THE PHYSIOLOGICAL & HEALTH EFFECTS OF A PILATES PROGRAM COMBINED WITH NUTRITIONAL INTERVENTION ON SUBJECTS WITH METABOLIC SYNDROME

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ABSTRACT

Background: As overweight or obese individuals can progress from normal physiology to metabolic syndrome to Type II Diabetes and other conditions, one area of question is whether relatively short interventions combining both nutritional and exercise interventions can make an impact on health status. The objective of this analysis was to determine the effects of a six-week intervention of Pilates exercise and nutritional modification on physiological variables and blood markers associated with metabolic syndrome.

Methods: 10 intervention subjects and 4 control subjects completed pre and post testing for physiological variables (VO2 peak, anaerobic threshold, isokinetic endurance/power, foot and gait function, dynamic balance and body composition). Subjects also completed a pre-diabetes blood marker screen (BioPhysical, Austin, TX) for various blood markers. The intervention group exercised using a Pilate’s method/device (AeroPilates, Stamina Fitness, Springfield, MO) that had both strength and cardiovascular components for five sessions per week, for six weeks. Additionally, they met with a registered dietitian weekly who developed a nutritional plan for each individual with a balanced calorie deficit diet based upon their energy needs with predicted REE/TEE and other variables. At the end of the six week period, both groups were re-assessed in both areas.

Results: The results indicated statistically significant improvement at the .05 level of confidence or lower for a number of measurements highlighted by overall weight loss (-7 Kg./7.5% of total weight), improved body composition (-2.58% body fat and -2.5 BMI), decreased waist/hip measurements (-9.3 cm/-5.9 cm), with a corresponding decrease in waist/hip ratio, decrease in systolic blood pressure (-10 mm/ hg) and a 19.7% increase in muscular endurance. Blood markers which demonstrated significant improvement included decreased total cholesterol, decreased triglycerides, decreased glucose levels & Hemoglobin A1c, decreased Plasmas Inhibitor Type 1 (PAI), and decreased Leptin.

Conclusion: For the time invested in the combination dietary modification & Pilates exercise program, the result was marked improvement in both the physiological and blood biomarker levels indicating improved health status and
Introduction

Metabolic syndrome is the name for a group of risk factors that elevates the risk for heart disease and other health problems, such as diabetes and heart disease (1, 2, 3). This condition has other names in the literature including metabolic syndrome X, cardiometabolic syndrome, syndrome X, insulin resistance syndrome, and Reaven’s syndrome. The term “metabolic” refers to the biochemical processes in the body’s normal function. Risk factors are traits, conditions, or habits that can increase the likelihood of developing a disease. It should be noted that criteria come from different sources including the International Diabetes Federation, the National Cholesterol Education Program, and the World Health Organization (4).

The National Cholesterol Education Program’s Adult Treatment Panel III report (ATP III) designated five conditions used in NCEP criteria. These conditions were used in this study, and include: abdominal obesity; elevated triglycerides, low HDL cholesterol, elevated blood pressure and elevated fasting blood sugar indicating insulin resistance, and/or on medications for any of the above. The risk of having metabolic syndrome is closely linked to being overweight and obesity as well as a lack of physical activity.

Exercise has been difficult for these individuals, who are estimated to be 25-30% of westernized populations because higher body weight in general causes more mechanical problems such as joint and spine pain during exercise. This therefore decreases motivation due to lack of measurable, short-term results in this area due to exercise not being sustainable. Additionally, activities with a high energy output, with an example being running are not well tolerated by this population.

Pilates has long been touted to develop flexibility and core strength, yet until recently did not have a recognized endurance component. A lack of scientific validation and study to popular claims clouded potential interventions and additional acceptance. For this study, a Pilates reformer and combined training program with both strength and aerobic components (AeroPilates, Stamina Fitness Products, Springfield, MO) was used as an exercise intervention with subjects who passed the classification criteria of having metabolic syndrome. This reformer is unique in that it incorporates a trampoline attachment for use with cardiovascular rebounding (See figures 1-4). As this form of exercise is considered somewhat gentle, and therefore appealing to this population, the question remained, whether this form of exercise combined with dietary modification would provide the necessary impetus for body composition improvement and measureable change in health status (5,6). In general, it appears this population positively considers forms of exercise which are perceived to be less rigorous as overall weight and subsequent joint issues mitigate exercise compliance with traditional modes of exercise.

