

Research article

Effects of six months of combined aerobic and resistance training for elderly patients with a long history of type 2 diabetes

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Abstract

This study evaluated the effects of a 6-month combined aerobic and resistance training program on the body composition, glycemic control, lipid profile, and functional capacity of older patients with a long history of type 2 diabetes. 25 subjects (65.9 ± 4.2 yrs; M/F: 13/12) with a long history of type 2 diabetes (16.7 ± 6.7 yrs) were randomly allocated into either the exercise or control groups. The exercise group trained three sessions a week. Each session consisted of a warm-up period, 30 minutes of moderate aerobic exercise, 10 minutes of resistance training with five leg muscle exercises (two sets of 10-12 repetitions at 50-70% of 1RM for each activity), and a cool-down period. The variables of body composition, glycemic control, lipid profile, and functional capacity were measured before and after the study period. Exercise training decreased waist-hip ratio and body fat of the trained subjects. Concentrations of fasting and 2-hour post-glucose challenge plasma glucose and serum insulin, and glycosylated hemoglobin decreased significantly in the exercise group. Exercise training improved the lipid profile and also increased the leg muscle strength and 6-minute walking distance of the trained subjects. The control group, however, increased their body fat and fasting plasma glucose, while other variables were not changed during the study period. The current results demonstrate that elderly patients with a long history of type 2 diabetes can benefit from the 6-month combined aerobic and resistance training program.

Key words: Type 2 diabetes, exercise training, glycemic control, lipid profile, functional capacity.

Introduction

Exercise training has been shown to be a useful option to treat and prevent type 2 diabetes (Albright et al., 2000; Gill and Cooper, 2008; Ivy, 1997; Praet and van Loon, 2009). Therapeutic effects of exercise training in patients with type 2 diabetes include improvements in glycemic control (Loimaala et al., 2009; Maiorana et al., 2002; Sigal et al., 2007), cardiorespiratory function (Larose et al., 2010; Loimaala et al., 2009; Maiorana et al., 2002), body composition (Walker et al., 1999), lipid profiles (Cauza et al., 2005; Dunstan et al., 1997), and skeletal muscle function (Cauza et al., 2005; Larose et al., 2010; Taylor et al., 2009). Both aerobic and resistance training have been applied in exercise prescriptions and both of them have yielded benefits in patients with type 2 diabetes. Aerobic training improves maximal oxygen uptake (VO₂max) (Belli et al., 2011; Cauza et al., 2005), while resistance training increases muscle force and muscle

fiber size (Brooks et al., 2007; Cauza et al., 2005). Both training methods have been reported to improve blood glucose control and insulin sensitivity in patients with type 2 diabetes (Belli et al., 2011; Brooks et al., 2007; Cauza et al., 2005; Holten et al., 2004). Furthermore, some studies which used combined aerobic and resistance training have also reported positive outcomes for such patients (Larose et al., 2010; Loimaala et al., 2009; Maiorana et al., 2002). It has been stated in a meta-analysis that combined aerobic and resistance training has additional benefits for improving insulin sensitivity and decreases in both body mass and fasting blood glucose concentration compared with those of aerobic or resistance training by themselves (Snowling and Hopkins, 2006).

Boule et al. (2003) conducted a meta-analysis study of the effects of exercise training in patients with type 2 diabetes. Their findings indicated that patients in previous studies had a mean age of 55.7 years and a mean duration of type 2 diabetes of 4.1 years. To our knowledge, few studies have investigated the overall benefit of exercise training for even older patients with a long history of type 2 diabetes. In the present study, we recruited a group of elderly patients (> 60 years) with a long history of type 2 diabetes (> 10 years) and our aim was to assess the effects of six months of exercise training on their body composition, glycemic control, lipid profile, and functional capacity. A recent report indicated reduced skeletal muscle function in Asian patients with type 2 diabetes (Tajiri et al., 2010). That is why in the present study, we designed a combined aerobic and resistance training program to obtain the beneficial results of an aerobic program with additional attention to the skeletal muscular performance, so as to produce a wider range of benefits to our subjects' overall health. We hypothesized that this combined exercise training would produce beneficial effects for this group of subjects.

