Original Research

Resistance and Aerobic Training Sequence Effects on Energy Consumption in Females

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ABSTRACT

Int J Exerc Sci 3(3): 143-149, 2010. The objective of this study was to investigate the effect of sequence of resistance and aerobic training on energy consumption on sedentary overweight females. Participants were 15 sedentary overweight females (age = 28.6 ±12 yrs; BMI = 28.1±7.8) Subjects did a counterbalanced intervention: resistance training (circuit training) first (intervention RT) or aerobic exercise first (intervention AT), while oxygen consumption was continuously measured for 80 min. Subjects performed a warm-up on the treadmill at 40% of their heart rate reserve for 5 minutes, then for 30 minutes did continuous walking or jogging on the treadmill at ~67% of their predicted maximum heart rate reserve. Immediately following treadmill exercise, subjects performed 25 minutes of resistance exercises including 2 sets of 12 reps at 67% of their 1RM of each exercise. Cool down consisted of five minutes on the treadmill with a gradual decline in speed. The energy used during the AT intervention was 431.2 ± 90.9 kcals compared to the RT intervention 398.3 ± 93.9 kcals. The mean difference was significant, (p =0.003). Based on the results of this study, aerobic exercise preceding resistance training has a greater impact on total energy consumption in females versus the reverse order.

KEY WORDS: excess post exercise oxygen consumption, concurrent training

INTRODUCTION

More than 67 percent of the United States adult population is either overweight or obese, with many looking for the most convenient and time-efficient way to lose weight. Exercise is considered one of the most important tools for preventing the accumulation of body fat and preserving fat free mass (Jakicic, Marcus, Gallagher, Napolitano, & Lang, 2003; Votruba, Horvitz, & Schoeller, 2000). To help maintain fat-free tissue including muscle mass and bone density, dynamic exercise of large muscles is encouraged (Jakicic et al.; Pollock, Gaeseer, Butcher, Després, Dishman et al., 1998). Resistance training and aerobic exercise are both necessary to receive maximum health and cardiovascular benefits; however, fitness programs lasting longer than one hour per session are associated with high dropout rates (Pollock, 1988; Price, Pollock, Gettman, & Dent, 1977). Perhaps, the reason it is becoming increasingly popular to combine resistance training and aerobic training in the same workout may be to reduce the time commitment and achieve several goals; however, there are few studies conducted on the effects of the sequence of concurrent training (aerobically and strength) on total energy expenditure.

Exercise increases energy demands however, the balance between fat and carbohydrate utilization is dependent on intensity and duration of the exercise, and the individual's fitness level (Hansen, Shriver, & Schoeller, 2005). In addition to changes during exercise, prolonged aerobic exercise is associated with an elevated post-exercise oxygen consumption (EPOC) (Burleson, O'Byrant, & Stone,1998; Drummond, Vehrs, Schaalje, & Parcell, 2005; Gillette, Bullough, & Melby, 1994). Resistance training appears to cause a greater EPOC than steady-state aerobic training when energy expenditure is matched for the exercise bout (Burleson et al., 1998). When continuous aerobic and resistance exercise are combined, EPOC may be elevated to a greater degree than through either exercise alone (Drummond et al., 2005).

The sequence of resistance training and aerobic training may also affect the magnitude and duration of EPOC, due to the different physiological effects that resistance exercise and aerobic exercise may have on muscle function and the respiratory system. Resistance exercise performed after treadmill exercise may not be as physically limiting because increased blood flow during aerobic exercise may have less fatiguing effects on the muscles used than resistance training. According Sporer and Wenger, (2003) when aerobic exercise precedes resistance training, muscle strength impairments are limited to the muscle groups used in the aerobic training. This may be due to the fact that when strength training follows aerobic training, the volume of work for the muscles used that can be successfully completed in a strength session is compromised without sufficient recovery.

We hypothesized that an aerobic session followed by a resistance training session would increase energy consumption and EPOC more than the reverse sequence. The purpose of the current study was to investigate which sequence of resistance and aerobic exercise resulted in the greatest energy expenditure and EPOC.

METHODS

Approach to the Problem

A counterbalanced intervention was used to compare energy expenditure and substrate utilization during resistance (utilizing a circuit training method) and aerobic training, controlling for heart rate and duration. Oxygen consumption was continuously measured (Parvomedics True One, Salt Lake City, UT) to determine energy expenditure and RER.

The aim of this project was to be able to generalize to sedentary females wanting to lose weight, therefore individuals were chosen based on body fat, and low level of daily activity (less than 60 min/week) and apparent ability to complete the exercise protocol.

Subjects

The subjects were 15 females (13 Caucasian, 2 African-American) recruited by flyers posted on the university campus and chosen based on activity and body fat (Table 1). The subjects were all medically cleared by their doctor to exercise and understood experimental risks. All subjects signed a University Institutional Review Board approved informed consent form prior to participation.

