-Joint Upper Body**	**Multi-Joint Lower Body**
- Free weight bench press (on stability ball)	- Free weight Fly (on stability ball)	- Lunge
- Free weight Overhead Press	- Lateral Raise	- Smith machine Split Squat
Multi-Joint Lower Body	**Single-Joint Lower Body**	**Single-Joint Lower Body**
- Lunge	- Leg Curl (machine)	- Leg Curl (machine)
- Smith machine split squat	- Leg Extension (cables)	- Leg Extension (cables)

Figure 1. Resistance Training Protocols

Post Program Testing:

Throughout the six week training program, the subjects recorded the weight lifted each session. This allowed for communication between the subjects and examiners. The log helped the subjects maximize their strength gains throughout the six weeks by attempting to reach the prescribed weekly weight. The log was turned in during the week of post testing. All subjects completed post program testing within one week of the last resistance training session.

Statistical Analyses

All analyses were performed using Statistical Package for the Social Sciences, Version 15.0 (SPSS, Inc, Chicago, IL). Measures of centrality and spread are presented as mean ± *SD*. Mean differences in the change in 10-RM values between exercise order groups from baseline to post-program were assessed with one-way analysis of variance (ANOVA). Tukey's post hoc tests were performed to determine differences between treatment groups. Mean differences in 10-RM values between baseline and post-program for all single and multi-joint exercises were assessed with paired *t*-tests. The probability of making a Type I error was set at $p < 0.05$ for all statistical analyses.

RESULTS

Results are presented for 18 of the 26 subjects (69 %) who completed this study. The reasons for failing to complete the exercise study were illness, injury, lack of time, and failure to adhere to guidelines. The baseline characteristics for subjects who completed the study are shown in Table 1. Statistical analyses revealed no significant differences ($p > .05$) in the change in 10-RM values between exercise order groups from baseline to post-program. The mean values and standard deviations (SD) for 10-RM values at baseline and post-program for all exercise order groups are presented in Table 2. Paired *t*-tests revealed significant improvements ($p < .05$) in 10-RM values for the following exercises in Group A: bench press, overhead press, free weight fly, lateral raise, lunge, split squat, leg curl, and leg extension. Likewise, analyses showed significant improvements ($p < .05$) in 10-RM values for all exercises in Group B. In Group C, paired *t*-tests revealed significant improvements ($p < .05$) in 10-RM values for overhead press, free weight fly, lunge, split squat, leg curl, and leg extension. No significant differences ($p > .05$) were found in 10-RM values for bench press and lateral raise.

Table 2. 10-RM values Pre and Post Testing (mean ± SD).

	Group A		Group B		Group C	
Conditions	**PRE (lbs)**	**POST (lbs)**	**PRE (lbs)**	**POST (lbs)**	**PRE (lbs)**	**POST (lbs)**
Bench Press	37.5 ± 7.1	*51.3 ± 6.4	48.0 ± 8.4	*62.0 ± 8.4	33.0 ± 6.7	46.0 ± 16.7
Overhead Press	28.8 ± 7.9	*35.0 ± 5.3	30.0 ± 6.1	*44.0 ± 5.5	28.0 ± 2.7	*34.0 ± 5.5
Free Weight Fly	28.1 ± 5.3	*41.3 ± 8.3	30.0 ± 6.1	*46.0 ± 5.5	23.0 ± 4.5	*36.0 ± 8.9
Lateral Raise	19.4 ± 3.2	*27.5 ± 2.7	21.0 ± 5.5	*28.0 ± 2.7	18.0 ± 2.7	21.0 ± 4.2
Lunge	47.5 ± 8.9	*71.3 ± 13.6	46.0 ± 5.5	*76.0 ± 8.9	48.0 ± 13.0	*66.0 ± 5.5
Split Squat	63.8 ± 9.5	*126.3 ± 28.3	74.0 ± 13.9	*129.0 ± 22.5	57.0 ± 10.4	*103.0 ± 17.2
Leg Curl	66.3 ± 9.2	*96.3 ± 15.1	65.0 ± 13.7	*93.0 ± 18.9	65.0 ± 11.7	*87.0 ± 20.2
Leg Extension	19.5 ± 6.2	*39.0 ± 12.4	19.2 ± 6.6	*33.6 ± 10.0	14.4 ± 5.4	*28.8 ± 6.6

* denotes significant mean difference ($p < .05$) in baseline and post-program 10-RM values.