Methods

Subjects

Thirty elderly patients (65.9 ± 4.2 yrs) clinically diagnosed with type 2 diabetes were the subjects of this study. They were recruited via local medical practitioners. The average duration of their type 2 diabetes was 16 years. Diagnostic criteria for type 2 diabetes were: 1) a fasting plasma glucose concentration of 7.0 mmol·L⁻¹ or higher or 2) a plasma glucose concentration of 11.1 mmol·L⁻¹ or higher two hours after an oral glucose challenge (Ameri-

can Diabetes Association, 2010). All subjects took oral hypoglycaemic drugs but none of them were being treated with insulin when enrolled. Exclusion criteria were heart disease, resting blood pressure greater than 160/95 mmHg, pulmonary diseases, impaired renal or liver function, or unable to participate in the exercise training protocol due to an orthopedic or neurological limitations. Before the baseline outcome measures data were collected, a third-party randomly assigned the enrolled subjects into five 6-people groups. Groups 1, 3 and 5 were allocated into the exercise group ($n = 18$), while groups 2 and 4 were allocated to the control group ($n = 12$). The exact details of the study were described to the subjects and a written informed consent to the study was obtained from each of them. All methods and procedures of this study were approved by the Ethics Committee of Tianjin University of Sport, China.

Study design

Subjects in the exercise group underwent six months of supervised exercise training according to the specific requirements (see Exercise training program section), while subjects in the control group were required to maintain their individual habits of physical activities and refrain from engaging in any other forms of prescribed exercise training during the study period. Each subject's body composition, predicted $VO_2\max$, blood pressure, blood glucose and insulin concentrations, glycosylated hemoglobin (HbA_{1c}), plasma lipid profile, leg muscle strength, and walking ability were measured at the baseline test as well as after six months of intervention. The three exercise tests (i.e. $VO_2\max$, leg muscle strength, and walking ability) were measured on separate days. Under the supervision of the researchers, all tests and training sessions were conducted in the Exercise Physiology laboratory and the sports grounds of Tianjin University of Sport. Prescribed medication, at the usual dosage, was continued through the course of the study under the supervision of each subject's medical practitioner. Meanwhile, all of the subjects were required to maintain their normal diet during these six months.

Anthropometric measures

Each subject's body mass and height were measured. Body mass index (BMI) was calculated by dividing body mass (kg) by height in metres squared (m^2). The waist girth was measured at the level of the umbilicus horizontally without clothing, while the hip girth was measured at the level of the greatest protrusion of the gluteal muscles with underwear. Waist-hip ratio (WHR) was calculated. All of these measurements were conducted by the same researcher. Each of these measurements was conducted three times and the average was reported.

After 10-12 hours of fasting, the total body fat of each subject was measured using the GE Prodigy direct digital DEXA bone densitometry (GE Healthcare, USA) with the subject was lying supinely. By means of the standard soft tissue analysis provided by the same company, the total body fat (%) was determined as the proportion of the total amount of fat in the entire body mass.

Blood pressure measurement

After the subject had remained seated for 10 minutes, blood pressure was measured at the brachial artery by the auscultatory method. The first Korotkoff sound registered the systolic blood pressure and the last one was considered as the diastolic blood pressure. All of these measurements were carried out by the same researcher.

Maximal oxygen uptake

$VO_2\max$ was predicted in a submaximal exercise test on a cycle ergometer. After a warm-up period, the initial workload was set at the speed of 50 rpm for females and 60 rpm for males with a 0.5 kg resistance for three minutes. The workload increased 0.5 kg every three minutes until the heart rate reached 120 bpm, then the subject kept on pedalling for two more minutes. $VO_2\max$ was predicted using the Åstrand nomogram with the consideration of subject's heart rate, sex and age. A Monark ergometer and a Polar heart rate monitor (Polar Electro, Finland) were used in this test.

Blood tests

Fasting blood samples were taken. Blood glucose was determined by a glucose analyser (YS2300, Yellow Springs, USA). Serum insulin was measured by immunoassay (Access Immunoassay System, Beckman Coulter, USA). HbA_{1c} was measured by enzymatic method (Bio-Rad, Hercules, USA). Blood glucose and insulin were also measured at 120 minutes of an oral glucose tolerance test with a 75g glucose challenge. The total cholesterol, triglycerides and high-density lipoprotein cholesterol (HDL-C) concentrations were measured by a Cobas Integra Bio-analyser (Roche, USA) using the standard kits. Low-density lipoprotein-cholesterol (LDL-C) was calculated by using the Friedewald equation (Friedewald et al., 1972). The blood samples of the post-test of the exercise group were taken 72 hours after the last training session.

