Journal of Undergraduate Kinesiology Research

Official Research Journal of the Department of Kinesiology
University of Wisconsin – Eau Claire

Volume 3 Number 1 December 2007

THE LASTING NEUROLOGICAL EFFECTS OF RESTISTANCE TRAINING: COMPARING STRENGTH GAINS IN PREVIOUSLY TRAINED AND NON-PREVIOUSLY TRAINED COLLEGE-AGED MALES

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ABSTRACT

Zemke BS, Batty RW, Sorenson AM, Ullom GM. The Lasting Neurological Effects of Resistance Training: Comparing Strength Gains in Previously Trained and Non-previously trained College-Aged Males. *Journal of Undergraduate Kinesiology Research* 2007;3(1):79-85. **Purpose:** Strength gains made during resistance training are made due to neurological and morphological adaptations. During a period of detraining, some of these adaptations are lost, which need to be regained during a period of retraining. The purpose of our study was to compare the rate of strength gains made in previously trained and non-previously trained males over a six week period. **Methods:** 12 males ages 18 to 23 who were not currently participating in a resistance training program participated in the study. Subjects were placed in one of two groups, either previously trained or non-previously trained. The previously trained group included subjects who had been on a resistance training program 2 times per week for greater than 12 weeks, but had not resistance trained for the past 6 months to 4 years. The non-previously trained group included subjects who had never been on a resistance training program for longer than 4 weeks. Subjects were asked to complete a minimum of 8 of 11 training sessions over a 6 week period. The subject's performance in bench press, overhead press, squat, and leg press were used to assess strength gains. Body fat % and circumference measurements were used to assess any morphological changes. **Results:** Both groups made significant output changes in each of the four exercises ($p < .05$); however, there were no significant changes between the two groups. There were also no significant changes in the morphological measurements. **Conclusion:** This study indicates that previously trained individuals do not make strength gains at a faster rate than non-previously trained individuals. To our knowledge, there have been no previous studies investigating the strength gains in previously trained and non-previously trained individuals. We believe this research will give important information to response expectations for a retraining period.

Key Words: Detraining, Retraining, Atrophy, Strength Retention, Neural Adaptations, Strength Training

INTRODUCTION

It is generally accepted that resistance training increases muscular strength (1-4). Other benefits of resistance training include increased bone density, muscle size, and androgenic hormones (5). These benefits can be obtained in all populations including athletes, the elderly and other special populations such as diabetics and hypertensives. Resistance training as it pertains to our study is defined as the systematic progression, over a period of weeks or months, of using weight plates as a resistive force against the contraction of muscles. The increases in muscular strength are due to both morphological and neurological changes (4,6). Morphological changes made are an increase in whole muscle size, hyperplasia, change in muscle fiber, and muscle architecture. The neurological changes that are made in response to resistance training are enhanced motor unit recruitment and firing frequency (6). It is known that the strength gains made during the first few weeks of resistance training are primarily due to neurological adaptations (4,7,8). Lemmer et al. reported a 31% increase in 1 repetition max (RM) leg extension in young males after a 9 week training period (9). After the initial weeks of resistance training, further gains made in strength are primarily due to morphological adaptations, although further neurological adaptations may also contribute (4,8).

Previous research has been done to measure the effects of detraining on strength (3,9). Detraining occurs with periods of training reductions or cessation, and results in the partial loss of both morphological and neurological training adaptations (1,3,4). Muscle fiber size decreases after two weeks of detraining in power athletes (3). A study by Lemmer et al. showed no significant decrease in 1-RM unilateral knee extension after 12 weeks of detraining, but showed an 8% decrease after 31 weeks of detraining in young resistance trained individuals (9). A study by Andersen et al. showed a significant decrease in muscular strength during concentric contractions after 3 months of detraining, while strength during eccentric contractions was maintained (3). This study states that muscular strength can be partially maintained after periods of detraining because of long lasting neural adaptations (3).

In the fitness world, it is a common assertation that a previously trained individual would make strength gains at a faster rate than a non-previously trained individual. To our knowledge, there have been no studies that compare strength gains in previously trained and non-previously trained subjects. It is unknown whether someone who has previous experience in resistance training would make strength gains at a different rate than someone who has little or no experience. This knowledge would be very useful for trainers and those who are recovering from an injury or a long cessation of training. Such knowledge would give a trainer further insight into expected training adaptations, with which trainers will be able to inform their patients of realistic retraining expectations. The purpose of our study was to compare the rate of strength gains made in previously trained and non-previously trained males over a six week period. We hypothesized that previously trained individuals would make faster strength gains than non-previously trained individuals due to the retainment of neurological pathways related to strength.

