Journal of Strength and Conditioning Research, 2001, 15(3), 309–314

Early-Phase Adaptations of Traditional-Speed vs. Superslow Resistance Training on Strength and Aerobic Capacity in Sedentary Individuals

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ABSTRACT

We performed a randomized exercise training study to assess the effects of traditional Nautilus-style (TR) or superslow (SS) strength training on muscular strength, body composition, aerobic capacity, and cardiovascular endurance. Subjects were 14 healthy, sedentary women, 19–45 years of age (mean ± *SD* age, 32.7 ± 8.9 years), randomized to either the SS or TR training protocols and trained 3 times per week for 10 weeks. Measurements were taken both before and after training, which included a maximal incremental exercise test on a cycle ergometer, body composition, and 1 repetition maximum (1RM) tests on 8 Nautilus machines. Both groups increased their strength significantly on all 8 exercises, whereas the TR group increased significantly more than the SS group on bench press (34% vs. 11%), torso arm (anterior lateral pull-down) (27% vs. 12%), leg press (33% vs. 7%), leg extension (56% vs. 24%), and leg curl (40% vs. 15%). Thus, the TR group's improvement in total exercise weight lifted was significantly greater than that of the SS group after testing (39% vs. 15%). Exercise duration on the cycle ergometer and work rate significantly improved for both groups, but there was no group-by-training interaction. No significant differences were found for body composition or additional aerobic variables measured. Both strength training protocols produced a significant improvement in strength during a 10-week training period, but the TR protocol produced better gains in the absence of changes in percentage of body fat, body mass index, lean body mass, and body weight. In addition, strength training alone did not improve $\dot{V}O_2max$, yet short-term endurance increased.

Key Words: Bod Pod, $\dot{V}O_2max$, strength gain, cycle ergometer, body mass index, 1 repetition maximum

Reference Data: Keeler, L.K., L.H. Finkelstein, W. Miller, and B. Fernhall. Early-phase adaptations of traditional-speed vs superslow resistance training on strength and aerobic capacity in sedentary individuals. *J. Strength Cond. Res. 15(3):309–314. 2001.*

Introduction

Conventional strength and endurance exercise training induces distinctly different adaptive responses when performed independently. Strength training is more anaerobic in nature and typically consists of high-resistance, low-repetition exercises that involve large muscle groups to increase the force-output ability and strength of the skeletal muscle (2, 26). Conversely, endurance training programs are characterized by prolonged rhythmic, low-resistance, high-repetition exercises, such as bicycling or running, to increase maximum oxygen uptake and endurance (2, 26). This would suggest that the adaptive response to training is specific to the particular training stimulus. Numerous studies, however, have concluded that strength training alone can improve aerobic capacity (7, 9, 16, 17). Yet, other studies have demonstrated that high-intensity resistance training improves strength without a concomitant increase in aerobic capacity ($\dot{V}O_2max$) (8, 10, 12). This type of training does appear to improve time to exhaustion during cycle ergometer and treadmill exercise testing but without altering $\dot{V}O_2max$ (10).

Superslow (SS) strength training is a resistance training program that involves performing very slow repetitions, approximately 15–20 seconds per repetition. The SS protocol consists of 10-second concentric and 5-second eccentric contractions (10/5). Conversely, a traditional Nautilus-type (TR) strength training protocol consists of a 2-second concentric contraction, then a short pause in the contracted position followed by a 4-second eccentric phase (2/4) (2, 3, 13, 20–24). It is believed that the increased amount of time that the muscle is under tension in the SS protocol enhances strength development, as asserted in several nonpeer-reviewed lay publications (2, 3, 13, 20, 22–25). Furthermore, there are nonsupported claims in the lay literature that SS weight training also enhances aerobic capacity (13). However, we were unable to locate any studies on SS weight training in scientific journals. Only one SS protocol study has been discussed in several nonscientific, non–peer-reviewed lay periodicals; it showed that the SS training group exhibited a slightly larger strength gain with training. Furthermore, the findings were not statistically significant (21–25). One study with nonsignificant results is insufficient to support the claims on the effect of SS weight training on aerobic capacity or endurance. Also, since the data were not published in the scientific peer-reviewed literature, the value of these findings is questionable.