Leg muscle function

Leg muscle strength was assessed in the dominant leg of each subject. A Cybex-Norm Isokinetic Dynamometer was utilized to measure both the peak torques of isokinetic plantar flexion and dorsal flexion at velocities of 30°/s and 60°/s. The subject was placed in a supine position with the knee joint fully extended. Thigh and waist straps were used for body stabilization. The range of motion at the ankle joint was set between 90° to 115°. Following a familiarization and a warm-up, two sets of three maximal contractions were performed and the highest value of these six contractions was recorded as the peak torque at the given velocity. Two sets of exercise were separated by one minute of rest.

Walking ability

After a detailed explanation of the procedure to the subjects and a warm-up period, the 6-minute walk test was carried out on sports grounds. The distance in meters was reported.

Exercise training program

The exercise group underwent three training sessions per week on the sports grounds and in a gymnasium for six months. The training session consisted of a 10-minute

warm-up period, which included walking and jogging, as well as muscle stretches. This was followed by 30 minutes of interchanged walking/running with the intensity controlled within the individualised 55-70% predicted heart rate maximum (HRmax) ($=220 - \text{age}$). Then there was 10 minutes of resistance training which included five leg exercises (knee flexion, knee extension, hip abduction, hip adduction, and standing calf raise) with the individualized workloads at 50-70% of 1RM on the multiple-station universal resistance training equipment. Each exercise of the resistance training was performed as two sets of 10-12 repetitions. The intensity of both aerobic and resistance training was prescribed according to the American Heart Association scientific statement (Marwick et al., 1999). At the end of each training session, there was a 10-minute cool-down period which involved slow walking and gentle muscle stretches. Each training session lasted for one hour and was fully supervised by the researchers. Every subject wore a heart rate monitor during the aerobic training so as to maintain the correct training intensity.

Statistical analyses

All the values were presented as mean \pm SD. Paired Student's *t*-test was applied to test the changes in the measured variables within the groups. To evaluate the effects of exercise training, unpaired Student's *t*-test was used to compare the baseline data, as well as the changes in the measured variables after the interventions between the groups. Pearson's correlation was run among the changes in blood glucose and insulin concentrations, HbA_{1c}, body fat, WHR, leg muscle strength and walking ability. Alpha

level was set a 0.05. All analyses were performed using the SPSS Version 11.5 for Windows (SPSS Inc. USA).

Results

The results were based on the observations of 15 subjects in the exercise group and 10 subjects in the control group who completed the study. Five subjects (three of the exercise group and two of the control group) dropped out of the study because of private reasons. As for those who successfully completed the training program, there were no reported physical injuries related to the training sessions or testing. Random grouping did not result in significant differences in the variables between the groups at the baseline (Table 1 and Table 2).

Table 1. Base-line characteristics of the exercise and control groups. All data are presented in means (\pm SD).

Variables	Exercise (n=15)	Control (n=10)
Gender (M/F)	8/10	5/6
Age (yr)	65.9 (4.2)	64.8 (6.8)
Diagnosed with diabetes (yr)	16.7 (6.7)	15.4 (7.3)

There were no changes in body mass nor BMI of both groups following the 6-month interventions. Exercise training decreased WHR of the exercise group and the change in WHR was significantly different to that of the control group. The changes in body fat of the two groups were significantly different; the exercise group decreased their body fat, while the control group increased this variable during these six months. Exercise

Table 2. Changes in the measured variables before and after six months of interventions. Data are means (\pm SD).