Age	Height (cm)	Body Fat %	BMI	Heart Rate Reserve
28.6 ± 12.0	165.5 ± 7.6	34.9 ± 9.1	28.1 ± 7.8	118 ± 34.4

Table 1. Population characteristics (N = 15)

Anthropometrics

The subjects were instructed to drink plenty of fluids prior to participation. Food intake prior to each trial was recorded and subjects were instructed to eat the same meal prior to testing and nothing to eat within 4-h of testing. Body fat, weight, height, and BMI were assessed. To be eligible to participate in the study body fat percentage must have been ≥ 22% measured by bioelectrical impedance (Inbody 520, BioSpace Inc. CA).

Pre-testing Measurements

Prior to the testing day, the subjects were trained to take their pulse and asked to take their resting heart rate before getting out of bed to be used in determining their exercise heart rate using the Karvonen method (Karvonen, Kentala, & Mustala, 1957) and were instructed not to perform any strenuous exercise within 48-h of testing. To assess loading capabilities, a one repetition of the maximum (1RM) for 8 different exercises using Bowflex® SelectTech® dumbbells (Nautilus, Inc) including squats, bench press, step ups, bent over row, triceps extension, lunges, bicep curls, and shoulder press was conducted. Subjects were familiarized with the equipment and after warm-up were given 3-4 trials to reach their 1RM for each exercise. A 3-5-min rest was allowed between each trial.

Experimental Exercise Sessions

Subjects did a counterbalanced intervention; circuit training first (RT) or aerobic exercise first (AT), depending on random assignment (half completed RT first and half completed AT first by drawing). Oxygen consumption was continuously measured during training including warm-up and cool down periods. Circuit training involves performing strengthening exercises quickly in a sequence. Circuit training was chosen for the resistance training because it has been shown to target fat loss, improve cardiovascular fitness, and appeals to this population (Fleck & Kraemer, 1987). Heart rate was closely monitored (Polar electro Inc.) during each aerobic workout. Once connected to the metabolic cart subjects in each intervention (RT and AT) first performed a warm-up on the treadmill at 40% of heart rate reserve (HRR) for 5 minutes. Subsequent to warm-up AT group did 30-min continuous walking or jogging at ~67% HRR (heart rate was closely monitored to keep subjects between 65 and 70% HRR). Immediately following treadmill exercise, AT group performed 2 sets of 12 reps at 67% of their 1RM of the bench press, triceps extension, bicep curls, bent over row, step ups, squats, lunges, and shoulder press for 25-min with 12.5-min allowed to complete each cycle allowing approximately 1.5-min for completion of each exercise. To capture the fast component of EPOC, VO2 was also monitored continuously for 15-min after exercise ended, while the subject sat in a chair (Table 2). Subjects in each intervention reversed the sequence of aerobic and resistance training on their second visit. Each intervention was separated by a minimum of one week.

Intervention (in minutes)	0-5	5-35	35-60	60-65	65-80
Circuit Training (RT)	Warm-up	Resistance Exercise	Treadmill	Cool Down	Seated Resting
Aerobic Exercise (AT)	Warm-up	Treadmill	Resistance Exercise	Cool Down	Seated Resting

Table 2. Timeline of intervention.

Statistical Analysis

The data recorded for all dependant variables during the exercise interventions were compared using paired *t*-tests.

Statistical significance was set at $P<0.05$. All data are presented as Means ± SD.

RESULTS

Participants were continuously monitored and completed each intervention with 100% compliance. The total kcals expended during the AT intervention was 431.2 ± 90.9 kcals compared to 398.3 ± 93.9 kcals for the RT intervention. There was a mean difference of 33 kcals, between the two interventions (Figure 1, a 2 tailed t-test was performed $t_{14}=2.51$ $P<0.05$). Mean treadmill speed for AT was 101.8 ± 13.1 $m \cdot min^{-1}$ (approx. 3.8 mph) and RT was 95.4 ± 20.9 $m \cdot min^{-1}$ (Figure 2). RER during AT (0.91 ± 0.07) was not significantly different than RT (0.90 ± 0.09).

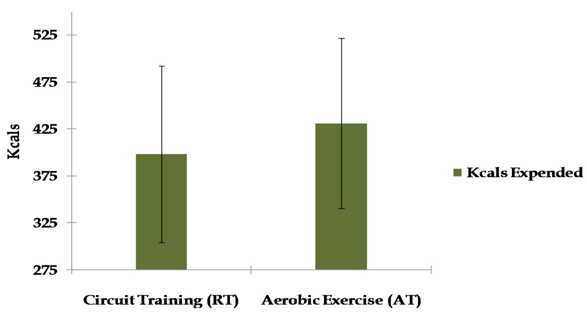

Figure 1. Total kcals expended during intervention.