Consequently, we conducted a randomized trial to evaluate the possible differential effects of TR and SS weight training on muscle strength and aerobic capacity.

Methods

Overview

We recruited sedentary volunteers to participate in the study to avoid the influence of prior exercise training. To evaluate strength, all subjects underwent 1 repetition maximum (1RM) testing on the 8 strength exercises used during strength training. Aerobic capacity was measured using a graded exercise test on a cycle ergometer with oxygen uptake measurements. Body composition was evaluated using the Bod Pod. Following all assessments, subjects were randomly assigned to either an SS or a TR group. Both groups trained 3 times per week for 10 weeks. All assessments were repeated following the 10-week training program to assess the effect of training.

Subjects

Fourteen healthy women volunteered to participate. At the time of testing subjects were not habitual exercisers nor had they performed any regular exercise within the past year. All subjects signed informed consent before participation, and the study was approved by the University Medical Center Office of Human Research.

Exclusion Criteria

Subjects were screened for contraindications to exercise through a health history questionnaire. Subjects who had a contraindication to exercise, e.g., orthopedic, cardiovascular, or metabolic diseases, were ineligible to participate. In addition, subjects were not taking any medications that would affect the results of the study. Subjects with a body mass index (BMI) (calculated as weight divided by the square of height) of 35 kg/m^2 or greater were also excluded from the study.

Testing Protocol

Before exercise testing, weight (in kilograms) was measured using the Bod Pod (4) (Life Measurement Instruments, Concord, CA) scale to the nearest 10 g, and height (in centimeters) was measured on a standard medical stadiometer. All tests were conducted before and after a 10-week training program and consisted of a maximal exercise test on an upright stationary cycle ergometer (Cybex International, Medway, MA), 1RM strength test on 8 Nautilus machines, and a body composition test using the Bod Pod.

Maximal Exercise Test. The maximal exercise test was conducted on a cycle ergometer using a pedal rate of 60–70 rpm at an initial workload of 50 W. The workload was increased 40 W every 180 seconds until the subject could no longer maintain a pedaling frequency of at least 55 rpm. At that time the resistance was immediately decreased to zero, and the subject continued to pedal slowly for a 120-second cool down.

Expired air was collected throughout the test and analyzed for minute ventilation and oxygen and carbon dioxide concentrations using a metabolic cart (Vmax, SensorMedics, Yorba Linda, CA). The metabolic cart was calibrated before each test. Data were collected breath by breath and compiled into 60-second averages. The highest 60-second average was considered the peak $\dot{V}O_2$. Heart rates were obtained at the end of each stage of the maximal exercise test using a Polar (Port Washington, NY) wireless heart rate monitor. The Borg scale was used to obtain ratings of perceived exertion (RPEs) during each stage of the test (1). Ventilatory measurements were examined to determine at which point the subject reached the ventilatory threshold, which was considered the point at which $\dot{V}CO_2$ increased at a faster rate than $\dot{V}O_2$ (V-Slope Method) (14). The ventilatory thresholds were computer determined based on the slopes of the $\dot{V}O_2$-$\dot{V}CO_2$ relationship. The following criteria were used to determine when subjects reached $\dot{V}O_2$max: RPE of 19 or 20, heart rate within ±10 $b \cdot min^{-1}$ of age-predicted maximal heart rate (220 − age), and a respiratory exchange ratio of at least 1.00.

Body Composition. The Bod Pod was used to estimate the percentage of body fat. The Bod Pod is a recently developed device based on the plethysmographic measurement of body volume using air displacement. As a subject is seated inside the fiber glass chamber of the Bod Pod, body volume is derived using the relationship among air pressure, temperature, and volume. The test consists of a 45-second measurement of body volume wherein the subject just sits quietly in the fiberglass chamber, followed by a second test wherein the subject's thoracic lung volume is measured through standard spirometry. Measured body mass and the derived body volume together permit a calculation of body density and subsequent estimation of the percentage of body fat and fat-free mass (4). The percentage of body fat was estimated according to the method of Siri (26).