Research Design & Methods

Fourteen previously sedentary subjects, (2 male, 12 female), were recruited with 10 being assigned to the intervention group, and 4 to the control group. Prior to the study, subjects were screened and met the criteria for metabolic syndrome as specified by NCEP-ATIII. For inclusion, participants had to have at least three of the metabolic syndrome criteria (7). Additionally, they could only have performed any exercise on a regular basis over the previous 90 days a maximum of twice per week, with that exercise being defined as light or moderate activity for a maximum of 30 minutes in duration. Upon review
of the criteria, eligible subjects completed a health & medical history and informed consent, they were reviewed and further confirmed to meet the criteria of metabolic syndrome and additionally deemed to have no medical limitations that would keep them from participation.

A blood profile measurement to determine key markers related to metabolic syndrome, obesity, insulin resistance and lipid profiles was used. The sample was taken in a fasting state (food and liquids), as per the guidelines (Pre-Diabetes Report, Biophysical Corporation, Austin, TX). These measures included C-Peptide, Adiponectin, Leptin, High Sensitivity CRP, PAI Type 1, Glucose, Hemoglobin A1C, Triglycerides, Total cholesterol, HDL cholesterol and LDL cholesterol. Other measurements are used in this particular screen, yet these were chosen as the reported indicators of both short and long-term potential change. There appears to be a moderate relationship between insulin resistance and these measures (8), and a specific relationship of adiponectin to obesity (9). HSCRP was included for analysis because of its relationship to the potential development of diabetes type 2 and the incidence of cardiovascular events (10,11). One aim of using this panel was to determine if these markers could positively change in a short period.

Baseline physiological measures included resting/initial measurements for height, weight, waist and hip circumference. Blood pressure was recorded via an automatic, medical cuff system (Omron Healthcare, Tokyo, Japan), and the lowest of the three measures was recorded. Body composition measurements were estimated using an InBody 720 device (Biospace, Seoul, Korea) that uses bioelectrical impedance was recorded noting fat mass, muscular mass, BMI and percent body fat (12,13). This also resulted in an estimate of Resting Metabolic Rate (RMR) based upon subject level of muscular mass. Each subject underwent additional physiological testing for aerobic capacity/volume of oxygen consumed at peak (VO2 peak), balance, isokinetic strength, basic torso flexibility, foot function (standing and gait measurements) using a three-dimensional force and gait pad.

VO2 peak was determined using an Oxycon Mobile measurement system (Care Fusion, Yorba Linda, CA) using a bicycle ergometer, which was also later used to measure energy expenditure of cardio-rebounding compared to other common aerobic modes of exercise (14, 15). After the unit was calibrated according to factory specification for ambient conditions, flow volume and gas calibration, each subject was fitted to a Hans Rudolph mask, with size and headgear specifications recorded for the post-test. After setting the ergometer, subjects were given 3 minutes of unloaded warm up, and progressed at 10 watts per minute from that point forward if they were less than 86 kg, and 20 watts per minute if they were over 86 kg. Test termination was volitional fatigue combined with a minimum Respiratory Exchange Ratio (RER) of 1.10 that needed to be obtained before test termination. VO2 peak, both absolute and relative was recorded, along with Anaerobic Threshold (AT), which was calculated using the V-slope method which was further correlated to a RER of 1.0. AT was also used to give the exercise participants a level of effort which had physiological correlation for energy system training. For post testing, the same protocol and criteria were repeated.