METHODS

Subjects

Twenty-four healthy men ages 18-23 years, who were not participating in any resistance training regimen upon the commencement of the study, volunteered to be in the study. The subject's data was divided into either the previously trained group or the non-previously trained group, in accordance to the subject's training history. The two identified groups based upon the training history of the subjects serves as the independent variable in this study. The previously trained group was defined as having participated in a resistance training program lasting 12 weeks or more, and have ceased such participation for the duration of six months to four years. The non-previously trained group was defined as having never participated in a resistance training program for more than four weeks. The study was approved by the University Human Subjects Institutional Review Board. All subjects were screened for hypertension and were at no apparent risk for disease. The subjects were recruited from UW-Eau Claire kinesiology classes and by word of mouth on campus, and signed an informed consent form.

Instrumentation and Procedures

To begin data collection we performed a baseline assessment of all subjects. These assessments included skinfold tests performed at 3 testing sites using a Lange skinfold caliper. Body fat percentage was calculated using the Jackson and Pollock three-site formula of chest, abdomen and thigh (10). The equation for Caucasian males 20 to 80 years old, 4.95/Db – 4.5, was used to calculate body fat for the subjects (10). All subjects had their blood pressure taken with a Pressostabil sphygmomanometer and Littmann Select stethoscope, and their height and weight assessed by a Seca stadiometer (Hamburg, Germany) and Detecto Double Beam Balance scale, respectively. Anthropometric measurements were taken at the bicep, chest, thigh and abdomen by a Gulick tape measure with a calibrated tension device according to National Strength and Conditioning Association standards (5).

Baseline Testing

In small groups, subjects were guided through the weight room for a simulation of a predesigned training program, while also receiving a brief tutorial on proper resistance training techniques prior to the test out date. With all researchers present, a testing session was held to obtain an 8 repetition maximum (8-RM) for each lift that the subjects were to perform throughout the program. Each subject was asked to perform eight repetitions of a single lift, beginning with a light weight and progressively adding more to determine the 8-RM. The 8-RM was determined according to NSCA protocol for the four lifts to be tested pre- and post-program. The protocol calls for approximately four sets of a specified lift with two to three minutes rest between each. The first set was performed at a weight appropriate for a warm up of ten repetitions. The second set was performed at an estimated weight for an eight repetition set, followed by an increased weight for the third and fourth set if necessary. Estimated weights were based upon the subject's perceived exertion. The four exercises tested under this protocol included the bench press, leg press, shoulder press and squats performed with a Magnum Fitness 400-perfect squat machine. Pictures of the equipment used for all four exercises are shown in Figure 1a-d. The 8-RM served as the dependent variable in this study and became the base weight that each individual was to begin with during the first training session of the program. The remaining lifts in the workout program were determined through organized trial and error. Each subject performed the exercise for four reps, and researchers used the subject's perceived difficulty of the four repetitions to determine appropriate eight rep weights for the workout.

Fig. 1a Bench Press

Fig. 1b Squat

Fig. 1c Overhead

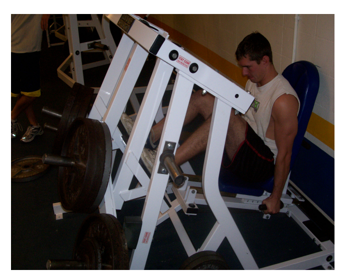

Fig. 1d Leg Press

Training Program

For the first three weeks of the program subjects were to perform one set of eight repetitions of each exercise. For the second three weeks, two sets of eight repetitions were performed. For the first three weeks, all subjects were told to perform repetitions until failure. During the program if a subject was able to perform nine or more repetitions of a single lift, their lifting load was increased by a percentage of their previous load based upon the number of repetitions completed. The chart "Percent of the 1RM and Repetitions Allowed (%1RM-repetition relationship)" was used to determine the appropriate weight (5). Every increase was rounded to the nearest increment of 2.20462262 kilograms (five pounds). For the last three weeks, the weight was increased five pounds for upper body exercises and ten pounds for lower body exercises when eight repetitions were completed on the second set.