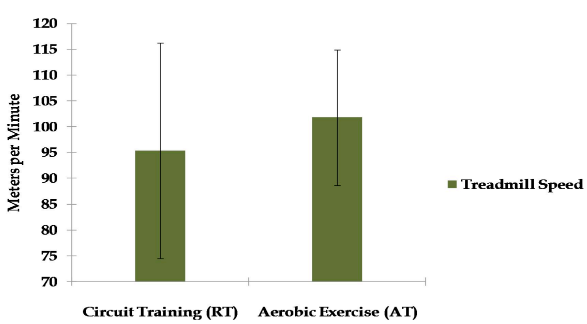

Figure 2. Treadmill speed during intervention.

DISCUSSION

The research hypothesis that aerobic training followed by and equal duration of resistance training would increase energy consumption more than the reverse sequence was supported by the data collected. The main finding and possibly the most interesting part is due to the unique design of this study. The aerobic exercise intensity based on maximum heart rate and the resistance exercise based on maximum lift capability. For the aerobic exercise first group (AT), individuals needed to increase the treadmill speed by 6.5 m · min-1 in order to comply with the parameters of the study by keeping their heart rate at the required level. This accounted for an additional 35 kcals expended in the aerobic portion of the AT exercise which was not offset by an increase in the resistance portion of the RT intervention. If aerobic exercise was preceded by resistance exercise (RT), then the treadmill speed was significantly reduced which led to a reduction in energy used for the aerobic portion of the exercise bout. Although the resistance exercise was clamped at 67% of 1RM and did not fluctuate with fatigue as the aerobic workout did, this type of method most mimics what occurs in the field when prescribing exercise for individuals that desire weight loss. This result is opposite of a previous study done by Collins and Snow (2003) which reported that the participants were able to perform at the same intensity as measured by heart rate instead of speed, for the same amount of time regardless of the sequence of resistance and aerobic training. However the current data agrees with Drummond et al. 2005 that found treadmill exercise to be more difficult when preceded by resistance exercise.

Aerobic exercise expended more kcals than resistance training during both interventions in this study (Figure 1). As expected this result agrees with prior research that aerobic exercise burns more kcals than resistance training when time and intensity are matched (Bloomer, 2005).

The kcals expended after the workout (EPOC), was relatively the same following an identical cool down in both groups. EPOC in the AT intervention was 27.8 ± 5.3 kcals versus 25.2 ± 5.8 kcals in the RT intervention. This suggests that regardless of which sequence resistance and aerobic exercise is completed, EPOC will be the same. This is in contrary to Drummond et al. 2005, who found aerobic prior to resistance training elevated EPOC to a greater degree than the opposite sequence despite similar exercise workloads between the two groups. Drummond et al. speculated that performing aerobic exercise after resistance exercise may have decreased the metabolic and muscular disturbances of resistance exercise that may have otherwise contributed to a greater EPOC. It should be noted that Drummond et al. measured EPOC for 30-min versus 15-min in the current investigation. It is speculated here that another important finding of the current study is that the treadmill cool down attenuated the metabolic effects of the resistance training.

Regarding substrate utilization during exercise the mean RER was the same for both interventions during the entire 80 minutes. Although the mean RER was the same there were differences noted during specific periods of each of the interventions. During the aerobic exercise of the AT intervention (RER = 0.91), the contribution from fat was lower than RT (RER = 0.88) indicating a higher intensity in AT; however this seemed to be offset by a higher contribution of fat during the resistance exercise in the AT (RER = 1.02) versus RT (RER = 1.05). We propose that during the resistance portion of the RT intervention there was greater anaerobic contribution due to resistance training being the initial exercise. Oxidative phosphorylation takes longer to be the prominent source of ATP therefore in the early stages of resistance training the significant contribution from lactate production offset the eventual dependence on aerobic metabolism. This is in agreement with previous studies that found that carbohydrates are the major fuel source of exercises requiring moderate to greater exercise intensities (Hansen, Shriver, & Schoeller, 2005; Kuo, Fattor, Henderson, & Brooks, 2004.

LIMITATIONS

These findings can only be generalized to overweight sedentary females. Since EPOC was measured for only 15-min there may be changes that occurred after this period that may have affected the outcome if data would have been measured for a longer period. This study used circuit training for the resistance training. The types of exercise used (treadmill and dumbbells) may limit the generalizations of the data. Other forms of exercise (bike, machines, etc) may produce different results.

PRACTICAL APPLICATIONS

The AT intervention had a greater impact on energy expenditure than the RT intervention during the 80-min of data collection. Often times, clients will determine intensity of cardiovascular exercise based on hear rate. If female adults control intensity based on their heart rate while doing cardiovascular exercise rather than doing a set speed, then doing aerobic exercise followed by resistance training may expend the most kcals. It is the responsibility of health professionals involved with female clients as well as fitness trainers and to be informed about the issue of sequencing exercises and its effect on energy consumption. Health and fitness professionals need to make recommendations and advise clients to do both strength and aerobic exercise to maintain long-term health. If the primary goal is energy use, then based on the current data, female individuals should do aerobic exercise prior to resistance training when combining the two.

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