Strength. Strength was evaluated by using 1RM on leg extension, leg curl, leg press, bench press, compound row, biceps curl, triceps extension, and torso arm (anterior lateral pull-down). The 1RM was defined as the greatest weight that could be lifted in a single concentric contraction with proper lifting technique. The 1RM protocol involved a series of single lifts with progressively heavier loads until the subject could not complete a repetition through the full range of motion. Subsequent trials were performed with lighter loads until the 1RM was determined within ±1.1 kg. One hundred twenty seconds of rest was provided between trials. The same order of 1RM testing was used during the pretraining and posttraining tests (6, 11, 14, 15). Although we did not perform reliability testing of the 1RM test protocol, similar protocols have been previously shown to be highly reliable (6, 14).

Training Procedures

Following testing, subjects were randomly allocated to 2 groups: the SS protocol (10-second concentric and 5-second eccentric contraction sequence) or the TR protocol (2-second concentric and 4-second eccentric contraction sequence). During the training, all subjects were instructed to continue their normal daily activities and maintain current dietary habits. Subjects were informed not to perform *any* aerobic or additional weight training throughout the study.

All subjects trained 3 days per week on alternating days with the following exercises: leg press, leg curl, leg extension, torso arm (anterior lateral pull-down), bench press, compound row (seated row), biceps curl, and triceps extension. Subjects were taught proper breathing technique to avoid the Valsalva maneuver during lifting. They were also taught proper form for each exercise during the week of introduction (3, 20).

Both groups performed each exercise with one set of 8–12 repetitions to muscular fatigue. The TR group began each exercise using 80% of 1RM until muscular fatigue was reached. The SS group used approximately 50% of 1RM. It is recommended that for the SS group the weight is reduced about 30% from what is normally used; however, the resistance must be increased gradually until 60–100 seconds of work per set is performed with good form. Subjects had their own progress charts, which tracked date, exercises, settings, weight, and repetitions. The weight was increased in 5% increments with the exception of leg press, which was increased in increments of 2.5%, when the maximum recommended repetitions could be completed with good form. Each exercise was separated by a 60- to 90-second period. A stopwatch was used to monitor this and repetition time.

Statistical Analyses

Because we could find no scientific information on possible differences between TR and SS resistance training programs, it was not possible to conduct a power calculation to determine the number of subjects required. However, expecting a 25% increase in strength with training would require 4 subjects or fewer per group to detect a significant increase in strength, with training at a power of 0.8 and a significance of $p < 0.05$.

Table 1. Descriptive characteristics of subjects (mean ± *SD*).

Variables	Total ($n = 14$)	Superslow protocol group ($n = 6$)	Traditional protocol group ($n = 8$)
Age (y)	32.8 ± 8.9	32.2 ± 9.4	33.4 ± 8.5
Height (cm)	161.7 ± 7.6	158.7 ± 8.1	164.8 ± 7.1
Weight (kg)	67.9 ± 11.5	70.5 ± 12.1	65.5 ± 11.1
Body mass index (kg/m^2)	25.8 ± 4.1	27.9 ± 3.3	24.2 ± 4.0
Body fat (%)	35.8 ± 5.5	38.2 ± 3.5	34.1 ± 6.2

Means and *SDs* were calculated for each of the variables. Analysis of variance with repeated measures was used to determine mean differences between groups and pretraining and posttraining within-group differences. An analysis of covariance was also conducted, controlling for body weight. Significance was set at $p \leq 0.05$.

Results

Descriptive characteristics of the subjects are shown in Table 1. There were no statistically significant differences between groups. Mean and *SD* values for the 8 exercises tested for 1RM, body composition, and BMI for both SS and TR groups appear in Table 2. Both groups demonstrated a significant training effect for all 8 exercises. However, a group-by-training interaction ($p < 0.05$) showed that the TR group improved significantly more than the SS group in total exercise weight lifted, leg press, leg curl, leg extension, torso arm, and bench press exercises ($p < 0.05$). Neither group exhibited any changes in body composition.