Post-Program Testing

Upon the conclusion of the six week training program, subjects were asked once again to undergo 3-site skinfold testing using a Lange skinfold caliper. The tests were performed by the same researcher that had performed them during the baseline testing. Weight and anthrompometric measurements were also measured again using the same instruments and procedures as the pre-testing. The subjects also re-tested their 8-RM with the same protocol used during pre-testing. The weight used during their final workout was used for the first testing set. Differences between pre and post-testing in lean body mass and anthropometric measurements were used to show increases in hypertrophy. Differences in the 8-RM for the four different lifts were used to show the strength gains made during the training program.

Statistical Analyses

All analyses were performed using Statistical Package for the Social Sciences version 14.0 (Chicago, IL). Paired *t*-tests were used to compare within group changes between baseline and post-program values for all anthropometric and strength parameters. An independent *t*-test was used to compare 8-RM values from baseline to post-program in all subjects. All measurements are expressed in mean and standard deviation. A *p*-value of <.05 was used as the level of significance.

RESULTS

Results are presented for the 12 of the 24 subjects (50%) who completed the study. The mean age of the participants was 20.17±1.59. Reasons for not completing the study were not completing the required number of workouts (10 subjects) and injury unrelated to the study (2 subjects). Table 1 shows the baseline and post-study subject characteristics. There were not significant differences in lean body mass and any of the circumference measurements between groups.

Table 1. Participant descriptive statistics (mean ± SD).

	Non-previously trained (*N*=7)		**Previously Trained (*N*=5)**	
Measurement	**Baseline**	**Post-study**	**Baseline**	**Post-study**
Body mass *(kg)*	72.31±7.62	72.89±7.11	84.74±10.06	84.78±9.65
Lean Body Mass (kg)	61.47 ±6.08	62.78±5.40	69.77 ±7.63	72.29±6.93
Body Fat *(%)*	12.54±4.68	13.66± 4.49	14.96± 3.67	14.44±5.47
Arm Circumference *(cm)*	28.50±1.58	29.43±1.17	32.90±3.38	33.10±2.77
Chest Circumference *(cm)*	91.07±3.69	91.50±3.96	98.80±9.16	99.90±8.92
Thigh Circumference *(cm)*	54.43±3.74	55.07±2.82	60.66±4.02	59.40±4.11
Abdomen Circumference *(cm)*	78.64±4.96	78.21±4.38	85.90±7.47	85.40±10.06

The subjects from both groups had significant strength gains in all four exercises from baseline testing to post-program (p<.05). The subjects had an 18% increase in bench press, a 38% increase in leg press, a 20% increase in shoulder press, and a 44% increase in squat 8-RM. The mean values and standard deviations for the four tested exercises are presented in Table 2. The baseline measurements for bench press, squat and overhead press in the previously trained group were significantly higher than the non-previously trained group (p<.05). After 6 weeks, there were no significant differences in strength gains between the two groups in any of the four measured resistance training exercises. Table 3 shows the strength gains made by the participants from baseline to post study for all four exercises.

Table 2. Participant 8-RM results (mean ± SD).

	Non-previously trained (*N*=7)		Previously Trained (*N*=5)	
Measurement	**Baseline**	**Post-study**	**Baseline**	**Post-study**
8-RM Bench Press Max *(kg)*	45.37±5.05	56.71±6.40	73.48±20.88	82.58±20.94
8-RM Overhead Press Max *(kg)*	33.37±5.36	41.80±7.03	47.18±13.29	54.44±12.02
8-RM Leg Press Max *(kg)*	165.24±13.36	219.35±24.03	171.46±29.31	246.75±30.86
8-RM Squat Max *(kg)*	62.87±12.95	99.47±17.93	88.90±26.75	115.22±28.22

Table 3. Participant 8-RM differences baseline to post study (mean ± SD).

Measurement	Non-previously trained (*N*=7)	Previously Trained (*N*=5)
8-RM Bench Press Difference*(kg)*	11.34±4.33	9.1±2.76
8-RM Overhead Press Difference *(kg)*	8.43±2.17	7.26±4.36
8-RM Leg Press Difference *(kg)*	54.10±19.95	75.29±28.8
8-RM Squat Difference *(kg)*	36.60±14.56	26.32±12.29

DISCUSSION

The strength gain increases in this study are consistent with that of other studies. Lemmer et. al found a 31% increase in 1-RM leg extension after 9 weeks of training (9). A study by Keeler et. al found a 33% increase in leg press 1-RM and a 34% increase in bench press in women after 10 weeks of training (11). The training volumes and/or frequencies slightly varied in comparison to this study. The finding of no significant morphological changes (p <.05) is also consistent with expectations. The National Strength and Conditioning Association states that hypertrophy has marked contributions to strength gains after 6-8 weeks of training (5). Since there were no significant gains in muscle hypertrophy, the strength gains made should be primarily attributed to neurological factors.

