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Comparison of Metabolic and Heart Rate Responses to Super Slow Vs. Traditional Resistance Training

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ABSTRACT

In order to compare the cardiovascular and energy expenditure demands of ''Super Slow'' (SST) and traditional (TT) resistance training 7 resistance-trained young men (24.3 ± 3.8 years) had energy expenditure (using indirect calorimetry) and heart rate evaluated during and for 15 minutes after a workout on separate days. Blood lactate levels were also evaluated before and after each intervention. Resting energy expenditure was evaluated in a fasted state using a ventilated canopy prior to any exercise stimulus and 21 to 22 hours after the SST and TT. $\dot{V}O_2$ and average heart rate were both significantly higher during the TT than during the SST. The net $\dot{V}O_2$ was also significantly higher during the 15 minutes recovery; however, average heart rate was not significantly different between the 2 groups. Total net energy expenditure from oxidative processes was 45% higher for the TT intervention (TT = 155 ± 28 kcal, and SST = 107 ± 20 kcal). The significant postexercise lactate difference was almost 2 times greater following the TT than after the SST (TT = 7.9 ± 1.7 $mmol{\cdot}L^{-1}{\cdot}min^{-1}$, and SST = 4.0 ± 2.0 $mmol{\cdot}L^{-1}{\cdot}min^{-1}$). Finally, adding the estimated energy expenditure of the blood lactate to the net energy expenditure from the $\dot{V}O_2$ produced a significant difference that is over 48% greater for the TT intervention (TT = 172 ± 29 $kcal{\cdot}min^{-1}$, and SST = 116 ± 22 $kcal{\cdot}min^{-1}$). No significant repeated measures analysis main effect was found for either resting energy expenditure or respiratory exchange ratio. The metabolic and cardiovascular stimuli were low with SST. Traditional resistance training increases energy expenditure more than SST does and thus may be more beneficial for body weight control.

Key Words: energy expenditure, strength training, lactate

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Introduction

Recently there has been a great deal of interest in the popular press concerning ''Super Slow'' resistance training (SST). With this form of resistance training all muscle actions are done in a very slow and deliberate manner. As recommended by Ken Hutchins in his book *Super Slow* (12), 10 seconds are taken to complete concentric muscle actions and 5 seconds to complete eccentric muscle actions. The proposed advantages of this type of training are many and include increases in strength and muscle size and loss of body fat (12). We are aware of few studies in the scientific literature that have evaluated SST. Keeler et al. (14) report that 10 weeks of traditional resistance training (TT) produced greater strength gains in the leg press, leg curl, leg extension, pull-down, and bench press than did 10 weeks of SST. Westcott et al. (19) compared SST with Nautilus controlled speed training (2 seconds concentric and 4 seconds eccentric) and reported a greater increase in 5 and 10 repetitions maximum (10RM) weight lifted following 10 weeks of resistance training. It is difficult to compare the 2 training studies because Westcott controlled speed in both training protocols and did not measure strength with 1 repetition maximum (1RM) testing.

To our knowledge no studies have evaluated the energy cost of SST despite claims that this type of exercise may be superior to both aerobic and traditional training for maintenance of body weight. The research that has been done concerning the energy cost of resistance training suggests that the energy expenditure is affected both by the absolute amount of work performed and the relative exercise intensity or percent of 1RM used in the exercise (7, 8, 13). A number of studies have reported increases in resting energy expenditure following a training regimen of sufficient intensity, volume, and duration to create muscle hypertrophy (11, 16, 18). Little is known concerning the acute effects of 1 bout of resistance training on resting energy expenditure; however, Melby et al. (15) reported that resting energy expenditure was increased over 9% the morning following a high-volume, high-intensity resistance-training session. Since both volume and intensity of work are likely to be low with SST training, it seems likely that energy expenditure may not be elevated as much during and following training as with a more traditional resistance-training session. Research is needed to measure the impact of SST on energy expenditure. Therefore the purpose of this study was to compare the increase in energy expenditure both during and 22 hours following either SST or TT.

