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Weight loss and exercise training effect on oxygen uptake and heart rate response to locomotion

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Abstract

Effects of resistance and aerobic training on ease of physical activity during and following weight loss are unknown. Purpose of study is to determine what affect weight loss combined with either aerobic or resistance training has on ease of locomotion (netVO₂ and heart rate). It is hypothesized that exercise training will result in increased ease, lower heart rate during locomotion. Seventy three overweight, premenopausal women were assigned to diet and aerobic training, diet and resistance training, or diet only. Subjects were evaluated while overweight, after diet induced weight loss (average 12.5 kg loss), and one year following weight loss (5.5 kg regain). Submaximal walking, grade walking, stair climbing, and bike oxygen uptake and heart rate were measured at all time points. Weight loss diet was 800 kcal/day. Exercisers trained 3 times/wk during weight loss and 2 times/wk during one year follow-up. Resistance training increased strength and aerobic training increased maximum oxygen uptake. Net submaximal oxygen uptake was not affected by weight loss or exercise training. However, heart rate during walking, stair climbing, and bicycling was reduced following weight loss. No significant differences in reduction in heart rate were observed between the 3 treatment groups for locomotion following weight loss. However, during one-year follow-up, exercise training resulted in maintenance of lower submaximal heart rate, while non exercisers increased heart rate during locomotion. Results, suggest that moderately intense exercise is helpful in improving ease of movement following weight loss. Exercise training may be helpful in increasing participation in free living physical activity.

Keywords

Aerobic training; Resistance training; calorie restriction

INTRODUCTION

Ease during locomotion increases with weight loss (4) even in the absence of physical training. This improved ease of activity may increase free living physical activity after weight loss (7) and improve chances for weight maintenance following the weight loss (18). Exercise training also increases ease of physical activity (1, 6, 7, 9). Despite its potential importance for improving quality of life as well as affecting weight gain, little is known concerning the affects exercise training has on ease of physical activity immediately following weight loss and long term after weight loss.

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Disclosure

The authors declare no conflict of interest.

High aerobic fitness is related to lower heart rate during walking and biking, increased participation in free living physical activity (7) and less weight regain (11). Because of its effects on aerobic fitness and its relatively high energy expenditure, endurance exercise training has been the modality that has been most studied in weight loss and weight maintenance programs. Strength is also associated with increased free living energy expenditure (19), and reduced weight gain (19). In addition, resistance exercise training programs not only increase strength but increase ease of walking and bicycling and increase free living physical activity (1, 6, 9, 12).

Despite the fact that both aerobic and resistance training are beneficial for preventing weight regain following weight loss, the authors are aware of few if any studies that have compared the effects of resistance and aerobic training on ease of physical activity during and following diet induced weight loss. The purpose of this study is to make those comparisons. It is hypothesized that both aerobic and resistance training during diet induced weight loss will decrease heart rate while walking, stair climbing and biking more than diet alone. It is further hypothesized that both aerobic and resistance training will maintain reduced heart rates walking, stair climbing, and biking during the year following the weight loss while those subjects who do not exercise train will experience an increase in heart rate while walking, stair climbing, and biking.

METHODS

Experimental Approach to Problem

Seventy-three subjects were evaluated three times: 1) at baseline in the overweight state; 2) after a diet induced (800 kcal/d) diet with or without exercise designed to reduce BMI to less than 25 kg/m²; and one year following achievement of BMI of 25 kg/m². Strength and aerobic fitness as well as heart rate (HR), respiratory quotient (RQ), and oxygen uptake (VO₂) during submaximal steady state cycle ergometry, stair climbing, treadmill walk on the flat, and a 2.5% grade treadmill walk were the primary study variables. Women reported normal menses and were nonsmokers. All testing was done in the follicular phase of the menstrual cycle. Women were weight stable for one month prior to all evaluations (three weekly body weight measurements with adjustments in energy intake made when needed). Food was provided by the General Clinical Research Center Kitchen for the last 2 weeks of all three weight stable conditions and during the 800 kcal/day dietary intervention. Macronutrient content of the diet was 20–22% fat, 20–22% protein and 56–58% carbohydrate. All women were admitted to the General Clinical Research Center two days prior to evaluations so that both physical activity and food intake could be monitored at all times. Testing was done in a fasted state in the morning after spending the night in the General Clinical Research Center.