Strength was assessed using an isokinetic dynamometer (HydraFitness, Belton, TX) set to approximate 300 degrees per second, which would give an indication of abilities and changes in muscular endurance for 20 repetitions including measures of chest press, basic row, shoulder press, lat pull down, knee extension, knee curl (16). Muscular power was assessed for peak torque with the same device with the measurement speed used of approximately 60 degrees per second. This device is not true isokinetic in nature as there is a slight acceleration up to the testing speed/resistance because of the fluid dynamics of the cylinder system used as resistance. In both measures, total force was recorded, as well the development of a strength/body weight ratio for each measure indicating both absolute and relative improvement accounting for changes in body weight (17, 18). The testing order was chest press/row, knee extension/leg curl, and concluded with shoulder press and lat pull down motions. In each case, the subject was familiarized
with the concept of The isokinetic testing was adjusting for their size with both a seat and leg arm adjustment, placing the leg extension/leg curl pad just above the ankle joint on the shin. Each participant was given practice repetitions to understand the speed/load demands of that particular movement and test parameter. Individual range of motion was set to be 5-10 degrees short of full flexion and extension in each movement, with a computer tone indicating the end of the range of motion thus signaling for the subject to move the lever arm in the opposite direction. In each movement, muscular endurance was assessed first, then the subject was given a one to two minute recovery, then power was assessed before sequencing to the next movement. This same order and protocol was repeated on the post-test for each subject.

Dynamic balance for right and left stability was assessed for a total time in balance out of a possible 30 seconds using a stability platform (Lafayette Instruments, Lafayette, IN). A measure of rotational flexibility along the spine was performed by having subjects sit up right on a therapy table, and grasping a Pilates stick, and placing that stick parallel to the floor surface directly bisecting the origin and insertion of the anterior deltoid, and holding the stick in that position with both hands. Subjects were instructed to keep hips flat, knees together yet bent, and to have the spine be vertical, which was controlled with an orientation rod being placed gently against the spine for reference to vertical. Subjects warmed up with two to three rotational movements twisting the shoulders as far as possible while maintaining the required positions. If the subject went past a reference point or mechanical requirement, they were instructed to repeat the movement again at a slower pace to allow the recording of the point of maximal rotational flexibility in this maneuver without violating any of the mechanical movement guidelines. The largest number of degrees of rotation was recorded from at least two trials.

Gait and foot function was assessed using a 3DO force pad which measures both standing/static foot pressure and basic walking mechanics (3DO Orthotics, Tustin, CA). Subjects were placed in light socks on the pad and instructed to hold motionless in normal posture. Once the graphic display indicated a relatively stable position, those pressure readings and weight distribution points were recorded. The subject was then instructed on how to walk across the pad in a normal walking movement (19). The subject was allowed to practice until they were comfortable with the sequence and felt they had a repeatable speed and gait reflective of a normal casual walking speed. These pressure readings and gait dynamics were recorded, with the result being an overall foot score indicating perfect function of 100, while scores less than that number indicate issues with basic stance or basic gait mechanics. The basic stance and gait scores were separated for comparison of changes to each area as a result of the Pilates program.

Exercise & Nutritional Intervention

Subjects in the intervention group completed two sessions of supervised training combining cardio-rebounding and Pilates exercise per week. Three other sessions were performed at home using that same routine for that week. The progression used consistently longer bouts of cardio-rebounding (unique to the AeroPilates device), intermixed with various Pilates exercises. Additionally, as the program progressed during the six weeks, the program utilized a very light form of interval training during weeks five and six in addition to what would normally be considered normal, or steady state cardio-vascular exercise. Programs were adjusted slightly based upon individual abilities as determined each week when attempting new exercise progressions (20, 21). Programs started with 40 minutes of duration and progressed to 45-50 minutes of duration by the conclusion of the program. Exercise sessions were recorded during each supervised visit, and for exercise sessions at home, each participant had an exercise progression sheet for that week that also served as a record keeping journal of actual activity. Participants were asked to refrain from any other exercise modes or programs during the intervention period to ensure the results and changes were the results of the prescribed exercise program.
The nutrition component of the research study intervention consisted of estimation of total energy expenditure, individual nutritional counseling, application of simple behavioral change strategies and self-monitoring (22). Nutrition counseling and education was administered by registered dietitians weekly for the six-week period.