Methods

Subjects

Seven male resistance-trained subjects participated in this study. All subjects were healthy, and free of any metabolic disorders and did not take medications that might affect energy expenditure. All subjects were nonsmokers and were weight-stable (defined as within 1% body weight during the previous 4 weeks). Subjects were all recreational resistance trainers using a combination of free weights and machines. All subjects had been resistance training at least 1 year and had been using a traditional program (2–3 sets of 8–10 repetitions with 65–70% 1RM). Institutional review board–approved informed consent was obtained before involvement in the study, in compliance with the Department of Health and Human Services regulations for the protection of human subjects.

Experimental Approach to the Problem

This study was designed to determine what effects SST and TT have on energy expenditure during, immediately following, and 22 hours after 1 bout of exercise. Exercise protocol for the SST was designed so that all the major muscle groups were exercised according to the recommendations of Hutchins (12), i.e., one set of 8 repetitions with 10 seconds concentric and 5 seconds eccentric muscle actions. The TT exercise protocol used exercises identical to those of the SST and was designed to take the same amount of time (29 minutes) required for the SST exercise protocol. Therefore, the TT exercise protocol consisted of 10 exercises, each consisting of 2 sets of 8 repetitions. Gas was collected in meteorological balloons and analyzed for percent oxygen, percent carbon dioxide, and volume using a Beckman OM-11, a Beckman LB-2, and a Tissot gasometer. A Delta Trac II Plexiglas canopy system was used to measure resting energy expenditure. A Vantage heart rate monitor and a YSI lactate analyzer were used to measure blood lactate. All instruments have been shown to be reliable (8, 11). Following 2 days of abstinence from exercise, subjects had resting energy expenditure measured in the morning after an overnight fast. One repetition maximum was measured for the following exercises later that morning: leg extension, bench press, biceps curl, leg curl, french curl, bent row, reverse curl, military press, upright row, and squat. Subjects were randomly assigned to treatment order, either SST followed by TT or TT followed by SST. Five to six days following the 1RM test, subjects underwent one of the 2 interventions, either SST or TT, between 9 and 11 AM in the morning. Three days following the first intervention, the subjects underwent the other intervention at the same time of day as the first intervention. In the morning following each intervention, resting energy expenditure was evaluated at 7 AM after an overnight fast.

Resting Energy Expenditure

Resting energy expenditure (REE) was measured between 7 and 8 AM after a 12-hours overnight fast. Subjects were not allowed to sleep, and measurements were made in a quiet, softly lit, well-ventilated room. Temperature was maintained between 22 and 24° C. Measurements were made with subject supine on a comfortable bed, head enclosed in a Plexiglas canopy. After a 15-minutes rest, REE was measured for 30 minutes with a computerized, open-circuit, indirect calorimetry system with a ventilated canopy (Delta Trac II, Sensor Medics, Yorba Linda, CA). The last 20 minutes of measurement were used for analysis. $\dot{V}O_2$ and carbon dioxide production were measured continuously, and values were measured at 1-minute intervals. Energy expenditure and respiratory exchange ratio were calculated from the $\dot{V}O_2$ and carbon dioxide production data.

1RM Test

All subjects were experienced in resistance training, so familiarization sessions were not necessary. Riding a bicycle ergometer for 5 minutes at 50 W served as a general warm-up. Subjects did a specific warm-up for each 1RM test by performing 5 repetitions with a weight they could normally lift 10 times. Using procedures we have previously reported (8, 13) the weight was gradually increased until failure occurred in each of the exercises tested (leg extension, bench press, biceps curl, leg curl, french curl, bent row, reverse curl, military press, upright row, and squat). The largest weight lifted was considered the 1RM. Depending on the type of 1RM test, the test-retest reliability in our laboratory for 1RM testing varies from 0.95 to 0.99 for intraclass correlation coefficients, with standard error of measurements varying from 1.5 to 4 kg for samples that have standard deviations that vary from 9 to 22 kg (8, 13, 17).