Subjects

All testing procedures and risks were fully explained, and women provided verbal and written informed consent for the protocol prior to the start of the study. The study was approved by the Institutional Review Board. All subjects were sedentary (no exercise training for the prior year), overweight (body mass index of 27–30 kg/ht²) and were randomly assigned to one of three groups: 1) Diet and aerobic training (19 subjects); 2) Diet and resistance training (26 subjects); 3) Diet and no exercise training (28 subjects). Differences in sample size between groups due to drop outs because of sickness, injury, or inability to complete weight loss program. During weight loss women assigned to exercise trained 3 times/week and during the one-yr follow-up women assigned to exercise trained 2 times/week. Subject characteristics are contained Table 1.

Procedures

Aerobic training—After a warm-up of 5 minutes of walking and 3–5 minutes stretching aerobic training entailed continuous walking/jogging on a treadmill (Quinton, Seattle WA, USA). During the first week of training, the subjects did 20 min of continuous exercise at 67% maximum heart rate. Duration and intensity increased each week so that by the beginning of the eighth week, subjects exercised continuously at 80% of maximum heart rate for 40 minutes. Subjects were encouraged to increase intensity (either speed or grade) when average exercise heart rate was consistently below 80% of maximum heart rate during both the weight loss and one-year weight maintenance phases. After the exercise session, subjects cooled down for 3–5 min with gradually decreasing exercise intensity.

Resistance training

After a warm-up on the treadmill for 5 min and 3–5 min of stretching, subjects did the following exercises: squats (Hammerstrength V squat, Life Fitness, Schiller Park, IL, USA), leg press, elbow flexion, lateral pull-down, bench press, (all Fit 5000 multistation, Paramount Fitness Line Los Angeles, CA, USA), triceps extension (Triceps Extension, Paramount Fitness Line Los Angeles, CA, USA), military press, leg curl, knee extension (all Body Solid, Forest Park, IL, USA) lower back extension, and bent leg sit-ups. After one week of familiarization training with a light weight one repetition maximum (1 RM) was measured. One set of 10 repetitions was performed at 65% 1 RM during the first week with percent of 1 RM increasing on subsequent weeks until at week four intensity was at 80% 1 RM. Starting week four two sets of 10 repetitions were attempted at 80% 1 RM for each exercise with 2 min rest between sets. Strength was evaluated every five weeks, and adjustments in training resistance were made based on the most current 1 RM in both the weight loss and one-year weight maintenance phases.

Resting oxygen uptake—Three consecutive mornings in a fasted state and after an overnight stay in the General Clinical Research Center resting oxygen uptake was determined between 6:00 and 6:50 a.m. Subjects remained awake in a quiet, softly lit, well ventilated room in which temperature was maintained between 22 and 24 degrees celsius. Subjects lay supine on a comfortable bed and oxygen uptake was measured using a ventilated hood system. After resting for 15 minutes, resting oxygen uptake was measured for 30 minutes with a computerized, open-circuit indirect calorimetry system (Delta Trac II, Sensor Medics, Yorba, CA, USA). The last 20 minutes was used for analysis. Oxygen uptake values used in the determination of exercise net VO_2 (i.e. exercise VO_2 – resting VO_2) were means of the 3 morning values. Coefficient of variation for repeat VO_2 measures is < 4% in our lab.

$\text{VO}_{2\text{max}}$ —A maximal modified Bruce protocol was used to determine $\text{VO}_{2\text{max}}$ (2). Heart rate was measured using a POLAR Vantage XL heart rate monitor (Gays Mills, WI, USA). Oxygen uptake and carbon dioxide production were measured continuously using a Sensormedics metabolic cart (Model #2900, Yoma Linda, CA, USA). Gas analyzers were calibrated with certified gases of known concentrations. Standard criteria for heart rate, respiratory exchange ratio, and plateauing were used to ensure achievement of $\text{VO}_{2\text{max}}$. All subjects achieved at least 2 criteria. Coefficient of variation for repeat measures of $\text{VO}_{2\text{max}}$ are less than 3% in our lab.