Total Energy Expenditure was calculated by taking estimated RMR (as estimated via muscular mass from the InBody 720 body composition analyzer), then multiplying that number by an activity factor of 1.45, and then subtracting 500-1000 kcals to reach calorie deficit. There is a strong correlation between overall muscular mass and resting energy expenditure. The co-efficient of 1.45 took into account caloric expenditure for digestion, everyday movement, and moderate physical activity. Participants’ daily caloric intake ranged from 1200-1500 calories. Based on the USDA evidenced based library, there is strong evidence a calorie restricted diet supports weight loss although the proportion of macronutrients does not (23, 24, 25, 26). On average, each person consumed 30-35% of daily food energy consumption from protein, with the balance of energy and nutrients being assigned by the RD with reference to lifestyle factors, specific medical conditions and subject preferences.

All sessions had a minimum visit time of 30 minutes with a maximum of 60 minutes. Nutrition counseling was provided to support direction of achieving a healthy and safe caloric deficit diet geared towards moderate weight loss. Registered dietitians calculated individual caloric intake targets by using their total energy expenditure (RMR x 1.45 for moderate exercise) and subtracting 500 to 1000 calories without going below 1200 kcals for any participant. The target goal of the plan was for participants to lose up to two pounds per week. Registered dietitians provided this specific nutrition counseling to participants each week in 30-60 minute sessions by telephone, face to face and by Skype. Participants were required to self-monitor intake with the use of online self-monitoring tools including www.myfitnesspal.com, www.sparkpeople.com or to write down via food diary/journal format. Self-monitoring has been demonstrated to be a tool that helps support weight loss and weight loss maintenance.

The nutrition parameters and guidelines developed were total calories; protein, fat and carbohydrate were individualized for all participants as per the described guidelines. Macro nutrient distribution was dependent on protein calculated by 1-1.1 grams/Kg of ideal body weight/ day. Adequate protein levels were aimed to decrease risk of increase of loss of lean muscle mass with weight loss and to provide greater satiety (23, 24, 25). Fat guidelines consisted of total fat constituting up to 35% of a day’s total caloric intake with no more than 10% of total caloric intake coming from saturated fat. Carbohydrate intake included a focus on foods with a low glycemic load. Carbohydrates had a required minimum of 60 grams a day to avoid putting participants into ketosis. Recommendation for carbohydrates included a maximum of two to three servings of fruit, six servings of non-starchy vegetables with up to four servings of starchy carbohydrates daily. Added sugar was limited to 28 grams/day for women or 36 grams/day for men. Carbohydrate intake was moderately low (25, 26).

Some participants had at least one meal or snack replacement to help support protein requirements as directed by their specific registered dietician (30, 31, 32, 33).

The registered dietician used nutrition assessment, intervention monitoring and evaluation in developing a specific nutrition prescription for all participants. During the first meeting of each subject with the RD, a sample menu was presented that matched the specified caloric intake of the subject based upon energy needs of both rest and exercise. Subjects were then encouraged to ask about substitutions to the plan which then further personalized the nutritional regimen to their likes and dislikes. During the weekly meetings, the RD’s performed checks via food logs, both in paper and in computer applications, and then aided participants in further refining their nutritional schedule.

Control subjects were instructed to not make any changes in lifestyle, exercise or nutritional patterns during the trial period other than what was
prescribed.