Pilot Work to Determine Resistance of SST

Two to three days following the 1RM test, preliminary exercise trials were done to determine what resistance to use while performing the 8 repetitions during the SST intervention. This was done by trial and error, first starting with 25% and then after a 5-minute rest increasing the resistance 2–5%, depending on the ease of the 25% trial. All the subjects could perform 8 repetitions with at least 25% of 1RM in the slow cadence (10 seconds concentric and 5 seconds eccentric) for all exercises. However, none of the subjects could com-

Table 1. Exercise interventions.

Exercise order for both exercise interventions: Leg extension, bench press, biceps, curl, leg curl, french curl, bent row, reverse curl, military press, upright row, squat.
Super Slow training: Eight repetitions with 25% 1 repetition maximum (1RM). Ten seconds concentric and 5 s eccentric for each repetition. Sixty seconds rest between sets. Total of 29 min between the beginning of first set and end of last set.
Traditional training: Two sets of 8 repetitions with 65% 1RM. Approximately 1 s concentric and 1 s eccentric for each repetition. Cadence between each set was controlled so that each set took 30 s. Sixty seconds rest between sets. Total of 29 min between the beginning of first set and end of last set.

plete 8 repetitions with more than 30% of 1RM with any exercise. The average maximal percentage that subjects could do at least 8 repetitions was 28%. Since all subjects could do at least 25% in the SST regimen, 25% 1RM was selected for this intervention.

Exercise Interventions

Prior to each resistance-training intervention, subjects rode a bicycle ergometer at 50 W for 5 minutes. Lifting began after a 1-minute rest. In both the SST and TT interventions exercise order was leg extension, bench press, biceps curl, leg curl, french curl, bent row, reverse curl, military press, upright row, and squat. Table 1 outlines the exercise interventions. Heart rate and $\dot{V}O_2$ were measured throughout the resistance-training interventions and for 15 minutes following the exercise. Blood lactate was sampled prior to exercise and 4.5 minutes following the interventions.

SST

Based on pilot work SST was performed with a weight that was 25% of 1RM. Eight repetitions with a 10 seconds concentric and a 5 seconds eccentric contraction were done for each of the 10 exercises. According to recommendations of Hutchins (12), 1 minute of seated rest was provided between all sets. The total time from the beginning of the first set to the end of the last set of SST was 29 minutes.

TT

Two sets of TT (no restriction on time of concentric or eccentric contractions) were performed with 65% of 1RM. The cadence between repetitions was controlled so that each set took 30 seconds. Although the velocity of the muscle actions varied slightly between subjects and even between repetitions for the same subject, the average time for concentric muscle actions was approximately 0.9 seconds, and the average time for eccentric muscle actions was about 0.8 seconds. One-minute rest was provided between sets. The total time from the beginning of the first set to the end of the last set of TT was 29 minutes.

Measurement of Work $\dot{V}O_2$ and Heart Rate

Minute-by-minute $\dot{V}O_2$ was measured during both interventions and for 15 minutes following the exercise using methods we have previously reported (7, 11). In brief, expired gases were collected in meteorological balloons over 1-minute durations. Bags were analyzed for percent oxygen and carbon dioxide on Beckman OM-11 and Beckman LB-2 gas analyzers, respectively. Volume of gas was determined in a Tissot Gasometer. Analyzers were calibrated prior to each test using Micro Scholander apparatus. Heart rate was measured continuously and recorded each minute using a Vantage Heart Rate Monitor.