The cardiopulmonary results are presented in Table 3. There was a significant training effect ($p < 0.05$) for both groups for total exercise time on the cycle ergometer and maximal work rate achieved, but there were no group or interaction effects. There were no other significant differences in the remaining cardiopulmonary variables between the 2 groups either before or after testing. The results of the analysis of covariance did not alter our findings for any of the analyses conducted. Thus, the significant findings were seen in the absence of changes in percentage of body fat, BMI, lean body mass, and body weight.

Discussion

The main findings of this study clearly indicate that TR low-volume strength training is superior to that of SS strength training for improving 1RM strength during the initial phase of strength training in sedentary women. The TR protocol resulted in significantly

Table 2. Mean ± *SD* values for weight training exercises, body composition measurements, and body mass index.

Variables	Superslow protocol ($n = 6$) Pretest	Superslow protocol ($n = 6$) Posttest	Traditional protocol ($n = 8$) Pretest	Traditional protocol ($n = 8$) Posttest
Total weight (kg)*	432.3 ± 73.9	498.1 ± 78.0†	394.0 ± 86.0	546.4 ± 93.4†
Leg press (kg)*	135.3 ± 27.0	144.9 ± 34.2†	119.9 ± 32.4	160.0 ± 53.0†
Leg curl (kg)*	31.7 ± 6.4	36.6 ± 5.9†	28.7 ± 5.2	40.2 ± 4.2†
Leg extension (kg)*	56.7 ± 15.6	70.3 ± 6.6†	52.8 ± 13.2	82.8 ± 8.4†
Torso arm (kg)*	50.6 ± 9.6	56.5 ± 10.8†	48.4 ± 11.5	61.2 ± 9.7†
Bench press (kg)*	36.6 ± 7.7	40.6 ± 8.1†	34.6 ± 7.9	46.3 ± 9.9†
Compound row (kg)	52.9 ± 7.5	63.7 ± 12.3†	48.7 ± 10.8	60.6 ± 10.4†
Triceps extension (kg)	45.9 ± 9.1	59.7 ± 11.5†	40.6 ± 12.2	59.1 ± 8.6†
Biceps curl (kg)	22.5 ± 4.9	25.7 ± 5.1†	20.2 ± 5.7	27.1 ± 6.1†
Body weight (kg)	70.5 ± 12.0	70.1 ± 13.4	65.5 ± 11.1	65.8 ± 11.5
Body fat (%)	38.2 ± 3.5	37.5 ± 4.0	34.1 ± 6.2	33.2 ± 5.7
Fat weight (kg)	27.4 ± 6.0	26.7 ± 8.0	22.7 ± 7.1	22.2 ± 6.8
Lean weight (%)	61.8 ± 3.5	62.5 ± 4.0	65.9 ± 6.2	66.8 ± 5.7
Lean weight (kg)	43.4 ± 6.4	43.1 ± 6.0	43.0 ± 5.6	43.5 ± 6.1
Body mass index (kg/m^2)	27.9 ± 3.3	27.8 ± 3.9	24.2 ± 4.0	24.2 ± 4.0

* Group-by-training interaction ($p < 0.05$); the TR group improved significantly more than the SS group.
† Significant change from pretest data ($p < 0.05$).

Table 3. Mean ± *SD* values for cardiopulmonary measures.