Results

All of the analyses of data were carried out by “R” for Windows (34). The results indicated as statistically significant have p-values lower than our rejection region of .05. By having p-values in this region we are expressing that there is a small probability that these results were generated completely by chance, and thus showcase the differences in quantitative health factors produced by the experimental group. As summarized in Table 1 for physiological data, analysis of the six week program with both parametric tests and independent samples t-tests revealed statistically significant (p<.05), reductions in weight (7.5%), body composition (5.7%), fat weight (13.6%), and overall blood pressure (6.4%). Lean mass did decrease slightly in the subjects during the training regime lean mass (-3.2%). There were also significant increases in VO2 Peak (9.6%), Anaerobic Threshold (14.6%), balance (22%), and combined torso rotation (18%). Other significant increases included Muscular endurance (20%), muscular endurance compared to weight (26.6%), and muscular power compared to bodyweight (14.8%). Overall waist circumference, hip circumference and waist to hip ratio measurements decreased. Additional investigations with this same group also indicated that cardio-rebounding, or the trampoline-like jumping motion with the Pilates carriage was slightly better in energy expenditure per minute compared to elliptical, treadmill and recumbent cycling exercise at the same rate of perceived exertion (Note: these results are referenced in this study yet are a separate study being submitted for publication). A separate treatment of blood profile markers revealed relatively significant (p<.05) improvement for selected variables as summarized in Table 2.

Discussion

It was obvious from the changes that the combined exercise and dietary modification program improved fitness level and physiological parameters. This study provides evidence that the use of a Pilates program utilizing a cardiovascular component combined with strict nutritional planning and supervision can have measurable effects in only six weeks in a population that has traditionally been resistant to weight loss. In fact, the amount of weight lost in 6 weeks (7.5%) exceeds the minimum requirement for medical significance (5% maintained for 1 year, NIH and 10% maintain for 1 year, IOM). This amount of weight loss can reduce the risk of developing Type II Diabetes by 2/3.

Because previous studies on Pilates have not used this array of physiological measures, direct comparison to previous efforts is not reasonable or justified (35, 36, 37, 38). Additionally, those studies did not have the same cardiovascular training component or this array of physiological measurements. Pilates has only mild research evidence to date for the improvement flexibility, dynamic balance and moderate evidence to enhance muscular endurance. Weight loss specifically as it relates to metabolic syndrome or other conditions have not been addressed to date with Pilates. A 7.5% weight loss in 6 weeks in this study is significant in that studies have demonstrated that a 7% weight loss is enough to yield significant improvements in CV biomarkers (39).