Ease and Economy of Physical Activity

Heart rate (HR), respiratory quotient (RQ), and oxygen uptake (VO_2) were obtained during submaximal steady state cycle ergometry (50 watts), stair climbing (60 steps/min up 17.8 cm steps), treadmill walk on the flat (4.8 km/hr), and a 2.5% grade treadmill walk (4.8 km/hr).

The duration of each of the tasks was between 4 and 5 minutes and steady state was obtained. Oxygen uptake and carbon dioxide production were also measured using a Sensormedics metabolic cart (Model #2900, Yoma Linda, CA, USA). See description of VO_2max for specifics. Net oxygen uptake (work steady state VO_2 minus resting VO_2) is reported in $\text{ml O}_2/\text{kg}/\text{min}$ and is considered exercise economy for walking and stair climbing. Since work was the same for all subjects during biking (50 W) bike oxygen uptake and economy is reported in l/min . Both HR and RQ increase as the intensity of exercise increases, therefore these two measures are considered to give an index of exercise difficulty. Since the tasks were performed in the steady state the RQ measure also gave an index of fuel utilization during the exercise.

Strength Measure

Using methods previously described (6), knee extension strength was measured isometrically. Forces were measured using a universal shear beam load cell (LCC 500; Omega Engineering, Stamford, CT, USA). Knee extension maximal force was measured at knee position of 110 degrees on the right leg at the level of the lateral malleolus. Subjects were restrained across the upper legs and hips with padded straps. After three warm-up trials, three maximal isometric contractions were recorded with 60 second rest between trials. Test retest reliability for this test has a coefficient of variability of $< 4\%$.

Statistics

Descriptives were examined using a one-way (group) ANOVA. A 3 (group) by 3 (time) repeated measures ANOVA was used to examine all variables of interest. Since physiological response during the 4 submaximal exercise tests was similar across the 3 time points for the two exercise training groups (no significant difference for deltas between aerobic and resistance trainers), T-test Bonferroni corrected post hoc tests were run comparing the pooled exercise subjects versus the no exercise control subjects for variables in which there was a significant time by group interaction. The aerobic and resistance exercisers were combined into one group (exercisers) so that overweight to post overweight and overweight to one year follow-up comparisons could be made. Pearson Product correlations were run between the post weight loss to one year follow-up difference for knee extension strength and VO_2max and locomotion heart rates. All statistical assumptions were met and significance was set at a P of < 0.05 .

RESULTS

There was a significant time and time by group interaction for both knee extension strength and VO_2max (for both $\text{ml}/\text{kg}/\text{min}$ and $\text{ml}/\text{kg FFM}/\text{min}$) with post hoc analysis showing that the strength group increased strength more than the other groups and the aerobic group increased VO_2max more than the other groups (Table 2). There was also a significant time and time by group interaction for HR during all four submaximal tasks (Table 3 and Table 4). Since physiological response during the 4 submaximal exercise tests was similar across the 3 time points for the two exercise training groups (no significant difference for deltas between aerobic and resistance trainers), the aerobic and resistance exercisers were combined into one group (exercisers) so that overweight to post overweight and overweight to one year follow-up comparisons could be made (Figures 1 and 2). Post hoc tests show that exercisers significantly decreased heart rate in all four tasks more than non exercise control subjects between baseline and one-year follow-up (Figure 2). Post hoc tests revealed that there was no significant differences in decrease in heart rate between exercisers and no exercise controls for any exercise tasks except bike between baseline and post weight loss (Figure 1).

There was no significant time, group, or time by group effect for the submaximal net oxygen uptakes or net energy expenditures for any of the four exercise tasks (Tables 3 and 4). There was no significant time effect for any of the 4 exercise tasks except stair climbing nor was there a time by group interaction for any task (Tables 3 and 4). However, quadratic time by group interactions were significant for the submaximal walk ($p < 0.02$) and grade walk ($p < 0.02$) while post hoc tests showed a significant decrease in RQ between overweight and post overweight state for the aerobic group submaximal walk and grade walk.

