ABSTRACT

Nuttamonwarakul A, Amatyakul S, Suksom D. Twelve Weeks of Aqua-Aerobic Exercise Improve Health-Related Physical Fitness and Glycemic Control in Elderly Patients with Type 2 Diabetes. JEPonline 2012;15(2):64-70. Aqua-aerobic exercise (AE) has been proposed as an alternative mode of exercise in the medical management of type 2 diabetic (T2DM) patients. The purpose of this study was to investigate the effects of a 12-wk AE training program on health-related physical fitness and glycemic control in older subjects with T2DM. Forty elderly subjects with diagnosis of T2DM were assigned either to the AE group (n=20) or the non-exercise control group (n=20). Thirty minute of continuous aerobic exercise in swimming pool (water temp ~34 to 36°C) at 70% of maximum heart rate, 3 days/wk were performed in the AE group. The aqua-aerobic training group demonstrated a significant reduction in body weight, percentage of body fat, blood pressure, resting heart rate, and a significant increase in VO$_2$ max and muscular strength at the 12th-wk of training (P<0.05). Glycosylated hemoglobin (HbA1c), cholesterol, triglyceride, and insulin decreased significantly (all P<0.05) in the AE group compared to the non-exercise control group. There was no significant correlation between HbA1c and VO$_2$ max (r =.302). These findings indicate that 12 wks of AE training may help prevent complications in elderly patients with T2DM.

Key Words: Water-Based Training, Hyperglycemia, Ageing, Fitness
INTRODUCTION

Type 2 diabetes mellitus (T2DM) is estimated to increase to 366 million in the year 2030, and often remains undiagnosed until complications become symptomatic. It is one of the fastest growing public health problems, especially since it is associated with numerous complications (e.g., retinopathy, nephropathy, and atherosclerotic heart disease) that result from prolonged hyperglycemia (22).

Normally, patients with T2DM are the elderly, showing a decline in muscle mass and increase of body fat. Aquatic exercise has been found to slow the age-associated physiological declines and decrease the risk for T2DM by improving the circulation, muscle strength, and endurance (13,17). Scientific reports are also available in regards to the cardiorespiratory response during underwater exercise (7), and a change in the blood lipid profile from a reduction in body fat and an increase in muscle mass in subjects with T2DM (21). However, there are only a few reports that describe the long-term effects of aquatic exercise in the older adults. In particular, more information is needed in regards to the effects of a regular aquatic exercise program on health-related physical fitness and glycemic control in the elderly T2DM subjects.

The purpose of this study was to investigate the effects of 12 wks of aqua-aerobic training on the physical fitness and glycemic responses in elderly subjects with T2DM.

METHODS

Subjects

Forty patients with T2DM (who were over 60 yrs of age) were medically screened before participation to ensure that they were not altering medications during the exercise training period. Volunteers were recruited via announcement at the medical center of the local community. This investigation was approved by research ethics committee from the supreme patriarch center on aging research and ethics committee, Ministry of Public Health. The subjects were randomly allocated for 12 wks to the aquatic exercise group (AE; n=20) or the non-exercise control group (NC; n=20). Clarification of the training and testing, possible risks and benefits of participating in the study were carried out prior to the subjects’ signing the informed consent form.

Procedures

The subjects were given AE instructions at the same time of day by qualified researchers 3 day-wk^{-1} for 50 min per day within therapeutic pool temperature of ~34 to 36°C continuously for 12-wk. Prior to each training session, the subjects were instructed not to modify their behavior or diet or do any other type of physical exercise. They were also asked to consume an appropriate amount of water and maintain their sleep-rest period. The subjects in the AE program performed at 70% of maximum heart rate (MHR). They were monitored by a HR monitoring device (Polar team 2pro, Finland) or rating of perceived exertion (RPE) scale of 10-16 in accordance with standard recommendations by ACSM for diabetic patients (1), which included a warm-up and a cool down period that consisted of 10 min of stretching followed by 30 min of aquatic exercise.