Overall, weight loss was significantly better than similar studies that blended both nutritional and exercise components. As metabolic syndrome encompasses a number of related conditions, the literature reflects interventions on various levels of selected, associated components, and with varying lengths and levels of subject intervention and control. One DASH study had a 4.9 kg weight loss in 9 weeks, with a drop in systolic/diastolic pressure of 9.3 and 5.3 mmhg respectively (40). Using a similar approach on arthritis patients elicited a 5.2 kg drop in weight in 18 months (41). One study aimed at measuring the effects of a dietary/exercise approach to diabetes management demonstrated a weight loss of 4.5 kg, a reduction of 4.4 c.m. from the waist and a triglyceride drop of .2 mmol/L (42). Some studies have been ethnically centric in subject pools, with an example result of a weight loss of 2.0 kg in three months in African-American subjects (43). Weight loss from the
Table 1. Overall Results for Intervention Subjects (averages)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre/Start</th>
<th>Post/Finish</th>
<th>Change</th>
<th>% Change</th>
<th>Statistical Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>97.8</td>
<td>90.4</td>
<td>-7.3</td>
<td>-7.5</td>
<td>0.00001</td>
</tr>
<tr>
<td>BMI</td>
<td>34.3</td>
<td>31.8</td>
<td>-2.5</td>
<td>-7.2</td>
<td>0.00004012</td>
</tr>
<tr>
<td>%Body Fat</td>
<td>43.6</td>
<td>41.0</td>
<td>-2.58</td>
<td>-5.7</td>
<td>0.00007149</td>
</tr>
<tr>
<td>Fat Weight (kg)</td>
<td>42.4</td>
<td>36.9</td>
<td>-5.5</td>
<td>-13.6</td>
<td>6.56E-07</td>
</tr>
<tr>
<td>Lean Weight (kg)</td>
<td>55.4</td>
<td>53.6</td>
<td>-1.8</td>
<td>-3.2</td>
<td>0.003056</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>112.65</td>
<td>103.38</td>
<td>-9.27</td>
<td>-8.2</td>
<td>0.0001708</td>
</tr>
<tr>
<td>Hips (cm)</td>
<td>119.89</td>
<td>113.79</td>
<td>-6.1</td>
<td>-4.9</td>
<td>0.0004596</td>
</tr>
<tr>
<td>Waist/Hip Ratio</td>
<td>0.939</td>
<td>0.908</td>
<td>0.031</td>
<td>-3.3</td>
<td>0.05</td>
</tr>
<tr>
<td>BP/Systolic</td>
<td>126.7</td>
<td>116.1</td>
<td>-10.6</td>
<td>-8.4</td>
<td>0.0009141</td>
</tr>
<tr>
<td>BP/Diastolic</td>
<td>85.4</td>
<td>80.4</td>
<td>-5</td>
<td>-5.8</td>
<td>0.04042</td>
</tr>
<tr>
<td>Balance (30 seconds)</td>
<td>11.38</td>
<td>13.93</td>
<td>2.55</td>
<td>22</td>
<td>0.001929</td>
</tr>
<tr>
<td>Foot/Gait Total (1-100)</td>
<td>60.8</td>
<td>65.6</td>
<td>4.8</td>
<td>7.9</td>
<td>0.05526</td>
</tr>
<tr>
<td>Foot/Static (1-100)</td>
<td>32.3</td>
<td>34.9</td>
<td>2.6</td>
<td>8</td>
<td>0.1027</td>
</tr>
<tr>
<td>Foot/Gait (1-100)</td>
<td>28.3</td>
<td>30.5</td>
<td>2.3</td>
<td>8.1</td>
<td>0.07691</td>
</tr>
<tr>
<td>VO2 Max/ml/kg/min-1</td>
<td>22.84</td>
<td>25.06</td>
<td>2.2</td>
<td>9.6</td>
<td>0.0005088</td>
</tr>
<tr>
<td>AT/ml/kg/min-1</td>
<td>16.3</td>
<td>18.69</td>
<td>2.39</td>
<td>14.6</td>
<td>4.42E-05</td>
</tr>
<tr>
<td>Muscular Endurance (ME)Total in kg/m</td>
<td>2636.28</td>
<td>3157.28</td>
<td>521</td>
<td>19.7</td>
<td>0.001522</td>
</tr>
<tr>
<td>ME/Bodyweight Ratio</td>
<td>26.95</td>
<td>34.92</td>
<td>7.97</td>
<td>26.6</td>
<td>0.001206</td>
</tr>
<tr>
<td>Muscular Power Total in kg/m</td>
<td>778.46</td>
<td>820.72</td>
<td>42.26</td>
<td>5.4</td>
<td>0.05677</td>
</tr>
<tr>
<td>M.P./Bodyweight Ratio</td>
<td>7.96</td>
<td>9.07</td>
<td>1.12</td>
<td>14.8</td>
<td>0.001569</td>
</tr>
<tr>
<td>Torso Flexibility-Right in degrees</td>
<td>48.3</td>
<td>55.5</td>
<td>7.2</td>
<td>14.9</td>
<td>0.004535</td>
</tr>
<tr>
<td>Torso Flexibility-Left in degrees</td>
<td>44.9</td>
<td>54.1</td>
<td>9.2</td>
<td>20.4</td>
<td>0.005447</td>
</tr>
</tbody>
</table>

Red/Very Significant
Blue/Moderate Significance
Black/Not Significant
perspective of various dietary regimens has demonstrated that low carbohydrate, low fat and the Mediterranean diet result in yearly weight loss totals of from 3.3 to 5.5 kg respectively, with no change in exercise demonstrating that dietary change will result in long-term weight loss (44).