The fact that the previously trained group had significantly higher 8-RM bench presses, squats and overhead press at baseline could be attributed to familiarity with the exercises and giving a maximal effort in weightlifting. The non-previously trained group had no experience with resistance training which could affect their performance in a maximal testing session. The previously trained subjects may have maintained strength from their previous training according to other studies (3,9). This is another explanation of why the previously trained group had greater strength at baseline. There were no significant differences in lean body mass at baseline between the two groups, so this cannot be used as an explanation.

This study suggests there is no difference in the rate at which previously trained and non-previously trained individuals make strength gains. Previous studies have shown that subjects can maintain strength over a period of detraining (3,9); however, our study shows that the rate at which they make strength gains during a retraining period is no different than that of a non-previously trained person.

This would suggest that the neurological adaptations of motor unit recruitment and firing frequency may have a physiological ceiling at which gains can be made. This finding is important because it can disprove the assertation that previously trained individuals would make faster strength gains, and label it as a myth.

One of the assumptions of this study is that the subjects gave a maximal effort during each testing session and all of the workouts. The previously trained group may have given a more maximal effort in the initial testing session because of their familiarity with the lifts and an increased comfort level. Differences in effort in any one individual should not account for significant differences between the two groups. Other assumptions of the study include that the subjects did not perform additional resistance training, and they maintained their normal sleep, diet, and aerobic exercise habits. The subjects may not have had a diet of proper macronutrient ratios which could contribute to their strength gains.

One of the limitations of the study is finding the 8-RM at baseline. The weights used during testing were estimations of the subject's ability based upon the subject's perception of difficulty at a warm-up weight. A less than accurate 8-RM could have been achieved due to excessive muscular fatigue if multiple sets were required for a single exercise. If the starting weight was inappropriate, these two factors could lead to an inaccurate 8-RM. Since all testing was done on the same day, subjects could have substantial carry-over fatigue on the exercises tested last. The subject's order of exercise testing was the same in baseline and post-testing to minimize this effect. In future studies it would be recommended to have two separate 8-RM testing sessions at baseline to better find the subjects' 8-RM. The sessions would be conducted the same and be conducted one week apart, and the second session would correct any inaccuracies in the subject's 8-RM.

A delimitation of our study is that it can only be applied to college-aged males. The findings are not directly applicable to different age groups or gender. The equation used during the first three weeks of the study to adjust weights is only an estimate and may not give a person's true 8-RM. There were instances where the equated weight was too heavy for the subject to complete the desired eight repetitions.

There are numerous possibilities for future research. A higher training frequency could elicit larger strength gains in the previously trained compared to the non-previously trained group. The previously trained group may better adapt to the increased physiological stress, leading to a different rate in strength gains between groups. A previously trained group with a higher training period such as greater than one year could have a higher training effect which could lead to larger strength gains. This study should also be done on different genders and age groups to see if similar results are obtained. A longer training study could also investigate if there are any differences in morphological changes between previously trained and non-previously trained individuals.

CONCLUSIONS

Our training program was sufficient for subjects in both groups to make significant strength gains compared from baseline to post-study. No significant changes were found in any of the morphological measures, so all strength gains should be primarily attributed to neurological adaptations. These findings are consistent with the commonly held view that neurological adaptations are the main contributor to strength gains in the first six to eight weeks (5). Our findings showed no difference between the strength gains made by the non-previously trained and previously trained groups, which nullifies our hypothesis. It is a commonly held opinion in the fitness world that a previously trained person would make strength gains at a faster rate than a non-previously trained person, but our research does not support this. We hope this research will lead to further studies investigating this matter so that this belief can be labeled as either a fact or myth.

ACKNOWLEDGEMENTS

We would like to thank all of the participants who volunteered their time and effort for this study. We would also like to thank Dr. Lance Dalleck for offering guidance and support for this study as well as the UW-Eau Claire Kinesiology Department for use of lab equipment and weight room access.

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