Effects of Resistance versus Aerobic Training on Coronary Artery Disease Risk Factors

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Individuals exhibiting "the metabolic syndrome" have multiple coronary artery disease risk factors, including insulin resistance, hyperlipidemia, hypertension, and android obesity. We performed a randomized trial to compare the effects of aerobic and resistance training regimens on coronary risk factors. Twenty-six volunteers who exhibited android obesity and at least one other risk factor for coronary artery disease were randomized to aerobic or resistance training groups. Body mass index, waist-to-hip ratio, glucose, insulin, body composition, 24-hr urinary albumin, fibrinogen, blood pressure, and lipid profile were measured at baseline and after 10 weeks of exercise training. Both groups showed a significant reduction in waist-to-hip ratio and the resistance training group also showed a reduction in total body fat. There was no significant change in mean arterial blood pressure in either group. Fasting plasma glucose, insulin, total cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides were unchanged in both groups. High-density lipoprotein (HDL) cholesterol increased (13%) with aerobic training only. Plasma fibrinogen was increased (28% and 34%, $P < 0.02$) in both groups and both groups showed a significant decrease (34% and 28%, $P < 0.03$) in microalbuminuria after their respective training regimen. In conclusion, resistance training was effective in improving body composition of middle-aged obese sedentary males. Only aerobic training was effective in raising HDL cholesterol. More studies are warranted to assess the effects of exercise on plasma fibrinogen and microalbuminuria. Exp Biol Med 228:434–440, 2003

Key words: insulin resistance; metabolic syndrome; resistance training; aerobic training; coronary artery disease

This work was supported in part by NordicTrack (Glencoe, MN).
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Received July 12, 2001.
Accepted December 12, 2002.

1535-3702/03/2284-0434$15.00

Cardiovascular disease is the major killer in the United States and most other industrialized nations. Hyperinsulinemia, hypertension, dyslipidemia, and android-shaped obesity are fundamental risk factors for coronary artery disease. These risk factors have a tendency to aggregate, and this combination has been called the metabolic syndrome (1). Insulin resistance is considered the central factor that links these risk factors, especially in genetically susceptible persons (2, 3).

Both clinical data and studies in animal models demonstrate that environmental manipulations may affect some of the biochemical indicators associated with the metabolic syndrome. For example, aerobic and resistance training can normalize skeletal muscle and adipose tissue insulin resistance associated with the metabolic syndrome (4, 5). Aerobic and resistance training can induce recruitment and/or translocation of GLUT4, the primary insulin-sensitive glucose transporter, and alleviate the insulin resistance associated with android-shaped obesity (4, 5).

Although numerous studies have confirmed the relationship between insulin resistance and the clustering of risk factors in the metabolic syndrome (2, 3), fewer studies have assessed the effects of training with regard to many classical cardiovascular disease risk factors in individuals with android-shaped obesity. Moreover, there is only a limited body of literature (6) assessing the benefits of aerobic versus resistance training in this genetically susceptible population.

Physical activity to reduce one's risk for cardiovascular disease is strongly recommended in the consensus statement from the Centers for Disease Control and Prevention and the American College of Sports Medicine (7). This statement documents the improvements in cardiovascular risk factors that occur with aerobic and resistance training. Although the statement recommends muscle strengthening exercise, little evidence is presented to support this recommendation, as few studies have been performed to evaluate the effects of strength (i.e., resistance) training on cardiovascular risk factors (6, 7). Moreover, even less research has been performed to evaluate the effects of aerobic versus strength training on factors comprising “the metabolic syndrome.” Accordingly, the objective of this project was to compare the benefits of aerobic or resistance training in individuals exhibiting several cardiovascular risk factors (e.g., hypertension, Type II diabetes, hypercholesterolemia, hypertriglyceridemia, or android obesity) associated with the metabolic syndrome. The measurement of glucose, insulin, plasma lipoproteins, blood pressure, and waist-to-hip ratios were performed to assess the effects of aerobic and resistance training regimens on classical metabolic syndrome risk factors. Because of the relationships between plasma fibrinogen (8), microalbumin (9), and insulin resistance, we also compared these parameters between subjects. We also assessed numerous anthropometric and metabolic parameters associated with increased cardiovascular risk.