Table 5 shows correlations for changes between post overweight and one year follow-up in aerobic and strength fitness and changes in locomotion heart rate. Changes in VO₂max were consistently related to changes in locomotion heart rate but changes in strength were not.

DISCUSSION

Despite no change in exercise economy, diet induced weight loss was associated with decreased heart rate during walking, stair climbing, and grade walking. Addition of exercise training during the diet induced weight loss did little to further decrease heart rate. However, during the year following the weight loss, inclusion of either aerobic or resistance training helped to maintain the decreased heart rate obtained during weight loss. Individuals who did not exercise train during the year following weight loss did not maintain the lower heart rate during locomotion. The aerobic trainers of course had enhanced aerobic fitness and the resistance trainers had enhanced strength. Taken together these data suggest that exercise training during and following weight loss has a positive affect on fitness that translates into increased ease (decreased heart rate) during locomotion one year following weight loss. Based on previous research this increased ease should translate into more free living (separate from exercise training) physical activity (7, 8) and in turn the increased physical activity should lead to reduced weight gain (3, 4, 18).

Both aerobic and resistance training had an affect on maintaining the weight loss induced decrease in heart rate during locomotion. A number of investigations have shown that either resistance training (1,6,9) or aerobic training (10, 14, 16) are accompanied by reduced heart rate in submaximal walking and running. To our knowledge no studies have compared resistance and aerobic training effects on walking and stair climbing heart rate during and following a diet induced weight loss. Aerobic and resistance training had only minimal additional affects on heart rate response to walking and stair climbing immediately following weight loss. However, the exercise training did have a positive affect on reducing the heart rate during cycling immediately following weight loss.

During the walk, grade walk and stair climbing subjects were required to do less work following weight loss because of their reduced body mass (approximately 15% less). The no exercise group thus reduced their heart rates during these tasks, and may have masked any changes induced by the exercise training. During biking, work did not decrease as much during weight loss, i.e. the work on the bike ergometer remained at 50 W. The work done to move the legs during each pedal cycle was of course reduced after weight loss since presumably subjects would have lost some mass from the legs. However, the overall decrease in work would be minimal when compared to walking and stair climbing. Therefore the effects of the exercise training on heart rate response during work is more easily detected without reduced work of moving lower body mass confounding the analysis. Observation of the biking data supports this contention, with the no exercise group not changing heart rate while the combined aerobic and resistance training groups decreasing heart rate 9 beats/min following weight loss. Therefore it can be concluded that exercise training during weight loss has a positive affect on improving ease of exercise in an absolute

task (such as cycling at 50 watts). However, exercise training during weight loss has less of an affect for tasks in which the work is being done to move reduced body weight.

Increased efficiency at low cycling intensity has been reported after weight loss (13, 15, 17) but not at higher intensity exercise (5). Consistent with studies that used higher intensity steady state exercise the present study did not find a difference in exercise economy for any of the moderate intensity submaximal exercise tasks following weight loss. Mechanisms for why exercise economy/efficiency increases at very low intensities, i.e. 25 W or less or equal to 2 METs) but not at more moderate, i.e. greater than 3 METs is unknown.

Consistent with the increase in biking efficiency found with low intensity exercise, RQ has been shown to decrease during low intensity (25 W and lower) biking (15)), showing less carbohydrate metabolism. Because biking efficiency was also increased requiring less energy expenditure, presumably subjects would be able to perform the biking task with less activation of inefficient fast twitch muscle fibers that would be more dependent on carbohydrate metabolism. We observed no weight loss related decrease in RQ for our moderate intensity exercises (including cycling), except for the stair climb. On the other hand similar to Amati et al (Amati 2008) we observed a decrease in RQ during the walk and grade walk for the aerobic exercisers but not for the resistance trainers or non exercisers.