Blood Sampling and Lactate Analysis

A volume of 100 μl of arterialized capillary blood was drawn from the fingertip immediately after exercise. Subsamples of 25 μl were analyzed for lactate using a YSI 23L lactate analyzer (Yellow Springs Instrument Co., Inc., Yellow Springs, OH). Duplicate subsamples were analyzed before and after exercise. A third subsample was analyzed if duplicate samples varied more than 0.1 $mmol\cdot L^{-1}$. Reported values are averages of the duplicate values that were within 0.1 $mmol\cdot L^{-1}$.

Net $\dot{V}O_2$ and Energy Cost of Exercise

Net $\dot{V}O_2$ was determined by subtracting resting $\dot{V}O_2$ from total $\dot{V}O_2$ consumed during work and recovery. The energy equivalent of 1 L of oxygen was assumed to be 5 kcal, so net energy expended from oxidative processes was calculated by multiplying net $\dot{V}O_2$ by 5 (8). Gladden and Welch (6) have published data that suggest that the slope of the relationship between exercise and increased blood lactate is 5.3 ml $O_2\cdot kg^{-1}\cdot mmol^{-1}$ $lactate\cdot L^{-1}$ blood. Using this relationship, the energy equivalent of increased blood lactate can be estimated to be 0.02698 $kcal\cdot kg^{-1}$ for each millimole increase of blood lactate following exercise. Total energy expenditure cost of the resistance exercise interventions was estimated by adding the energy cost of oxidative processes to the energy cost of increases in blood lactate (energy from lactate [kcal] = [amount of lactate (mmol)/blood volume (L)]·0.02698·body weight [kg]).

Statistical Analyses

One-way analysis of variance with repeated measures was used to determine differences between resting energy expenditure and resting respiratory exchange ratio. Two-way analysis of variance with repeated measures on both factors (Time—work vs. recovery and Mode—traditional vs. Super Slow) was used to evaluate heart rate and $\dot{V}O_2$ during work and recovery.

Table 2. Descriptive statistics for 7 resistance-trained Caucasian men.

Age (y)	24.3 ± 3.8
Body mass (kg)	79.3 ± 7.5
Height (cm)	179.3 ± 6.0
1RM* leg extension (kg)	85 ± 11
1RM bench press (kg)	117 ± 22
1RM arm curl (kg)	53 ± 9
1RM leg curl (kg)	44 ± 8
1RM french curl (kg)	50 ± 17
1RM bent row (kg)	79 ± 17
1RM reverse curl (kg)	41 ± 14
1RM military press (kg)	68 ± 14
1RM upright row (kg)	57 ± 10
1RM squat (kg)	144 ± 36

* 1RM = repetition maximum.

Paired *t*-tests were used to determine differences between net energy expenditure and postexercise lactate. Alpha was set at 0.05 in all tests.

Results

Subject descriptive characteristics are contained in Table 2. Table 3 contains the heart rate and net $\dot{V}O_2$ results during exercise and recovery. Repeated measures analysis of variance for net $\dot{V}O_2$ indicated a significant main effect for Mode, indicating TT was higher than SST (14.7 L higher during exercise and 8.0 L higher during recovery). Repeated measures analysis of variance for heart rate also indicated a significant main effect for Mode, indicating TT was higher than SST (24 b·min^{-1} higher during exercise and 18 b·min^{-1} higher during recovery). Table 4 contains the blood lactate and net exercise energy expenditure results. The significant postexercise lactate was almost 2 times greater following the TT intervention than following the SST intervention (7.9 vs. 4.0 mmol·L^{-1} blood). Finally, adding the estimated energy expenditure of the blood lactate to the net energy expenditure from the $\dot{V}O_2$ produced a significant difference that is over 48% greater for the TT intervention (172 vs. 116 kcal). No significant repeated measures analysis of variance differences were found for either resting energy expenditure or respiratory exchange ratio (Table 5). Power for accepting the null hypothesis is low ($p = 0.19$ for $n = 7$ and moderate effect size). However, when one examines the effect size difference of −0.33 for the SST resting energy expenditure, it is very unlikely the SST condition would result in a large enough positive effect size to show increased resting energy expenditure even with addition of 3 or 4 times as many subjects. In other words, the trends in this data (i.e., mean resting energy expenditure after the SST *lower* than the pre-exercise value) make it highly unlikely that a small sample size is preventing the detection of an SST-induced increase in resting energy expenditure.