Materials and Methods

Subjects. Untrained males volunteered for participation in this study after receiving a detailed explanation of the study and providing written informed consent. All volunteers were selected from a large pool of individuals that responded to a local newspaper article and/or newspaper advertisements asking for volunteers that met our initial screening criteria. This study was approved by the University of Tennessee Institutional Review Board-Committee on Research Participation. Subjects volunteered for random assignment to 10 weeks of either resistance ($n = 12$) or aerobic ($n = 14$) training. All potential volunteers were initially screened to determine if they met the previously set criteria of the study. Final subject selection criteria for participation in the study were as follows: exhibited android-shaped obesity (i.e., a waist to hip ratio > 0.95 and a body mass index (BMI, kg/m^2) > 27 with at least one clinically diagnosed risk factor (i.e., hypertension, Type II diabetes, hypercholesterolemia, or hypertriglyceridemia) associated with the metabolic syndrome. Subjects were then screened for disease by medical history, physical examination, and a graded treadmill exercise stress test. All subjects who were engaged in any type of diet or exercise program were eliminated during the initial screening. Only subjects who were nonsmokers, who were not taking insulin, and had no evidence or history of coronary artery disease were selected for participation in this study. Subject characteristics are summarized in Table I. All subjects were instructed to maintain their typical diet and activity pattern throughout the study, and compliance with this instruction was assessed via food frequency and physical activity questionnaires administered at the beginning and end of the study. With the exception of the exercise provided by the study, neither parameter changed significantly over the course of the study.

Anthropometric, hemodynamic, blood, and urine parameters were assessed at the beginning and end of the study. Body composition (via bioelectrical impedance analysis [RJL Systems, Detroit, MI] in the fasted state and before morning exercise), and exercise performance were also evaluated at the beginning and end of the study.

Training Programs. Training programs, performed at the University of Tennessee research facilities, were designed to mimic exercise programs typically performed by sedentary individuals using commercial equipment (Nordic Track equipment; Nordic Track, Glencoe, MN) designed for home use. Subjects were randomly assigned to resistance or aerobic training regimens.

Resistance training. Twelve male volunteers trained three times a week nonconsecutively for 10 weeks using commercially available resistance training exercise equipment (Nordic Flex Gold, Glencoe, MN). All subjects were instructed on the proper technique for each exercise by a trained instructor and were familiarized with the equipment before initial testing. The resistance training program con-

Table I. Physical Characteristics of Middle-Aged, Android-Obese Men in Resistance and Aerobic Training Groups at Baseline and after 10 Weeks of Training

	Resistance (n = 8)		Aerobic (n = 11)	
	Pretraining	Posttraining	Pretraining	Posttraining
Age (year)	48 ± 6[a]	48 ± 6	47 ± 7	47 ± 7
Height (inches)	70 ± 2	70 ± 2	71 ± 2	71 ± 2
Weight (pounds)	225 ± 21	223 ± 19	243 ± 27	242 ± 28
BMI[b]	32 ± 4	32 ± 3	34 ± 4	34 ± 4
W/H ratio[c]	1.03 ± 0.03	0.99 ± 0.03*	1.01 ± 0.04	0.99 ± 0.04*
Percentage of body fat	25.8 ± 5.3	21.9 ± 3.1*#	25.6 ± 5.1	25.3 ± 6.1#
Fat-free mass (pounds)	166.5 ± 12.4	174.1 ± 11.9*	180.9 ± 25.7	181.5 ± 29.4
Compliance (%)	—	96.7	—	96.4

[a] Values are mean ± SD.
[b] Weight (kg)/height (m^2).
[c] Waist circumference (in)/hip circumference (in).
* $P < 0.05$ versus before training.
# Significant difference in training effect, resistance versus aerobic groups ($P < 0.05$).

sisted of three sets of lifts using sub-maximal effort to complete each of 10 lifts/set. Subjects performed a brief warm-up consisting of static stretching before and after each training session. Eight different exercises were performed during each workout: military press, leg extension, bench press, leg curl, lateral pull-down, triceps push-down, biceps curl, and sit-ups. Subjects trained with a partner and all training sessions were carefully supervised by the investigators. Each subject was encouraged to perform each set and repetition with utmost effort. The exercise performed, the sets and repetitions completed, and the average amount of weight lifted (i.e., resistance as determined from the Nordic Flex Gold digital readout) was recorded for every exercise session.