The subjects understood that at any time they experienced uncomfortable feeling they could stop exercising. All parameters were assessed for 12-wk pre- and post-aquatic training. Bioelectrical impedance (BIA) instrument (RJL System, Detroit, USA) was used to determine body composition. Body weight, height, and percentage of body fat were also measured. Resting HR and blood pressure were taken after 10 min rest. Muscle strength was evaluated by isometric hand grip and leg strengths using a digital grip and back-leg dynamometer (Tokyo, Japan). Flexibility was also measured by flex-
meter (Tokyo, Japan). The Modified Bruce treadmill (Quinton, USA) protocol with a gas analyzer (Cosmed, Rome, Italy) was used to measure maximal oxygen uptake (VO_{2\text{max}}). Perceived exertion was rated every minute using the Borg scale. The attainment of VO_{2\text{max}} was validated if two of the following four criteria were satisfied: (1) oxygen uptake plateau despite increasing exercise intensity (=120 mL·min^{-1}); (2) respiratory exchange ratio =1.15; (3) maximal HR within 10 beats·min^{-1} of the age-predicted maximal value; and (4) a Borg scale value =17. An 8-hr overnight fast of blood samples were taken before and after the 12-wk of training. All samples were immediately analyzed by a certificated clinical laboratory for glycosylated hemoglobin (HbA1c), cholesterol, triglyceride, and insulin.

Statistical Analyses
Data were expressed as means ± standard deviation. The differences of various parameters between before and after 12-wk exercise training were analyzed by paired t-test. The differences of comparing data between groups were analyzed using unpaired t-test. All differences with P<0.05 were accepted as statistically significant.

RESULTS
General Physiological Characteristics
As shown in Table 1, only the AE group showed a significant decrease (P<0.05) in body weight, resting HR, and blood pressure (systolic and diastolic blood pressure) after 12-wk aquatic exercise training.

Table 1. General Physiological Characteristics Data.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Aquatic Exercise Group (n=20)</th>
<th>Control Group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>After 12 wks</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>62.8±8.6</td>
<td>61.1±8.3*</td>
</tr>
<tr>
<td>BMI (kg·m^{-2})</td>
<td>25.7±3.4</td>
<td>25.6±3.9</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>117.6±15.0</td>
<td>115.2±13.4*</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>74.7±11.6</td>
<td>71.7±8.3*</td>
</tr>
<tr>
<td>HR rest (beats·min^{-1})</td>
<td>82.3±11.3</td>
<td>73.3±7.8*</td>
</tr>
</tbody>
</table>

Values are mean ± SD. BMI; Body Mass Index, SBP; Systolic Blood Pressure, DBP; Diastolic Blood Pressure, HR; Heart rate. *represents statistical difference from pretest at P<0.05 and †represents statistical difference between groups at P<0.05.
Health-Related Physical Fitness
Grip strength and VO$_2$ max were significantly increased (P<0.05) in the AE group compared to the Control group. In addition, changes of VO$_2$ max was significantly higher than baseline (P<0.05) in only the AE group. There were no significant differences in leg strength and flexibility for both groups (Table 2).

### Table 2. Health-Related Physical Fitness Data.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Aquatic Exercise Group (n=20)</th>
<th>Control Group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>After 12 wks</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>39.4±505</td>
<td>38.5±5.8*</td>
</tr>
<tr>
<td>Grip strength (kg·BW$^{-1}$)</td>
<td>0.35±0.03</td>
<td>0.41±0.02*</td>
</tr>
<tr>
<td>Leg strength (kg·BW$^{-1}$)</td>
<td>0.8±0.3</td>
<td>0.8±0.3</td>
</tr>
<tr>
<td>Flexibility (cm)</td>
<td>8.9±8.2</td>
<td>9.2±10.0</td>
</tr>
<tr>
<td>VO$_2$ max (mL·kg$^{-1}$·min$^{-1}$)</td>
<td>23.6±0.5</td>
<td>24.0±0.5*</td>
</tr>
</tbody>
</table>

Values are mean ± SD. VO$_2$ max; Maximal oxygen uptake. *represents statistical difference from pretest at P<0.05 and †represents statistical difference between groups at P<0.05.

Glycemic Control
Glycemic control data are shown in Table 3. The results demonstrate that Glycosylated hemoglobin (HbA1c), cholesterol, triglyceride, and insulin were significantly decreased (P<0.05) after 12-wk of aquatic training in the AE group. However, there was no significant difference in these variables in the Control group. Also, no significant correlation were found between HbA1c and VO$_2$ max (r =.302).