Discussion

Contrary to claims made by the advocates of SST, the energy expenditure for approximately 30 minutes of

Table 3. Oxygen uptake and heart rate response to 2 different resistance training regimes in 7 resistance-trained men.*

	Traditional		Super slow	
	Work	Recovery	Work	Recovery
Heart rate (b·min^{-1})†‡	143 ± 8	119 ± 12	113 ± 12	95 ± 11
Net oxygen uptake (L)†‡§	22.9 ± 2.0	8.2 ± 2.0	14.7 ± 2.6	6.7 ± 1.7

* Two-way analysis of variance with repeated measures on both factors (Time—work vs. recovery and Mode—traditional vs. Super Slow).

† Significant time difference <0.01.

‡ Significant mode difference <0.01.

§ Significant time by mode interaction <0.05.

Table 4. Metabolic response to 2 different resistance training regimes in 7 resistance-trained men.

	Traditional	Super slow	Paired *t*-test probability
Net energy expenditure during work and 15 min recovery, calculated from oxygen uptake (kcal)	155 ± 28	107 ± 20	<0.01
Post exercise lactate (mmol·L^{-1}·min^{-1})	7.9 ± 1.7	4.0 ± 2.0	<0.01
Net energy expenditure during work and 15 min recovery, calculated from sum of oxygen uptake and energy equivalent of blood lactate (kcal)	172 ± 29	116 ± 22	<0.01

Table 5. Resting energy expenditure and respiratory exchange ratio data for 7 resistance-trained Caucasian men before and 22 hours after the 2 resistance training exercise interventions.*

Variable	Pre exercise	Post traditional	Post Super Slow
Resting energy expenditure (kcal)	1,822 ± 121	1,834 ± 79	1,802 ± 131
Resting respiratory exchange ratio	0.89 ± 0.02	0.88 ± 0.03	0.87 ± 0.04

* One-way repeated measures analyses of variance indicated no significant differences in resting energy expenditure or respiratory exchange ratio.

SST training was less than 120 kcal and substantially lower than that for a TT session of similar duration. In addition, resting energy expenditure was not increased 22 hours following a SST training session. Finally, the relatively low metabolic stimulus, less than what would be expected during walking at 3 miles·h^{-1} and low exercise heart rate make it unlikely that the training stimulus would be sufficient to improve aerobic fitness. These data suggest that if the training goal is to expend energy as a means of body weight loss or weight maintenance, other forms of exercise would be more productive.

The energy expended during the TT intervention was similar to what would be expected based on previous research (3, 7, 8, 13). It is not surprising that the energy expenditure during SST was lower than in the TT intervention. Both total work and relative exercise intensity influence energy expenditure during exercise (7, 13). The exercise intensity of the TT was 2.6 times greater than that of the SST intervention. Based on our previous research this would be expected to cause a 25–100% greater energy expenditure for equivalent work outputs at the higher intensity (7, 9). In addition, over 4 times more work was done during the TT intervention as with the SST intervention. However, the TT intervention had energy expenditure that was only 48% larger than that of the SST intervention. The SST intervention was done at a very slow velocity of contraction (10 seconds concentric and 5 seconds eccentric), one that had similarities to isometric muscle actions. So the metabolic cost of the SST probably had an added isometric component. Although isometric muscle actions require relatively small amounts of energy, the addition of an isometric component would increase the energy cost of this exercise above what would be expected from the amount of mechanical work completed.