Increases in strength were documented by comparing the average weight lifted during 10 repetitions for each exercise from the first week of exercising (pretraining) and the average weight lifted during 10 repetitions for the last week of exercise (posttraining). Three exercises representing typical lifts using major muscle groups in the upper and lower body are reported for strength comparisons (i.e., bench press, lateral pull-down, and leg extension). The same procedures were followed at each testing session and subjects were encouraged to use sub-maximal exertion during each testing period.

Aerobic training. Fourteen male volunteers trained three times a week nonconsecutively for 10 weeks using ski exercise equipment (Nordic Track 900). All subjects were instructed on the proper technique and were familiarized with the aerobic training equipment before the initial testing. The aerobic training program consisted of approximately 40 min of training at 60%–85% of each subject's predicted maximal heart rate. During the first week, subjects were acclimated to the equipment and, by the second week, almost all subjects were working at approximately 85% maximal heart rate and exercising for 40 min. For the duration of the study, subjects were encouraged to increase intensity (speed and/or resistance) to accommodate conditioning. Subjects performed a brief warm-up consisting of static stretching and low intensity exercise before and after each training session. Subjects trained with a partner and all training sessions were carefully supervised. Heart rate, time, distance, and caloric expenditure (via Nordic Track digital readout) were recorded for each exercise session. Training was evaluated and quantified by comparing the average caloric expenditure and distance traveled for the first week of noninstructional exercise versus the average caloric expenditure for the last week of exercise.

Measurement of Blood Pressure. Resting blood pressure was measured (via sphygmomanometer) three times in the recumbent position on each of two nonconsecutive days before starting the exercise training regimen and three times at least 72 hr after the final training session. The mean of three stable baseline blood pressure measurements (for the two baseline measurements) obtained before training was compared with the mean of three stable posttraining blood pressure measurements. All blood pressure measurements were performed and recorded by a single investigator.

Plasma and Urine Measures. Venous blood was collected from subjects following a 12-hr fast on two nonconsecutive days before starting the training regimen and once at least 72 hr after the final training session. Plasma glucose and insulin concentrations were determined in duplicate using the standard glucose oxidase (Sigma, St. Louis, MO; accuracy and precision data: within run range of coefficients of variation [CV] 0.8%–1.3%, between run range of CV 1.3%–2.4%) and radioimmunoassay (INCSTAR, Stillwater, MN) methods, respectively. Simplified measures of insulin sensitivity were also calculated using fasting plasma insulin alone or with glucose (10). Cholesterol (total, HDL, and LDL) and triglyceride measurements were performed in duplicate using appropriate kits (Sigma). Plasma fibrinogen (accuracy and precision data: within run range of CV 1.9-2.88%, between run range of CV 4.3%–6.5%) and 24-hr urinary microalbumin (accuracy and precision data: within run range of CV 1.7%–3.0%, between run range of CV 2.2%–4.3%) concentrations were measured via immunoprecipitation using commercially available kits (INCSTAR).

Statistical Analysis. All data were evaluated for normality of distribution and homogeneity of variance before hypothesis testing. Main effects of training modality (aerobic and resistance) and time (baseline, midline if applicable, and endline), and training modality by time interactions were assessed using two-way repeated measures analysis of variance. Statistical significance was conferred at $P \leq 0.05$. When main effects were detected, the Tukey test was used for *post hoc* comparisons. Only subjects completing at least 80% of their scheduled training sessions were included in the statistical analysis. All values are reported as mean ± SD.