Some studies have shown that adding exercise beyond dietary modification only increases the results slightly over nutritional modifications only, with up to a 7.2% drop in BMI over 36 month period (45). It may be the reason for these results to be less dramatic per unit of time was in this study the participants performed both more rigorous exercise with a greater volume per week, with an average of four to five sessions per week, compared to a number reported in many studies of three sessions per week. However, even more dramatic changes are possible, even in a short period as demonstrated with an adolescent, residential program that had an average weight loss of 4.0 kg in two weeks (46).

In postulating the reasons for the changes beyond the effects of the nutritional regimen, it is likely the energy system or cardiovascular component of this particular Pilates program is more of a factor in the physiological changes compared to the strength component. As this piece of equipment has a trampoline bed that allows for active jumping in a cardiovascular fashion, it had relatively high energy expenditure per minute. This was compared to treadmill walking, recumbent cycling and total body elliptical exercise at the same level of rate of perceived exertion using the Oxycon Mobile measurement system. Because this level of energy expenditure is not found in other Pilate’s devices, this is theorized to be a factor in the physiological changes the subjects made in the short period as it can be used as a form of circuit training with similar results (47, 48, 49, 50).

As Pilates exercise provides less specific muscular overload because of postural support needed during exercises, it is not unexpected to have muscular endurance improve more significantly than muscular power. It is very difficult to overload the muscular system in the same manner as conventional resistance training; therefore having the same results.

### Table 2. Progressions and modifications of exercise protocol.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre/Start</th>
<th>Post/Finish</th>
<th>Change</th>
<th>% Change</th>
<th>Stat Sig (Intervention-Control&gt;0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-Peptide (nmol/l)</td>
<td>1.36</td>
<td>1.22</td>
<td>.14</td>
<td>10.24</td>
<td>0.07565</td>
</tr>
<tr>
<td>Adiponectin (mg/L)</td>
<td>8.91</td>
<td>08.43</td>
<td>0.48</td>
<td>5.39</td>
<td>0.1562</td>
</tr>
<tr>
<td>Leptin (ug/L)</td>
<td>30.61</td>
<td>20.35</td>
<td>10.26</td>
<td>33.52</td>
<td>0.07589</td>
</tr>
<tr>
<td>HSCRP (mg/L)</td>
<td>62.76</td>
<td>80.19</td>
<td>17.43</td>
<td>27.77</td>
<td>0.8331</td>
</tr>
<tr>
<td>PAI Type 1 (IU/L)</td>
<td>47.28</td>
<td>41.89</td>
<td>5.39</td>
<td>11.40</td>
<td>0.1919</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>5.97</td>
<td>5.47</td>
<td>.50</td>
<td>8.46</td>
<td>0.04025</td>
</tr>
<tr>
<td>HgbA1C %</td>
<td>5.75</td>
<td>5.62</td>
<td>0.13</td>
<td>2.26</td>
<td>0.2489</td>
</tr>
<tr>
<td>Triglycerides (mmol/L)</td>
<td>2.39</td>
<td>1.66</td>
<td>.73</td>
<td>30.72</td>
<td>0.003911</td>
</tr>
<tr>
<td>Cholesterol (mmol/L)</td>
<td>5.15</td>
<td>4.75</td>
<td>.40</td>
<td>7.89</td>
<td>0.0144</td>
</tr>
<tr>
<td>HDL (mmol/L)</td>
<td>1.26</td>
<td>1.22</td>
<td>.04</td>
<td>3.08</td>
<td>0.7081</td>
</tr>
<tr>
<td>LDL (mmol/L)</td>
<td>2.79</td>
<td>2.74</td>
<td>.05</td>
<td>2.04</td>
<td>0.1062</td>
</tr>
</tbody>
</table>
is not likely. This was mirrored in the fact the subjects lost small amounts of muscular mass which would have likely been diminished with the loads and resistance levels in conventional resistance training. However, given the relatively rapid weight loss of the subjects, some muscular mass loss is expected as per reports from related studies.