Variable	Exercise (n=15)			Control (n=10)		
	Pre-test	Post-test	Change	Pre-test	Post-test	Change
Body mass (kg)	66.9 (8.5)	67.1 (9.1)	.2 (2.1)	68.4 (10.2)	68.1 (9.0)	-.3 (2.3)
BMI ($\text{kg}\cdot\text{m}^{-2}$)	25.2 (2.5)	25.3 (2.7)	.08 (.81)	25.8 (2.5)	25.8 (2.0)	-.10 (.87)
Body fat (%)	24.1 (6.6)	22.7 (6.5)	-1.3 (2.9)*	24.7 (5.6)	25.7 (5.7)†	1.0 (1.0)
Waist-hip ratio	.93 (.04)	.88 (.04)††	-.04 (.05)*	.90 (.05)	.92 (.07)	.02 (.04)
Systolic blood pressure (mmHg)	139 (17)	130 (19)†	-9 (14)	135 (15)	137 (18)	2 (18)
Diastolic blood pressure (mmHg)	74 (7)	73 (10)	-1 (9)	73 (9)	77 (5)	4 (7)
VO ₂ max ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	41.3 (8.9)	44.4 (6.3)	3.1 (8.9)	37.3 (6.8)	37.6 (6.8)	.3 (2.7)
Plasma glucose ($\text{mmol}\cdot\text{L}^{-1}$)						
Fasting	6.86 (1.40)	6.19 (1.47)†	-.66 (1.11)**	6.24 (1.66)	6.69 (1.73)†	.45 (.62)
2-hr postchallenge	13.9 (5.8)	9.83 (4.33)††	-4.03 (3.65)*	11.11 (5.26)	10.58 (4.41)	-.53 (3.19)
Serum insulin ($\mu\text{U}\cdot\text{ml}^{-1}$)						
Fasting	9.62 (3.23)	7.37 (2.65)†	-2.25 (3.11)	11.68 (4.30)	11.22 (4.79)	-.46 (1.13)
2-hr postchallenge	41.5 (18.5)	28.3 (11.2)††	-13.3 (11.4)**	49.0 (25.6)	50.0 (26.0)	1.0 (.8)
HbA _{1c} (%)	6.69 (1.08)	6.14 (.71)††	-.55 (.58)*	5.92 (.81)	5.98 (.63)	.06 (.46)
Total cholesterol ($\text{mmol}\cdot\text{L}^{-1}$)	5.47 (1.27)	4.47 (1.08)††	-.99 (.95)**	5.05 (.89)	5.41 (.96)	.36 (.54)
Triglycerides ($\text{mmol}\cdot\text{L}^{-1}$)	1.85 (.97)	1.45 (.54)	-.40 (.96)*	1.79 (1.07)	2.22 (1.21)	.43 (.75)
HDL-C ($\text{mmol}\cdot\text{L}^{-1}$)	.94 (.18)	.85 (.22)	-.09 (1.91)	.94 (.35)	.88 (.26)	-.06 (.26)
LDL-C ($\text{mmol}\cdot\text{L}^{-1}$)	4.17 (1.15)	3.33 (1.03)††	-.82 (.89)**	3.75 (.90)	4.08 (.74)	.34 (.70)
Peak torque of isokinetic plantar flexion						
at 30 degree $\cdot\text{s}^{-1}$ (Nm)	31.5 (18.5)	44.3 (20.2)†	12.7 (9.6)**	24.6 (14.7)	26.9 (13.1)	2.3 (6.4)
at 60 degree $\cdot\text{s}^{-1}$ (Nm)	15.3 (8.2)	25.2 (15.4)†	10.4 (16.3)	13.7 (11.6)	16.2 (11.3)	2.5 \pm 8.0
Peak torque of isokinetic dorsal flexion						
at 30 degree $\cdot\text{s}^{-1}$ (Nm)	14.5 (5.5)	17.9 (4.5)††	3.5 (5.3)	10.6 (5.7)	11.5 (5.5)	.9 (4.3)
at 60 degree $\cdot\text{s}^{-1}$ (Nm)	9.6 (3.5)	12.0 (4.6)†	2.6 (3.9)	8.6 (2.8)	10.9 (5.9)	2.3 (5.7)
6-min walk (m)	538 (56)	596 (52)††	58 (39)**	523 (50)	513 (54)	-11 (30)

BMI, body mass index; VO₂max, predicted maximal oxygen uptake; HbA_{1c}, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol. * $p < 0.05$; ** $p < 0.01$, comparison of the changes between the groups. † $p < 0.05$; †† $p < 0.01$, between the pre- and post-tests within the groups.

subjects decreased their systolic blood pressure after training, but the change was not different to that of the control group. There was no change in diastolic blood pressure in both groups. The trained subjects increased their VO_2 max by 11.5% at the end of the study, while the control subject only had 1.0% improvement in this variable. However, the difference between these changes was not statistically significant (Table 2).