Variables	Superslow protocol ($n = 6$) Pretest	Superslow protocol ($n = 6$) Posttest	Traditional protocol ($n = 8$) Pretest	Traditional protocol ($n = 8$) Posttest
$\mathrm{VO_2}$(L·min^{-1})	1.78 ± 0.38	1.76 ± 0.36	1.82 ± 0.43	1.87 ± 0.42
$\mathrm{VO_2}$(ml·kg^{-1}·min^{-1})	24.5 ± 4.4	25.5 ± 4.7	28.3 ± 7.6	29.0 ± 7.0
Peak heart rate (b·min^{-1})	177.7 ± 9.3	172.3 ± 17.2	174.6 ± 18.8	178.5 ± 12.3
Peak rating of perceived exertion	18.3 ± 1.0	19.0 ± 1.1	17.6 ± 2.4	18.4 ± 2.2
Peak respiratory quotient	1.15 ± 0.11	1.19 ± 0.08	1.18 ± 0.11	1.21 ± 0.06
Peak expired volume per unit time	90.7 ± 18.3	85.3 ± 7.6	92.9 ± 20.7	89.9 ± 21.6
Exercise time (min)	8.0 ± 2.3	8.8 ± 2.4*	8.4 ± 1.6	8.9 ± 2.3*
Work rate (W)	123.3 ± 30.1	150.0 ± 33.5*	130.0 ± 30.2	145.0 ± 42.4*
Anaerobic threshold (%)	71.0 ± 6.4	73.2 ± 12.0	66.6 ± 17.9	71.7 ± 15.0
Anaerobic threshold (L·min^{-1})	1.27 ± 0.20	1.27 ± 0.20	1.20 ± 0.40	1.30 ± 0.30

* Significant change from pretest data ($p < 0.05$).

greater improvements in strength than the SS group for the leg press, leg curl, leg extension, torso arm, and bench press exercises ($p < 0.05$). Thus, the posttraining total exercise weight was also significantly greater in the TR group. Although the SS strength training group significantly improved strength in all 8 exercises as well, the TR protocol was far more effective and favorable for improving strength in sedentary individuals. Interestingly, these changes occurred in the absence of changes in percentage of body fat, BMI, lean body mass, and body weight. The TR protocol may also be more appealing because it takes less time to complete a workout and is less difficult.

Very little research has been conducted on SS strength training. Some work has been described in nonpeer-reviewed lay publications. For instance, Westcott (21) performed a study that compared TR to SS strength training. Seventy-four participants performed one set of 13 Nautilus exercises 3 days per week for 8 weeks. The SS group had slightly greater strength gains than the TR group (12.3 vs. 10 kg, respectively). However, these findings were not statistically significant, and the study has not been subject to peer review. As such, this article (21) provides no research support for the proposition that SS training is better than TR resistance training.

Hurley et al. (12) studied untrained males for 16 weeks of high-intensity, variable-resistance, Nautilus strength training. Two-second concentric and 4-second eccentric contractions were performed for each of 8–12 repetitions during one set on each of 14 exercises performed 3 to 4 times per week. Rest between sets was minimal, because subjects were encouraged to move as quickly as possible to the next machine. Muscular strength increased markedly in the training group, as evidenced by a 44% average increase in 1RM in the various exercises (12). Gettman et al. (8) and Hickson et al. (10) have reported similar findings, and the results of our study are consistent with this previous research.

Strength increases without body composition changes suggest that the adaptations were predominantly neural. However, one must be cautious in this interpretation because the measure of muscle hypertrophy may not have been sufficiently sensitive to detect changes that may have been evident with technologies such as magnetic resonance imaging or muscle fiber analysis. Enoka (5) suggested that an important neural component may explain at least some of the strength gains that result from resistance training, and it can be argued that strength gains can be achieved without structural changes in muscle but not without neural adaptations (5, 23). Thus, early gains in strength appear to be more influenced by neural factors, but later long-term gains are almost solely the result of hypertrophy. This may explain why we found strength gains in all exercises, without a change in body composition. However, Staron et al. (18) have shown that muscle adaptations occur as soon as 2–4 weeks after initiation of heavy resistance training, but without measurable changes in anthropometric variables. This may partly be due to a change in percentage of muscle fiber type, from type IIb to type IIa (18). It is also possible that the muscle fiber changes were due to a greater training volume in the study of Staron et al. (18), since they used 2 warm-up sets followed by 3 sets to exhaustion of 6–12 repetitions. This training volume was considerably greater than the training volume of 1 set of 8–12 repetitions used in our study.