Results

Physical Characteristics. Age, weight, height, BMI, waist-to-hip ratio, percentage of body fat, and fat-free mass were not statistically different between the resistance and aerobic groups at baseline (Table I). Both the resistance and aerobic groups exhibited a significant decrease in waist-to-hip ratio after 10 weeks of training. The extent of reduction in waist-to-hip ratio was not significantly different between the two groups. The resistance group demonstrated a significant decrease in percentage of body fat and a significant increase in fat-free mass, which was not apparent in the aerobic group (Table I).

Blood Pressure. Systolic, diastolic, and calculated mean arterial blood pressures were not statistically different between the resistance and aerobic groups before or after training (Table II). There were also no significant exercise-induced blood pressure changes in either group. However, because the blood pressure of hypertensive individuals is more likely to respond to interventions than that of normotensive individuals, we performed a separate analysis of the

Table II. Blood Pressure of Middle-Aged, Android-Obese Men in Resistance and Aerobic Training Groups at Baseline and after 10 Weeks of Training

	Resistance (n = 8)		Aerobic (n = 11)	
	Pretraining	Posttraining	Pretraining	Posttraining
Systolic (mmHg)[a]	133.4 ± 9.6[b]	132.8 ± 8.8	132.7 ± 5.2	132.3 ± 8.3
Diastolic (mmHg)[a]	90.4 ± 6.3	90.6 ± 5.4	90.3 ± 5.4	91.5 ± 4.1
Diastolic (>90 mmHg)[c]	95.0 ± 8.5	94.5 ± 4.5	95.5 ± 11.0	92.2 ± 6.5*
Mean arterial pressure (mmHg)[a]	104.8 ± 7.5	105.0 ± 6.4	104.5 ± 5.0	104.9 ± 5.3

[a] All subjects.
[b] Values are mean ± SD.
[c] Hypertensive subjects only; n = 4 for resistance group and n = 6 for aerobic group.
* $P < 0.05$ versus before training.

effects of aerobic and resistance training on blood pressure in hypertensive and normotensive subgroups. The individuals with elevated diastolic blood pressures (>90 mmHg) demonstrated a significant decrease in diastolic blood pressure only with aerobic training, but not with resistance training (Table II).

Plasma Measures. There were no significant differences in plasma glucose or insulin concentrations among resistance and aerobic groups before, during, or after training. Plasma total cholesterol, LDL cholesterol, and triglycerides (data not shown) did not change significantly with either resistance or aerobic training. However, HDL cholesterol was significantly elevated with aerobic training (Table III).

Plasma fibrinogen was not significantly different between the aerobic and resistance groups. However, there was a surprising 22%–25% increase in fibrinogen after 10 weeks of exercise in both groups ($P < 0.05$; Table III). There was no difference in baseline microalbuminuria between the two groups, and both groups exhibited a 25% decrease after 10 weeks of exercise (Table III).

Effects of Exercise. *Resistance training.* Eight of the 12 male volunteers completed at least 80% of their scheduled training sessions (i.e., the minimal inclusion criteria set for this study) and therefore were included in the final statistical analysis. There was a significant increase in performance as demonstrated by a 153% increase in submaximal weight lifted over 10 repetitions for the three different exercises used to determine changes in performance for each individual (leg extension, bench press, and lateral pull-down).

Aerobic training. Eleven of the 14 male volunteers completed at least 80% of their scheduled training sessions and therefore were included in the final statistical analysis. There was a significant increase in performance demonstrated by a 277% increase in the average estimated caloric expenditure during the last week of exercise versus the first week of exercise. This difference was also conferred by a significant ($P < 0.05$) increase in the total distance traveled during each exercise bout (data not shown).