No significant increase in resting energy expenditure was found with either intervention. The mean resting energy expenditure following the SST was actually lower than the pre-exercise resting energy expenditure, suggesting very strongly that 1 SST session, as recommended by the SST advocates (12), has no effects on energy expenditure. We have previously reported increases in resting energy following 16 weeks (18) and 25 weeks (11) of resistance training. The first study, in which resting energy expenditure was measured approximately 40 hours after the last bout of resistance training, found a relatively large increase in energy expenditure despite relatively small increases in muscle mass. The second study, which had resting energy expenditure measured approximately 95 hours after the last bout of resistance training, found a smaller increase in resting energy expenditure despite a much larger increase in fat-free mass. Taken together, the results of these 2 studies can be interpreted to suggest that there may have been an acute effect of a resistance-training bout that was still present at approximately 40 hours but dissipated by 95 hours. Consistent with the concept of an acute increase in resting energy expenditure following a bout of resistance training, Melby et al. (15) showed resting energy expenditure was elevated almost 10% approximately 17 hours following a very high intensity, high-volume resistance-training program. It appears that neither training stimulus in this study was sufficient to increase resting energy expenditure approximately 22 hours after the resistance-training stimulus. The studies of both Treuth et al. (18) and Hunter et al. (11) were performed with older, untrained subjects, whereas the training volume in the study of Melby et al. (15) was markedly greater (a total of 60 sets for 10 exercises). The subjects in this study were young and relatively fit. All subjects trained regularly with weights. It is possible the relatively low volume training stimulus was not great enough in either protocol for an acute increase in resting energy expenditure to occur in trained subjects. Relatively low blood lactate values are supportive of a relatively low training stimulus in these trained subjects. Although the blood lactate levels were much greater for the TT condition than for the SST condition (7.9 ± 1.7 vs. 4.0 ± 2.0 mmol·L^{-1}), indicating greater metabolic stress for the TT condition, the relative metabolic stress for even the TT condition may have been moderate compared with some high-intensity training programs. For example, Bush et al. (1, 2) have consistently reported blood lactate values in excess of 14 mmol·L^{-1} following relatively high volume resistance training. It is likely that neither exercise condition in this study was of sufficient volume to elicit an increase in resting energy expenditure in trained subjects.

Of course, this study cannot address the potential for SST increasing resting energy expenditure mediated by muscle hypertrophy. Studies that have measured increases in both fat-free mass (FFM) and resting energy expenditure suggest that the resting energy expenditure will be increased by 10–20 kcal·day^{-1} for each pound resistance training increases FFM (11, 16, 18). We are aware of no long-term exercise studies suggesting that SST induces muscle hypertrophy. The available research suggests that the resistance must be relatively high (between 50–80% of maximum) for training-induced increases in muscle size (4, 5, 10). Few studies in the scientific literature have compared strength improvements through SST and TT. Keeler et al. (14) report that 10 weeks of TT produced greater strength gains in both the upper body and lower body, probably because the resistance needs to be very low (less than 30% of 1RM) in SST. No significant changes in FFM were reported for either group, probably because of the relatively small sample size and short duration of training (only 10 weeks). However, the SST mean for FFM actually showed a decreasing trend (43.4 to 43.1 kg), whereas the TT group showed an increasing trend (43.0 to 43.5 kg). The results of Keeler et al. (14) are certainly not supportive of an increased hypertrophy response with SST.

In conclusion, these results demonstrate that the energy expenditure during SST is very low and dramatically less than that found in TT. Resting energy expenditure is not elevated 22 hours after a bout of SST. In addition, blood lactate and heart rate responses to the SST support the premise the exercise stimulus is insufficient to produce a metabolic or cardiovascular adaptation to training.

Practical Applications

These results suggest that SST may not be optimal for either increasing energy expenditure or improving cardiovascular responses to training. For example, over 30 SST workouts would have to be undertaken to burn the equivalent of 1 pound of fat tissue (3,500 kcal in a pound of fat/116 kcal each workout = >30 training sessions). Both aerobic resistance training and TT may be more beneficial than SST for increasing energy expenditure and cardiovascular fitness.

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