### Table 3. Glycemic Control Data.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Aquatic Exercise Group (n=20)</th>
<th>Control Group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>After 12 wks</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>7.7±1.1</td>
<td>6.6±0.7*</td>
</tr>
<tr>
<td>Cholesterol (mg/dL)</td>
<td>231.6±30.0</td>
<td>221.0±29.6*</td>
</tr>
<tr>
<td>Triglyceride (mg/dL)</td>
<td>178.7±82.3</td>
<td>161.9±73.9*</td>
</tr>
<tr>
<td>Insulin (µU/mL)</td>
<td>23.6±4.1</td>
<td>22.5±3.4*</td>
</tr>
</tbody>
</table>

Values are mean ± SD. HbA1c; glycosylated hemoglobin. *represents statistical difference from pretest at P<0.05 and †represents statistical difference between groups at P<0.05.
DISCUSSION

The important findings in this investigation are that the AE program of 12-wk training enhanced health-related physical fitness and glycemic control in the T2DM subjects older than 60 yrs of age by reducing weight, percentage of body fat, and blood pressure while increasing VO\textsubscript{2} max and muscular strength. Also, there were improvements in HbA1c, cholesterol, triglyceride (TG), and insulin responses. Several studies (11,14,18) have shown that improved glycemic control is associated with decreased rates of chronic complication and cardiovascular diseases. For example, combined resistance and aquatic exercise training improved the subjects’ glycemic control, which is in agreement with Volaklis et al. (20). The AE group showed a significant difference in HbA1c when compared to the control group. It is clear that the AE training protocol represents a useful procedure to control glycemia of older subjects with T2DM.

Favorable changes in subjects with T2DM found in this study were decreased in body weight, percentage of body fat, and hemodynamic responses after 12-wk AE training that help protect against the risk factors for micro- and macrovascular diseases in type 2 diabetic patients associated with obesity, dislipidemia, and hypertension. In fact, regular aqua-aerobic exercise seems to be effective in reducing the level of triglycerides and lipoprotein cholesterol in patients with T2DM relates to weight loss (5). Previous study (20) reported improvements in total cholesterol and TG when compare to a dry-land exercise training. Weight loss has also been reported to lead to a decrease in insulin resistance (2).

In general, increasing physical activity intensity levels have proven to be effective in reducing blood pressure in the elderly (15). Changes in resting heart rate and blood pressure (systolic and diastolic blood pressures) at 12 wks of training in the AE group are consistent with the findings of an earlier study (8). This finding is consistent with the benefits of Aqua-aerobic exercise training as an excellent type of exercise to improve the hemodynamic responses of diabetic patients. This was demonstrated with the decrease of resting HR and the improvement in blood pressure in T2DM subjects. It may be due to the improvement in the sensitivity of the aortic baroreceptors, which contributed to a more efficient regulation of blood pressure (4,9,10). Furthermore, the hydrostatic pressure of being in the water may have helped to increase the venous return to the heart and thus improved the subjects’ blood circulation (6).

A significant increase in VO\textsubscript{2} max and grip strength were found at the end of the 12-wk of AE training. This should be viewed as a positive physiological response (in terms of cardiovascular disease). These changes may increase muscle mass and enhance blood flow in the muscle along with a reduction in body fat that helps to contribute to glucose tolerance in elderly patients with T2DM. Scientific reports (3,16,19) indicate that water training is an effective stimulus for increasing muscular strength, functional mobility, and it also produces the same energy expenditure in water as on land to maintain aerobic performance. During exercise (at 70% of MHR), recruited skeletal muscles require four- to fivefold more energy for contraction, using blood glucose, muscle glycogen, and fatty acids derived from adipose tissue as metabolic fuel (12).

CONCLUSION

Regular aqua-aerobic exercise training improved health-related physical fitness and glycemic control in T2DM subjects. Therefore, aquatic exercise is a recommended treatment for elderly patients with type 2 diabetes. Of course it must be individually adjusted to the physiological and metabolic limitations of each patient.
ACKNOWLEDGMENTS
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