Discussion

Results of this study demonstrate that both aerobic and resistance training regimens resulted in improved performance and elicited beneficial effects in individuals exhibiting several classical cardiovascular risk factors associated with the metabolic syndrome and other anthropometric and metabolic parameters associated with increased cardiovas-

Table III. Plasma and Urine Measures of Middle-Aged, Android-Obese Men in Resistance and Aerobic Training Groups at Baseline and after 10 Weeks of Training

	Resistance (n = 8)		Aerobic (n = 11)	
	Pretraining	Posttraining	Pretraining	Posttraining
Plasma				
Glucose (mg/dl)	146.1 ± 52.2[a]	145.2 ± 52.8	112.2 ± 25.8	116.6 ± 23.3
Insulin (p*M*)	20.3 ± 9.9	20.6 ± 8.1	22.5 ± 6.8	20.1 ± 8.8
Total-Cholesterol (mg/dl)	203.0 ± 41.6	205.6 ± 43.6	205.0 ± 44.3	209.1 ± 42.3
HDL-C (mg/dl)	31.7 ± 8.4	32.0 ± 7.8	29.8 ± 7.0	33.7 ± 4.0*
LDL-C (mg/dl)	93.0 ± 70.4	114.3 ± 63.2	129.8 ± 56.7	133.2 ± 39.5
Fibrinogen (mg/dl)	156 ± 7	200 ± 10*	156 ± 10	210 ± 11*
Urine				
Microalbuminuria (mg/24 hr)	34.4 ± 3.3	25.6 ± 1.5*	34.7 ± 7.5	27.1 ± 5.2*

[a] Values are mean ± SD.
* Significant training effect ($P < 0.05$).
# Significant difference in training effect, resistance versus aerobic groups ($P < 0.05$).

cular risk (1–3). Although both groups exhibited modest decreases in waist-to-hip ratio after 10 weeks of training, only the resistance training group exhibited a decrease in body fat, from 26% to 22%, with an associated increase in lean body mass as determined by bioelectrical impedance analysis. However, other indices of cardiovascular risk were improved in the aerobic group only, as discussed below. This suggests that an optimal training regimen for this population may require both resistance and aerobic components.

It is widely believed that training increases HDL cholesterol, and several studies confirm this belief (11). Moreover, changes in blood lipids consequent to exercise training are related to changes in fat mass (11). A 2-year study also showed a slight increase in HDL cholesterol levels with exercise (12). Those studies that do show increased HDL generally involved more rigorous training regimens (12, 13), although there is some disagreement on this point as well (14). One study trained men at different intensity levels for 4 months and found that only the higher intensity level produced an increase in HDL level (12). The fact that our study demonstrated an increase in HDL with aerobic training indicates that our subjects may have been exercising at high intensity. Although there is some suggestion that men with low HDL levels are less likely to respond to training than men with higher HDL levels (15), our data do not support this concept. However, consistent with other studies of strength training and lipid profiles (14), we found no effect of resistance training on HDL levels. Our data and data from other studies (14) suggest that aerobic training of sufficient intensity and duration is more effective than resistance training in elevating HDL levels.

The present study did not include a diet modification component, and no effect on weight was observed. Indeed, the literature suggests that exercise alone has subtle effects on body weight in overweight subjects (16, 17). However, training does appear to mobilize abdominal fat (18). Waist-to-hip ratio was improved with training when training plus diet was compared with diet alone (17). Miller *et al.* (13) examined the effect of strength training on waist-to-hip ratio and found no effect (19). Both aerobic and resistance training groups had improved waist-to-hip ratio in our study. Although the magnitude of these changes were small, a 0.05 reduction in waist-to-hip ratio can reduce your risk classification by one category (e.g., high risk to moderate risk). A review comparing aerobic training with weight training concluded that weight training resulted in greater increases in fat-free mass (20). Other studies have confirmed the resistance training-induced reduction in fat mass and increased fat-free mass (13, 21). Our study also demonstrated that weight training resulted in greater increases in fat-free mass not apparent with aerobic training. We also found that resistance training was more effective than aerobic training in reducing body fat. Although there is evidence that resistance training can reduce body fat (13, 20, 21), other studies have found that aerobic training resulted in decreased body fat, whereas resistance training did not (14). We have no explanation for this discrepancy, although body fat was determined by electrical impedance in our study and by hydrodensitometry in the other study (14). This discrepancy needs to be further evaluated in similar studies by electrical impedance and hydrodensitometry to rule out possibility of measurement error.