Although the aerobic and resistance training decreased heart rate during the submaximal tasks similarly, the mechanisms for the improvements are probably different. Improvements in aerobic fitness would be accompanied by increases in blood volume and increased maximal and submaximal stroke volume. Increased stroke volume would be expected to translate into reduced heart rate at rest and during submaximal exercise. Resistance training normally has little effect on aerobic capacity and maximal stroke volume. However, it does affect strength and increased strength is associated with a reduction in neural activation of muscle during submaximal tasks (6;9). It could therefore be argued that stronger individuals will not have as great an activation of the sympathetic nervous system during standardized tasks such as walking or riding a stationary bicycle, i.e. a lower percent of maximal force will be needed to perform a standardized task so less relative muscle activation and less disturbance of homeostasis. Reduced neural-hormonal disturbance would then be accompanied by changes in extrinsic control of heart rhythm so that heart rate is reduced. Of course either stroke volume or arterial-venous differences would have to accompany the reduced heart rate if oxygen uptake remained the same as it did in this study. It is impossible to know from the present study whether submaximal stroke volume or arterial-venous differences occurred.

Practical Application

Exercise economy was not affected by weight loss or exercise training. However, heart rate and thus difficulty in walking, stair climbing and bicycling was reduced following weight loss. Although exercise training did not have an affect on exercise heart rate following weight loss, exercise training during the year following weight loss maintained reduced exercise heart rates obtained during weight loss. The results of this study, therefore, suggest that at least some moderately intense exercise training may be helpful in improving aerobic and strength fitness and ease of movement during and especially following weight loss. This strategy may be helpful in improving health and preventing or at least slowing weight regain since reduced heart rate and thus more ease in locomotion may translate into increased participation in free living physical activity (7, 8) and in turn improved body weight maintenance (3, 4, 18). Although, not tested in this study it is probable that combined aerobic and resistance training may have an additive affect on improving ease of locomotion following weight loss.

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Heart Rate Response Changes from Overweight to Reduced Weight

Figure 1. Locomotion heart rate response changes from overweight to post overweight in 73 women. (Error brackets standard error of the mean and stars indicate significant difference between exercisers and diet only group, $p < 0.05$).

Heart Rate Response Changes from Overweight to One-Yr Follow Up

Figure 2. Locomotion heart rate response changes from overweight to one year following weight loss in 73 women. (Error brackets standard error of the mean, and stars indicate significant difference between exercisers and diet only group, $p < 0.05$).

Table 1

Descriptive variables for 73 women.

	Aerobic Train (19 subjects)	Resistance Train (26 subjects)	No Exercise (28 subjects)	P
Age (yrs)	34.4±8.0	33.9±6.8	35.7±5.2	0.594
Height (cm)	162.4±5.1	165.5±8.5	166.4±5.5	0.123
Weight (kg)	74.8±5.7	77.3±9.3	78.7±6.5	0.033
BMI (kg/m ²)	28.4±1.6	28.0±1.1	28.2±1.4	0.272

Table 2

Fitness measures for 73 women(aerobic 19, resistance 26, no exercise 28 subjects).

	Overweight	Post Overweight	One-yr follow-up	p
Knee extension strength (kg)				
Aerobic	46.7±11.4	45.8±12.4	49.6±17.3	T<0.001
Resistance	52.6±18.5	59.1±14.8	63.7±18.4	G<0.064
No exercise	55.4±16.7	54.8±20.7	56.3±16.0	TxG<0.008
VO ₂ max (ml/kg/min)				
Aerobic	28.9±4.6	35.5±5.5	36.0±6.1	T<0.001
Resistance	28.5±3.8	33.3±5.4	32.3±6.1	G<0.019
No exercise	27.2±3.4	32.5±4.5	29.4±4.2	TxG<0.002
VO ₂ max (ml/kg ffm/min)				
Aerobic	51.3±7.4	52.9±7.3	55.9±6.7	T < 0.002
Resistance	50.5±7.2	49.1±7.2	51.3±7.0	G < 0.012
No exercise	47.6±5.0	47.4±5.9	48.2±5.5	TxG<0.024

VO₂max = maximal oxygen uptake

Table 3

Submaximal stair climb and walk measures for 73 women(aerobic 19, resistance 26, and no exercise 28 subjects).