Concentrations of fasting plasma glucose and fasting serum insulin were significantly decreased in the exercise group after training. The control group, however, increased their fasting plasma glucose during the experimental period. The changed amounts in fasting plasma glucose were statistically different between the two groups. In the oral glucose tolerance test, the concentrations of plasma glucose and serum insulin at two hours after glucose challenge were significantly reduced in the exercise group following six months of training. There were no significant changes in these concentrations in the control group. The changes in the 2-hour post-glucose challenge serum insulin were significantly different between the two groups. The HbA_{1c} was decreased in the exercise group but no significant change in the variable was found in the control group. The change in HbA_{1c} following the interventions were markedly different between the two groups (Table 2).

Exercise training decreased the concentrations of total cholesterol, triglycerides, and LDL of the trained subjects; the amounts of change in these variables were significantly different to those of the control subjects. Concentration of HDL remained the same in both groups after the experimental period (Table 2).

The exercise training program increased the peak torque of isokinetic plantar flexion and dorsal flexion both at 30°/s and 60°/s movements. However, only the change in the 30°/s plantar flexion was significantly different with that of the control group. The 6-minute walking distance was increased after exercise training and the change was significantly different with that of the control group. Muscle strength and 6-min walking distance did not change significantly in the control subjects (Table 2).

Correlation analyses showed that the amount of decreased WHR was associated with the changes in the 2-hour post-glucose challenge serum insulin ($r = 0.54$, $p < 0.05$), total cholesterol ($r = 0.59$, $p < 0.05$), and triglycerides ($r = 0.60$, $p < 0.05$). All other correlation analyses were not statistically significant ($p > 0.05$).

Discussion

The major finding of the present study was that six months of supervised combined aerobic and resistance training produced significantly therapeutic effects on body composition, glycemic control, lipid profile, leg muscle strength and walking ability in elderly patients with a long history of type 2 diabetes. The results support the hypothesis of our study.

Though body mass and BMI did not change following exercise training, a significant decrease in WHR and body fat was found in the exercise group. The control subjects experienced some increases in both such meas-

urements after the study period. The smaller WHR of the exercise group at the post-test might indicate a decrease in abdominal obesity. Evidence from the literature demonstrates that higher WHR or abdominal obesity heightens the risk of type 2 diabetes and is strongly associated with future glucose deterioration (Blaha et al., 2008), development of cardiovascular diseases (Cameron et al., 2009), and lower exercise capacity (Fang et al., 2005; Segerstrom et al., 2011) in patients. The results of our study suggest that the current exercise training program can be an effective treatment to reduce abdominal obesity in elderly patients with a long history of type 2 diabetes. This finding is supported by previous studies in people with short-term type 2 diabetes (Cuff et al., 2003; Maiorana et al., 2002). We also found that the decrease in WHR positively correlated with the improvement in the insulin-resistance state, as well as the decreases in plasma lipid profile of the patients. Decreased body fat but non-changed body mass of the trained subjects suggested that their lean body mass has been increased following training. This would be one of the reasons that led to the improved glycemic control of the exercise group, as skeletal muscle represents the largest mass of insulin-sensitive tissue (Maiorana et al., 2002).

We found an 11.5% increase in VO_2 max from the exercise group, which was very similar with the outcomes of other studies (Boule et al., 2003). Though it is not statistically significant in the present study, this outcome is still encouraging, as patients with diabetes with a low maximal exercise capacity may have higher mortality rates than those who are active and fit (Wei et al., 2000). Another study also reported that the increases in both diabetic retinopathy and urinary albumin excretion were associated with a decrease in peak VO_2 in people with type 2 diabetes (Estacio et al., 1998). Therefore, any increase in VO_2 max would be a favorable change for such patients. A possible explanation of the insignificant difference in VO_2 max between the groups may be the moderate exercise intensity used in the present study. It has been stated in a review that higher exercise intensity tends to produce larger improvements of VO_2 max in people with type 2 diabetes (Boule et al., 2003).

High blood pressure has been considered as one of the key risk factors associated with the development of type 2 diabetes (American Diabetes Association, 2010). The trained subjects of the present study decreased their systolic blood pressure by 9 mmHg, while the control subjects increased this variable by 2 mmHg following the interventions. However, the changes in this variable were not significantly different between the groups. The decrease in systolic blood pressure after exercise training is support by other studies in patients with type 2 diabetes (Christos et al., 2009; Jorge et al., 2011; Wagner et al., 2006).