Although it is unclear whether aerobic or resistance training is better for decreasing waist-to-hip ratio and percentage of body fat, it is clear that resistance training increases fat-free mass more effectively than aerobic training. Fat-free mass is one of the more important determinants of resting metabolic rate (13). Furthermore, a study examining resistance training with and without aerobic training showed a significant increase in resting metabolic rate with resistance training, whereas the resistance/aerobic training group showed a significant decrease in resting metabolic rate (13).

Results of this study also demonstrate a paradoxical increase in serum fibrinogen levels in both the aerobic and resistance groups. There is strong evidence that elevated fibrinogen is an important risk factor for coronary artery disease, and numerous studies support this relationship (8, 22). Furthermore, studies indicate that people who train have lower fibrinogen levels than those who do not (23). Trials of the effects of physical activity on fibrinogen have been conflicting (23–26), and this may be due to complex interplay between environmental and genetic factors in the regulation of plasma fibrinogen levels (27). In agreement with our results, Weight *et al.* (28) reported that the fibrinogen levels of competitive distance runners increased approximately 2-fold 24 hr after exercise and remained elevated for 6 days, and suggested that this increase was secondary to an observed increase in interleukin-1 activity after exercise. Thus, although chronic exercise leads to low steady-state fibrinogen levels, exercise may acutely cause an increase in these levels. Accordingly, our observation of a 25% increase in fibrinogen levels may have resulted from taking this measurement too soon (~72 hr) after the last exercise session. More studies are necessary to assess the effects of aerobic and resistance training on plasma fibrinogen.

Studies clearly show that physically active individuals are less likely to develop hypertension than sedentary individuals (29–31). Furthermore, aerobic exercise may decrease blood pressure more effectively than strength training (32). The effect is greater in hypertensive than in normotensive subjects and is greater in those who achieve more gain in fitness (32, 33). Although debatable, our study is consistent with other investigators (28, 32, 33) in that blood pressure responded to aerobic training only in those who were hypertensive and resistance training had no effect on blood pressure. Furthermore, the training-induced changes we observed in blood pressure are consistent with the magnitude of changes seen by other investigators (32).

A number of researchers have performed oral glucose tolerance tests on patients before and after training. Both aerobic and resistance training have resulted in lower insulin levels, especially during glucose tolerance testing of nondiabetic patients (14, 33–35). However, resistance training has also been reported to lower fasting insulin levels (14). In contrast, we found no significant effect of either training modality on fasting insulin or glucose measurements (10).

Microalbuminuria is a well-recognized early risk factor for diabetic kidney disease and has also been shown to be an independent predictor of early cardiovascular mortality (9, 35). Accordingly, our observations that both resistance and aerobic training caused a 25% decrease in microalbuminuria suggest the possibility of cardiovascular and renal protection resulting from either training modality in middle-aged obese men. This suggests that more trials should be performed to study the impact of training on microalbuminuria in diabetes and other forms of renal disease, and to determine the significance of microalbuminuria in patients with the metabolic syndrome without overt diabetes.

In summary, both aerobic and resistance training regimens resulted in improved performance and elicited beneficial effects in individuals exhibiting at least two classical cardiovascular risk factors (i.e., hyperinsulinemia, hypertension, dyslipidemia, and android obesity) associated with the metabolic syndrome. Aerobic training appeared to be beneficial with regard to HDL cholesterol, blood pressure (in individuals with a diastolic reading >90 mmHg), waist-to-hip ratios, and microalbuminuria. Resistance training appeared to be beneficial with regard to waist-to-hip ratios, body composition, and microalbuminuria. Paradoxically, both training regimens increased plasma fibrinogen levels, although this is not the first reported observation of this phenomena (26). Future studies should focus on key cardiovascular risk factors associated with the metabolic syndrome in a large randomized trial containing an aerobic training, resistance training, and control group.

In conclusion, both modes of training appear to be effective in reducing numerous coronary risk factors in middle-aged men at increased risk for coronary artery disease. However, each type of training also provides unique benefits. This research suggests that an optimal training regimen for individuals who exhibit cardiovascular risk factors associated with the metabolic syndrome may require both resistance and aerobic components.

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