Effects of physical training on metabolic control in elderly type 2 diabetes mellitus patients

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1. The specific role of physical activity in the treatment of type 2 diabetes is still subject to discussion. A randomized prospective study was performed, investigating both the influence of physical training on metabolic control and the feasibility of physical training in the elderly.

2. A total of 58 patients (mean age: 62±5 years; range: 55–75 years) with type 2 diabetes were randomized to either a physical training or a control programme. The training programme consisted of three sessions a week, aiming at 60–80% of the maximal oxygen uptake (VO₂max). The 12 week supervised period was followed by a 14 week non-supervised one. The control group followed an educational programme. VO₂max was assessed during exercise on a cycle ergometer. Glycosylated haemoglobin (HbAlc) was used as a measure for glucose control, and an insulin tolerance test was performed to test insulin sensitivity. Multivariate analysis of variance, with repeated measures design, was used to test differences between groups.

3. Fifty-one patients completed the study. VO₂max was higher in the training group than in the control group both after 6 weeks (P<0.01 between groups) and after 26 weeks [training group: 1796±419 ml/min (prestudy), 1880±458 ml/min (6 weeks), 1786±591 ml/min (26 weeks); control group: 1859±455 ml/min (prestudy), 1742±467 ml/min (6 weeks), 1629±504 ml/min (26 weeks)]. Blood glucose control and insulin sensitivity did not change during the study. Levels of total triacylglycerols, very-low-density lipoprotein-triacylglycerols and apolipoprotein B were significantly lower after 6 weeks (P≤0.01, P≤0.05, P≤0.05 between groups respectively), and so was the level of total cholesterol after 12 weeks of training (P≤0.05 between groups).

4. Physical training in obese type 2 diabetic patients over 55 years of age does not change glycaemic control or insulin sensitivity in the short-term. Regular physical activity may lower triacylglycerol and cholesterol levels in this group of patients.

5. Finally, physical training in motivated elderly type 2 diabetic patients without major cardiovascular or musculoskeletal disorders is feasible, but only under supervision.

INTRODUCTION

The prevalence of type 2 diabetes mellitus increases with age, and is consequently often diagnosed in the elderly [1, 2]. The pathogenesis consists of insulin resistance and impaired secretion of insulin, leading to hyperglycemia [3, 4]. Obesity and physical inactivity predispose people to type 2 diabetes [4, 5]. They are associated with hypertension, hyperlipidaemia and consequently with vascular disease [6–8].

In the past 15 years a number of investigators have studied the effects of regular physical activity on glucose tolerance [e.g. glycosylated haemoglobin (HbA1c)], insulin sensitivity and lipid profile [9–24] in type 2 diabetic patients, but the question of whether regular physical activity might be a tool in the management of the disease in this group of patients, who are mostly of advanced age, has not yet been fully answered. It is known that in addition to lowering blood glucose levels and increasing insulin sensitivity, exercise may also improve mild-to-moderate hypertension, lipid profile and excess weight. The high prevalence of insulin resistance and inactivity in the elderly have led to the question of whether regular physical activity can improve insulin resistance and consequently glucose tolerance in type 2 diabetic patients.

Physical activity is generally recommended in the management of diabetic patients. The National Institute of Health has published a consensus in which regular physical activity is advocated as an...
adjunct to diet in the treatment of type 2 diabetes [25]. However, most references are based on high-intensity training programmes in young and middle-aged male diabetic patients. Obviously this cannot be extrapolated to patients over 55 years of age, because serious doubts have been expressed about the feasibility of physical training in elderly type 2 diabetic patients [18, 23].

The purpose of this randomized controlled prospective study is to investigate the effect of physical training on fitness, glucose tolerance and lipid profile in obese type 2 diabetic patients over 55 years of age, who are rather advanced in their type 2 diabetes and under poor metabolic control. In addition, the feasibility of physical training in this particular group of diabetic patients is assessed.

Part of this study was presented at the European Association of the Study of Diabetes in Düsseldorf, Germany (1994) and the International Diabetes Federation in Kobe, Japan (1994).

METHODS

Subjects

Ninety-two type 2 diabetic patients, classified according to the criteria of the National Diabetes Data Group [26], were admitted to the study. They were recruited via advertisements in newspapers, a Diabetes Association paper, and on regional television. General practitioners were informed and were asked to refer patients. Inclusion criteria were: a known duration of disease of at least 1 year, a body mass index (weight/height$^2$) of more than 25 kg/m$^2$, treatment with at least oral glucose-lowering drugs or insulin, and an age of over 55 years. Reasons for exclusions were: angina pectoris grade II–IV (New York Heart Association criteria) or silent ischaemia, autonomic neuropathy, moderate or severe intermittent claudication, impaired renal function (serum creatinine more than 150 µmol/l), use of medication interfering with glucose metabolism or heart rate, except for their oral glucose-lowering drugs or insulin therapy, and presence of other major diseases. In phase 0 (prestudy), 34 participants were excluded because of cardiovascular disorders ($n = 8$), musculoskeletal problems ($n = 3$), other medical reasons ($n = 6$), expected non-compliance ($n = 13$), and social factors ($n = 4$). These patients were not different from the group studied as far as the characteristics of interest for this study were concerned. Thus, 58 patients were randomized to either a physical training group ($n = 30$) or a control group ($n = 28$). During phase 1 (physical training or control period), 5 patients of the training group were excluded from analysis: 1 patient underwent an embolectomy of the lower leg, 1 patient could not continue to participate because of back pain, and 3 patients missed more than 25% of the training sessions. Two patients of the control group were excluded: 1 patient because of hyperglycaemia, for which hospitalization was needed, and 1 patient due to non-cooperation. All patients were instructed to keep their usual diet and habitual physical activity. By means of a questionnaire the total group was classified post hoc into more active or less so, according to prestudy physical activity.