	Overweight	Post Overweight	One-yr follow-up	p
Submax Stair HR (beats/min)				
Aerobic	133.3±17.1	115.3±16.6	118.1±19.8	T<0.001
Resistance	135.3±17.1	118.1±18.9	126.5±17.5	G=0.515
No exercise	132.1±17.7	119.8±17.0	130.4±18.0	TxG<0.030
Submax Stair RQ				
Aerobic	0.83±0.05	0.78±0.02	0.81±0.06	T<0.038
Resistance	0.83±0.04	0.79±0.04	0.82±0.04	G=0.597
No exercise	0.83±0.05	0.80±0.04	0.83±0.04	TxG=0.717
Submax Stair NVO ₂ (ml/kg/min)				
Aerobic	11.9±1.5	12.4±1.3	12.4±1.5	T=0.144
Resistance	12.2±1.4	12.1±1.6	12.6±0.9	G=0.315
No exercise	11.8±1.6	11.5±2.3	12.1±1.6	TxG=0.926
Submax Walk HR (beats/min)				
Aerobic	119±17	106±17	105±15	T<0.001
Resistance	119±15	106±17	111±18	G=0.640
No exercise	117±15	107±14	117±12	TxG<0.002
Submax Walk RQ				
Aerobic	0.81±0.05	0.77±0.04	0.81±0.06	T=0.452
Resistance	0.81±0.03	0.81±0.06	0.80±0.04	G=0.330
No exercise	0.81±0.05	0.81±0.04	0.82±0.82	TxG<0.111
Submax Walk NVO ₂ (ml/kg/min)				
Aerobic	9.7±1.3	9.5±1.3	9.1±0.9	T=0.328
Resistance	9.2±1.06	9.1±1.8	9.0±1.5	G=0.179
No exercise	9.1±1.6	9.4±1.9	9.3±1.6	TxG=0.689

HR = heart rate; RQ = respiratory quotient; NVO₂ =net oxygen uptake

Table 4

Submaximal grade walk and bike measures for 73 women(aerobic 19, resistance 26, and no exercise 28 subjects).

	Overweight	Post Overweight	One-yr follow-up	p
Submax Grade Walk HR (beats/min)				
Aerobic	132±16	116±14	118±17	T<0.001
Resistance	133±17	119±20	127±19	G=0.358
No exercise	132±16	122±17	131±15	TxG<0.008
Submax Grade Walk RQ				
Aerobic	0.86±0.06	0.80±0.04	0.84±0.06	T<0.114
Resistance	0.85±0.04	0.84±0.06	0.85±0.05	G=0.117
No exercise	0.86±0.06	0.86±0.04	0.86±0.05	TxG<0.151
Submax Grade Walk NVO ₂ (ml/kg/min)				
Aerobic	12.6±1.6	12.3±1.8	12.5±1.2	T=0.373
Resistance	11.7±1.3	11.9±2.0	12.1±1.4	G=0.352
No exercise	11.9±1.5	12.3±1.9	12.0±1.8	TxG=0.582
Submax Bike HR (beats/min)				
Aerobic	131±17	124±17	124±20	T<0.001
Resistance	131±20	120±18	128±24	G = 0.985
No exercise	127±15	126±16	129±14	TxG<0.04
Submax Bike RQ				
Aerobic	0.97±0.09	0.96±0.08	0.96±0.09	T = 0.626
Resistance	1.00±0.10	0.99±0.08	1.00±0.09	G = 0.378
No exercise	0.96±0.09	1.00±0.08	0.99±0.08	TxG<0.109
Submax Bike NVO ₂ (l/min)				
Aerobic	0.808±0.114	0.793±0.102	0.800±0.110	T = 0.650
Resistance	0.768±0.136	0.775±0.107	0.798±0.087	G = 0.706
No exercise	0.792±0.085	0.780±0.112	0.798±0.089	TxG=0.705

HR = heart rate; RQ = respiratory quotient; NVO₂ = net oxygen uptake

Table 5

Relationships between difference (post weight loss to one year follow-up) aerobic and strength fitness and difference in locomotion. (n = 73)

	Difference in Knee Extension Strength	Difference in VO ₂ max
Difference in submax stair heart rate	0.04 (0.77)	– 0.45 (<0.01)
Difference in submax walk heart rate	– 0.03 (0.82)	– 0.31 (<0.01)
Difference in submax grade walk heart rate	– 0.04 (0.77)	– 0.29 (<0.02)
Difference in submax bike heart rate	– 0.04 (0.77)	– 0.23 (<0.06)