The HbA_{1c} measure can represent average glycemic control over the preceding six to eight weeks (Kilpatrick, 2008). This long-term variable had a significant decrease in the exercise group of the present study. Many studies, which conducted the combined aerobic and resistance training in type 2 diabetes patients, also reported the same result (Church et al., 2010; Larose et al., 2010;

Maiorana et al., 2002; Sigal et al., 2007). However, two studies of elderly patients (average 63.4 yrs and 69.3 yrs) with type 2 diabetes did not find any change in HbA_{1c} after 16 weeks of combined aerobic and resistance training (Cuff et al., 2003; Tessier et al., 2000). Physiological complex of HbA_{1c} and the small sample sizes in these previous studies and the differences in the exercise training protocols may explain the differences in HbA_{1c} outcomes between our study and previous research. Our results suggest that exercise training can improve HbA_{1c} in elderly patients with a long history of type 2 diabetes.

Resting and 2-hour postchallenge blood glucose concentrations were also decreased in the exercise group of this study. More importantly, the decreases in the concentrations of glucose and insulin at 2-hour post-glucose challenge also correlated with improvement in insulin sensitivity. The enhancement of insulin-stimulated glucose transport in skeletal muscle would likely be one of the mechanisms for this outcome (Henriksen, 2002). Improved insulin action has also been found in people with type 2 diabetes and sedentary overweight people following four to eight months of exercise training (Slentz et al., 2009; Tokmakidis et al., 2004). The overall results of HbA_{1c}, blood glucose and insulin of our study suggest that even elderly patients with a long history of type 2 diabetes can improve their glycemic control after exercise training.

Dyslipidemia has been found in people with type 2 diabetes from a population-based, epidemiological study (Lorenzo et al., 2003). Previous studies have reported that exercise training improved lipid profile of people with type 2 diabetes. These benefits include decreases in total cholesterol, triglycerides, and LDL, and increase in HDL (Christos et al., 2009; Dunstan et al., 1997; Jorge et al., 2011; Lehmann et al., 1995; McAuley et al., 2002; Ronnema et al., 1988; Ruderman et al., 1979). The average age of the subjects of these studies was in the middle of fifty. Only two of these studies had elderly subjects (> 65 years), but the result from those elderly subjects was not reported separately by the authors (Lehmann et al., 1995; McAuley et al., 2002). In the present study, we found significant decreases in total cholesterol and LDL of the exercise group, while the control group showed an increase in both variables at the post-test. Our results indicate that combined exercise training can improve lipid profile of elderly type 2 diabetes patients with a long diagnosed history.

Patients with type 2 diabetes usually show lower muscle strength (Anderson et al., 2004; Park et al., 2006) and lower leg skeletal mass compared with non-diabetic people (Tajiri et al., 2010). This deficit in muscle function may lead to insulin resistance in these patients (Maiorana et al., 2002; Tajiri et al., 2010). The exercise training program in the present study helped improve the muscle strength of the elderly patients. This outcome agrees with previous studies of patients with type 2 diabetes (Christos et al., 2009; Larose et al., 2010), though the subjects of these studies were younger than the subjects in our study.

The Short Form-36 Health Survey (SF-36) is a self-administered health status assessment that is commonly used to measure the quality of life. People with

type 2 diabetes have shown very poor results in the physical component score of the SF-36 (Reid et al., 2010). This score is largely determined by people's walking ability. It is very possible that the increased walking ability of the subjects of the present study would markedly improve their quality of life. This opinion is supported by another study in elderly patients with type 2 diabetes (aged 69.3±4.2 years), in which 16 weeks of combined exercise training increased both walking ability and the attitude score of quality of life (Tessier et al., 2000). In addition, this improvement in walking ability may also be associated with a lower incidence of all-cause and cardiovascular disease mortality (Gregg et al., 2003).

The limitation of the present study was that only one exercise training program was applied. Therefore, we could not compare our results with those of other types of training nor analyze the dose-response relationship between the amount of exercise training and health benefits for such patients. The present outcomes only indicate that this exercise training program can help elderly people with long-term type 2 diabetes.

Conclusion

The outcomes of the present study showed that trained subjects achieved significant improvements in their body composition, glycemic control, lipid profile and functional capacity following the 6-month combined aerobic and resistance exercise training program. These results demonstrate that even elderly patients with long-term type 2 diabetes can obtain benefits from combined aerobic and resistance exercise training.

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Key points

- Exercise training is effective for elderly patients with long-term type 2 diabetes
- Exercise prescription for elderly patients with type 2 diabetes should contain both aerobic and resistance activities

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