Balance was significantly better, with likely factors being both the increase in leg endurance and the added core strength from various Pilates maneuvers. Torso flexibility was also significantly improved. Just outside of statistical significance, foot function increased overall. Subjects were almost equally split in improvement in the two base measures of static function and gait mechanics, thus with the improvement trends split, this did not have a clear path of statistical improvement. However, it is our observation that a number of factors lead to increased foot function including use of the foot bar during leg exercises and increased proprioception during cardio-rebounding as well as improved balance (51). It is postulated that given more time, this would have increased in a later measure.

Blood marker measurements demonstrated clear trends, especially considering the short term nature of the study. Hemoglobin A1C dropped by an average of 2.26%. Further investigation of this marker with sustained exercise and nutritional compliance is warranted as overall changes were substantial compared to previous interventions in just Pilates or programs that contained both a strength and cardiovascular component (52, 53). Additionally, a minor conclusion, and a possible research direction, is that blood markers which demonstrate levels and qualification for metabolic syndrome, can change in a short period, indicating these profiles have value at charting health status in this population.

As body fat makes Leptin, the corollary here is Leptin fell more in the weight loss group, although it is interesting it fell 10% in the control group. Produced by adipocyte and with increased fat mass, Leptin levels are usually high in subjects with metabolic syndrome. Leptin is a satiety hormone but when the brain is being ‘over signaled’ by Leptin, it turns of its usual response. Leptin resistance makes people not feel as ‘satisfied’ with eating. There was a decrease in Leptin levels with fat loss. (30.6 ng/ml down to 20.35 on average). All subjects except one (with the least weight loss) had a drop in their levels. This would paradoxically increase satiety as the brain would become more sensitive to Leptin signals again.

Subjects experienced a drop in fasting blood glucose from 5.97 to 5.47 mmol/L (9%). In addition, 6 of 10 study participants had a high fasting glucose prior to the intervention, 3 of these had a normal fasting glucose post-intervention. This is a relatively large change for the period of the study, probably resulting from both the relatively high energy expenditure in exercise per week (estimate of 1600-1900 kcal per week), and the stringent dietary regime prescribed by the registered dietitians.

Triglycerides decreased 30.72% for the intervention group and -.4% in the control group. The fact that such a short-term intervention can produce such a dramatic drop in blood glucose and in triglycerides, two very important biomarkers indicating risk for progression to Type II Diabetes, warrants longer-term study of this intervention (54, 55). HDL cholesterol had a very small decrease, which is in line with reported studies that initial weight loss has a corresponding decrease in HDL, and with stabilized weight and continued activity HDL will typically increase long-term after that initial decrease.

Fat cells make adiponectin, a potent insulin sensitizer. One might think then that as fat mass increases, an individual would have a higher adiponectin level. Unfortunately, this is not true. As a person gains fat weight, adiponectin levels fall, and this has been postulated to be an independent risk factor for Type II DM (54, 55, 56, 57). With sustained weight loss, adiponectin levels should rise as insulin resistance falls. However, we were not able to demonstrate this in such a short duration study period.

Conclusion

In conclusion, as measured in this study, this specific form of Pilates training (AeroPilates), combining both cardio-rebounding and traditional Pilate's
exercises with an individually established dietary program resulted in significant weight loss and increased measures of physiological function and improved health status for individuals with metabolic syndrome (58). These results were similar, and in some cases exceeded gains reported with other forms of more intense exercise for normal subjects without metabolic syndrome.

However, these results were unique in that the program was applied to a population where weight loss and physiological change and improved health status is generally more difficult than for those not affected with this condition, and over a relatively short period of intervention. Additional study is needed to determine if this program and these benefits would extend to an already exercising population with the same condition or related conditions. In this short study, we saw improvements in Glucose, HgbA1C, Triglycerides and total cholesterol.

This suggests that the Pilates/individualized nutrition intervention improved biomarkers for diabetes and insulin resistance as well as body composition, and that further study should be considered to measure the magnitude of the improvements at 6 and 12 months, and beyond.

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People

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