DISCUSSION

The hypothesis stated that there would be greater strength gains when performing multi-joint exercises prior to single-joint exercises (group B). Results show that there was no significant strength gain in any particular group. This study suggested that the order of exercises do not make a significant impact on strength gains in a six week training study among untrained college-aged women. Other studies have shown that in acute training program, individuals who train larger muscle groups prior to small muscle groups experienced less fatigue than those training small muscle groups before larger muscle groups (5). It was hard to compare past research to this study, because strength gains were measured with a chronic exercise program rather than an acute program. There were no studies found that have completed a chronic resistance training program, so it becomes difficult to compare this study to previous acute program studies. Most of these acute program studies measured fatigue levels and this study measured strength gains.

The delimitations of the study were the length of study was short for a chronic resistance training study, population studied (college-aged women), untrained individuals, and the number of days per week trained. More results may have been seen if the study was longer, possibly allowing for larger strength gains. Along with the overall length of the study, the number of session per week could have influenced the results. The assumptions were that the subjects resistance trained 2 non-consecutive days per week for 6 weeks. It was also assumed that the subjects followed an assigned resistance training order that was given at the beginning of the study. Another assumption made was that the subjects used proper form when resistance training. It was also assumed that the subjects did try to achieve maximal weight for baseline testing. Lastly, it was assumed that the instruments and resistance training machines were reliable and valid. The 10 rep max was a valid test, because the test measured the dependant variables of initial strength compared to final strength measurement. The reliability of the test could have been affected by either the person performing the test or the subject being measured. If the tester was unsure about technique of the lift or if the subject were to have performed the lift incorrectly, then the reliability of the test could be questioned. Finding the correct weight to hit fatigue at 10 reps depended on the client's confidence and self-awareness; this could obstruct the reliability of testing if the subjects did not do the amount of weight that could actually be lifted. Starting at a weight that is comfortable but challenging for untrained women is not the most reliable way of finding the 10 rep max, because of the mental limitations that come with inexperience. If all the subjects performed the lift correctly, understood what fatigue meant, and understood when a certain weight was too heavy to maintain correct form, then the test should be repeatable with similar results. However, if this did not happen, then it could decrease the reliability on the subject's initial starting weight, but throughout the program the resistance was always increasing which compensated for this initial limitation.

According to the data there were no significant ($p>.05$) strength gains. From a practical standpoint all subjects made strength gains. It is also important from practical standpoints to understand that there were still important findings from this study. When analyzing the data with a paired sample T-test, group A and B had significant strength gains in all 8 lifts. Group C only had significant strength gain in 6 of the 8 exercises. It was predicted that this was from fatigue levels of group C. Group C completed all upper-body multi-joint, all upper body single-joint, all lower body multi-joint, then all lower body single-joint. Doing all exercises using the same muscle groups could have caused the earlier fatigue in group C, and this may be the reason why group C saw the least amount of strength gains within their group. The initial strength gains in untrained subjects are primarily due to neural adaptations, as the muscle becomes more efficient during submaximal exercise (8). Within the first one to two months the neural adaptations are due to motor unit recruitment, synchronization of recruitment, increased coordination, increased learning, and increased activation of prime mover muscles (8). Subjects also saw strength gains due to increases

in load and volume of exercises (9). Throughout the program these training variables were manipulated, which caused strength gains. According to Kraemer, by increasing any of the eight variables an individual should see strength gains (10).

Overall, the results of this study contradict the American College of Sports Medicine (ACSM) recommendation to perform exercises of large muscle groups prior to small muscle groups within a training session for a healthy adult (4). These suggestions are based on research that has been completed looking at acute training sessions and fatigue level within one training session. When comparing order of resistance training exercises, there were no significant strength gains seen when performing large muscle groups prior to small muscle groups. This challenges prior research that was concluded from results in an acute training program. Therefore, when looking at this chronic training study it challenges the ACSM findings. Although within an acute training session, one may experience earlier onset of fatigue when performing small muscle groups prior to large muscle groups, this study shows that there are no significant strength gains over a 6-week training period when performing exercises in this order.

Future research should look at completing a full body workout, and incorporating multi vs. single joint exercise order into the program. Also, the subject of exercise order and other populations is important to compare to this research, for example, men, trained populations, and elderly populations. Lastly, increased sessions per week and longer overall training program would also provide significance to future research.

CONCLUSIONS

When looking at a six week long resistance training program analyzing data with the one-way ANOVA, there was no significant strength gains when comparing groups. However, when comparing within each group, group A and B saw significant strength gains with all exercises. Group C saw significant strength gains in only 6 out of the 8 lifts. It was concluded that the order of exercises within group C caused an earlier fatigue level, which resulted in less strength gains throughout the six weeks. From the data we collected, it is concluded that when designing a resistance training program, exercises involving the same muscle groups should not be performed consecutively. Overall, any order of resistance training will create strength gains in a chronic resistance training program.

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