Dose Response Effects of Aerobic Exercise on Insulin Sensitivity and Metabolic Syndrome

The United States is faced with a major health problem, metabolic syndrome, which is often linked to the sedentary lifestyles that many Americans live. In turn, metabolic syndrome and insulin resistance have been linked to diabetes mellitus. Hispanic Americans and African Americans are at higher risk for diabetes than non-Hispanic Whites. Our aim was to compare the effects of low-intensity and moderate intensity aerobic exercise on the degree of change and delay time required to detect change in various factors affiliated with metabolic syndrome. We tested men and women (aged 18–60 years) who had at least two parameters of metabolic syndrome and are at high-risk of developing atherosclerosis and cardiovascular disease. We measured various factors associated with metabolic syndrome throughout the 24-week study, including blood pressure, body mass index, waist circumference, and weight. We also conducted tests to determine other parameters of metabolic syndrome: plasma glucose levels, hemoglobin A1c levels, triglyceride levels, and HDL and LDL cholesterol levels. We compared the outcomes of each test of the two aerobic groups to the non-aerobic group (control group) and expected that the low- and moderate intensity aerobic groups would have a greater change in insulin sensitivity and abdominal adiposity. If this proved true, this would suggest that low and moderate aerobic exercise could lower metabolic syndrome factors.

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Background

Metabolic syndrome is a combination of metabolic disorders that increase one's risk of developing type 2 diabetes, cardiovascular disease, and atherosclerosis. It is estimated that approximately 47 million people have metabolic syndrome and, by 2010, 50–75 million people will be affected in the United States alone. If any of the parameters of metabolic syndrome is present, the patient is at high-risk of having insulin resistance, signifying that the body's normal amounts of insulin are not adequate enough to produce a normal insulin response from fat, muscle and liver cells. Due to the lack of response, the pancreas continuously produces insulin, which eventually leads to elevated levels of insulin and glucose in the blood. If the condition remains, kidney damage, fatty liver, blindness and amputations may result. There is no known cause for this syndrome; however, the parameters that define it include: a large waist circumference, high fasting blood triglyceride levels, high blood pressure, high fasting plasma glucose levels, and low HDL cholesterol levels. These characteristics may be elevated due to genetics, age and/or lifestyle. Our aim was to determine the degree of change and the amount of time it would take to spot a change in these factors correlated to metabolic syndrome. We compared three exercise groups.

Insulin resistance and insulin sensitivity are correlated with metabolic syndrome. The more insulin resistant one is the less insulin sensitivity; the less insulin resistant one is, the more insulin sensitivity. The lower the insulin resistance, the risk of having metabolic syndrome is reduced. By performing low and moderate aerobic exercise, insulin sensitivity levels would decrease as well as insulin resistance and levels of metabolic syndrome parameters.

Methods and Materials

Prior to the start of the research study IRB approval and informed written consent were obtained. Men and women aged 18–60 years who had at least two parameters of metabolic syndrome and body mass index of 25–40 were recruited. At the first visit, the participants went through: screening; signed a consent form; completed a medical history and physical exam; had a 12-lead EKG; a 75-gram OGTT; and were assessed on general laboratory parameters (urine analysis test, blood urea levels [BUN] enzyme AST and ALT levels, white and red blood count, weight and waist circumference). Participants meeting entry criteria were invited to participate in visit 2, which included a cardiopulmonary exercise test on a treadmill to assess their VO_2 max as well as endurance time. If entry criteria were met at this visit, the participant came back for vist 3 to be tested for metabolic parameters, had a DEXA scan, a carotid IMT, and a hyperinsulinemic euglycemic clamp. The metabolic parameters included triglyceride levels, HDL and LDL cholesterol levels, fasting plasma glucose levels, and total cholesterol levels. The DEXA scan was used to measure body composition and percent total fat mass vs lean body mass. The carotid IMT was conducted on the participant to measure plaque buildup in the carotid

arteries that supply the head and brain with blood. The clamp was administered on this visit as well to measure insulin sensitivity. The clamp was administered in the fasting state while using an infusion rate of regular human insulin (80 mU/m^2/min with an initial 5 minute bolus) and a variable rate infusion of 20% glucose to maintain euglycemia (100 mg/dL ± 5%) which is a normal concentration for glucose in the blood, for 3 hours. At the final thirty minutes, measurements of plasma insulin levels were taken. After completing these tests the participant was randomized into one of the three exercise groups: the stretching group, the low-intensity group, or the moderate-intensity aerobic group.

The low- and moderate-intensity aerobic groups both walked on treadmills. The low-intensity group walked at a 30% VO_2 reserve while the moderate intensity walked at a 60% VO_2 reserve. No matter what group the participant was placed into, all began with 20-minute sessions, 3 times per week at the DREW-NIH Exercise lab. Duration and frequency progressed as the study continued. Duration increased an additional 5 minutes every week until the target of 60 minutes was achieved. Frequency increased an additional session every 8 weeks until the target of 5 sessions per week was achieved. Along with continuing their exercise regime, the participants were required to answer dietary questionnaires beginning at week 3. Some of the metabolic parameters were measured at every session (participant's weight, waist circumference, and blood pressure) while others were conducted monthly or weekly. In order to recalculate the participant's absolute exercise intensity the CPXT was conducted every two months after Visit 2. At the beginning of week 9 and 17 hemoglobin A1c levels and DEXA scans were conducted. To keep track of insulin sensitivity throughout the supervised 24 weeks the HOMA- IR and QUICKI was used in place of the euglycemic clamp for short-term evaluation.

At the end of the supervised 24 week study, on the 24th week visit, metabolic syndrome parameters were re-tested. The participants were asked to continue unsupervised exercise for another 24 weeks. The metabolic syndrome parameters and fat mass percentages of the three exercise groups were then compared to baseline.

Results

The average weight and waist circumference of the low-intensity aerobic group was significantly lower at the end of the supervised 24 weeks compared to that of the moderate intensity and stretching group. The average plasma glucose and weight loss was always higher for the stretching group. This was also similar in the average increase in fat-free and lean body mass for the stretching group, where the rates stayed in the same range at the end of the 24 weeks compared to baseline. The moderate aerobic group ranged in the middle of both the low intensity and stretching group.

Discussion

The low and moderate aerobic groups were exercising on a treadmill and lost more weight and lowered their waist circumference more than the control group. This could be partly due to the fact that participants were using more calories. A previous study by Poehlman found an improvement in the glucose infusion rate in 14 non-obese Caucasian women who trained at a high intensity but had no change in their body composition. Our study showed that by performing low and moderate aerobic exercise, participants lost fat mass and increased their fat-free and lean body mass. Therefore, it suggests that, although as an individual they did not lose a significant amount of weight, they did gain muscle. This suggests that low and moderate aerobic groups who exercise for an extended period of time will lose fat mass and lower their levels of metabolic syndrome parameters.

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