Strength training typically has not been regarded as an effective means of increasing maximal oxygen uptake. Many programs emphasize the use of heavy weights, few repetitions, and long rest periods between sets and exercises. Thus, most research has shown either no increase in maximal oxygen uptake or only mild-to-moderate, usually nonsignificant, improvements (10, 12). The relative ineffectiveness of strength training on improving cardiovascular fitness may be attributable to several factors, such as the relatively low level of oxygen uptake required during strength exercises and the duration of rest intervals (19).

Hutchins (13) claims that SS weight training is more effective than TR weight training for improving $\dot{V}O_2$max, supposedly due to a greater muscle involvement and increased time of contraction, thereby using greater degrees of both aerobic and anaerobic energy pathways. Consequently, Hutchins claims that SS is considered more of a steady-state exercise and, therefore, more aerobic than that of the traditional steady-state definition (13). However, there is no research to justify this claim, and moving more slowly does not necessarily produce greater muscle involvement, nor is the time involved in a single set enough to produce steady-state metabolism.

Based on our data (Table 3), we do not support the position of Hutchins (13). Aerobic capacity did not improve, either in relative or absolute terms, following 10 weeks of strength training for either protocol. Additionally, the ventilatory threshold was unchanged in both groups. Thus, we found no improvement in any variables reflective of aerobic capacity as a result of resistance training. However, exercise time (in seconds) to exhaustion and maximal work rate improved significantly in both groups, but there were no between-group differences nor was there a group-by-training interaction for these 2 variables. Our data are similar to those of Hickson et al. (10) that show that strength training alone can improve short-term endurance without a concomitant increase in aerobic capacity.

The characteristics of the study population may influence the results of strength training programs. For example, several studies examining the elderly population have shown improvement in aerobic capacity following a strength training program. Briefly, Frontera et al. (7) and Hepple et al. (9) found improvements in $\dot{V}O_2$max following 9 and 12 weeks of high-intensity (at approximately 80% of 1RM) strength training, respectively. Frontera et al. (7) also reported substantial gains in strength, mean fiber area, and citrate synthase activity. Additionally, both research groups (7, 9) found significant increases in capillaries per fiber in the vastus lateralis. These data suggest that the increase in aerobic capacity in older individuals may be due to adaptations in oxidative capacity and increased muscle mass of strength-trained muscles (9). However, similar findings are typically not seen in younger populations, unless the strength training is conducted as circuit weight training (7). Since we did not use a circuit weight training approach, our findings are consistent with a number of previous studies in similar populations.

There are numerous potential confounding factors that may have a bearing on the interpretation of these findings and deserve further discussion. Self-motivation may influence exercise time. A few subjects may have terminated their exercise before fatiguing the muscle, despite close supervision. However, we tried to prevent this by using words of encouragement and cheering for the subjects. Additionally, they were instructed not to change their current diet or to participate in any additional exercise throughout the study. However, it is unlikely that the subjects exercised outside our sessions based on self-reports and our results. It is possible that these sedentary subjects did increase caloric intake or change eating habits in some way, since body composition did not change even with initiation of an exercise program.

Regardless, it appears that SS strength training is no better at enhancing strength development than TR strength training. In fact, we found that TR strength training is more effective at improving strength in many of the exercises in the absence of changes in percentage of body fat, BMI, lean body mass, and body weight. In addition, strength training alone has no significant effect on aerobic capacity, but our study suggests that it is capable of improving short-term endurance.

Practical Applications

The results of the present investigation have practical applications when recommending resistance training to sedentary individuals to improve strength and endurance. Our current study implies that the TR protocol of one set to fatigue will significantly improve strength during a 10-week period. Although SS strength training does improve strength, the TR protocol produces greater improvements, is less time consuming, and will most likely lead to better exercise adherence. However, further research is required. Until such time, we recommend the TR protocol to produce greater improvements in strength and endurance. Additionally, since strength training alone does not appear to improve aerobic capacity, some form of aerobic activity would be beneficial.

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