Patients who previously were treated with beta-blocking agents were switched to either angiotensin-converting enzyme inhibitors or calcium antagonists at least 4 weeks before the start of the programme. All women were post-menopausal.

All patients gave their written consent. The study was approved by the Ethical Committee of the Diakonessen Hospital Utrecht.

Study design

The study consisted of four phases. Phase 0 included the run-in period in which patients could apply for the study, and physical, laboratory and cardiovascular examinations were performed. After randomization the training group started physical training under supervision over a period of 6 weeks (phase 1). To avoid a study bias, the control group followed a concise education programme, but received no instructions concerning exercise. Phase 1 ended with physical and laboratory measurements and an exercise test. In phase 2, patients in the training group were encouraged to perform physical activity for another 6 weeks at home according to personalized training advice. After phase 2, physical and laboratory measurements were carried out again. In phase 3, lasting for 14 weeks, the training group patients trained at home, but without regular encouragement. This period ended with the same examinations as phase 0.

Schedule of measurements

Phase 0 included the following assessments: medical history, data on medication, alcohol consumption and smoking, physical examination, blood pressure after a 15 min rest while sitting on a chair (the mean of three measurements), weight and height, waist and hip circumference, skin-fold thickness measurements [27] and ophthalmologic examination. Laboratory measurements comprised: haemoglobin, haematocrit, creatinine, alanine aminotransferase, erythrocyte sedimentation rate, fasting glucose, HbaA$_1C$ (duplicate measurements), serum lipids (total cholesterol, very-low-density lipoprotein (VLDL)-cholesterol, low-density lipoprotein (LDL)-cholesterol, high-density lipoprotein (HDL)-cholesterol, total triacylglycerols, VLDL-, LDL- and HDL-triacylglycerols, apolipoprotein A1, apolipoprotein B), and C-peptide, fasting and after glucagon stimulation. Finally, a cardiopulmonary exercise test to detect coronary insufficiency, an exercise test to measure maximal oxygen uptake ($V_{O_{2, max}}$) and an insulin tolerance test [28] as a measure of insulin
sensitivity, were performed. Habitual physical activity was established by questionnaire [29], and diet recording by a 3-day record method. At the end of phase 1, blood pressure, body weight, waist/hip ratio and skin-fold thickness measurements were determined. The following laboratory examinations were done: fasting blood glucose, HbA1c (in duplicate), lipid profile, C-peptide, fasting and after glucagon stimulation, and the insulin tolerance test. In addition, determination of VO2max and diet recording were performed. In phase 2, anthropometric and laboratory measurements (HbA1c and lipid profile) were carried out. At the end of phase 3, measurements as mentioned in phase 0 were repeated, except the cardiovascular exercise test.

The VO2max measurements and laboratory parameters were performed within 72 h after the last bout of exercise.

Anthropometric measurements

Waist and hip circumferences were determined in the standing position using a flexible steel tape. The waist was measured as the smallest girth between the costal margin and iliac crests. The hip was measured as the circumference at the level of the great trochanters. Skin-fold thickness was measured in mm with a caliper at the triceps, biceps, subscapular (at an angle of about 45° to the vertical) and supra-iliac (in the mid-axillary line) sites, as described by Durnin and Womersley [27]. The mean of two measurements was taken as thickness of the area. In the case of skin-folds of more than 50 mm, 50 mm was taken as the value for calculations.

Cardiopulmonary and maximal exercise test (VO2max)

A standard graded cardiovascular exercise test with ECG and blood pressure monitoring was carried out on a cycle ergometer (Lode, Groningen, The Netherlands) before the study to detect coronary insufficiency and to provide all participants the opportunity to become familiar with the exercise equipment before measuring VO2max. The exercise test consisted of a 3 min 30 W warming-up period, followed by increments of the load of 30 W every 3 min until exhaustion or detection of severe ischaemia.

The maximal oxygen uptake exercise test was carried out with the same graded exercise protocol as the cardiovascular test. Every 1 min the pulse rate was recorded with a Sport-tester PE 3000® (Polar Electro Inc., Helsinki, Finland) in order to determine the maximal pulse rate with exhaustion. Expired gas was analysed with an oxycon-β analyser (Mijnhardt, Bunnik, The Netherlands). Oxygen uptake during the exercise test was defined as maximal not before at least three of the following four criteria were reached: (1) a plateau of maximal oxygen uptake in the face of an increasing absolute work load; (2) respiratory quotient (RQ = VO2/ VCO2) of more than 1.0; (3) ventilation equivalent (eqO2 = Ve/VO2) of more than 30; and (4) a maximal heart rate within the range of reference measurements (HRmax = 220 minus age ±10) [30].

Training schedule

The training group underwent the physical training programme under the supervision of a physician and a physiotherapist. The intensity of work was set at 60–80% of VO2max, monitored on the basis of the heart rate, and calculated individually on the basis of the exercise test. The training programme was based on the recommendations of the American Diabetes Association [31]. The patients were taught to measure their own pulse rate and encouraged to keep up the desired heart rate during each training session.

The training consisted of exercising major muscle groups (bicycle ergometer, swimming, treadmill, rowing etc.) three times a week over a period of 50 min, preceded and followed by warming-up and cool-down periods with stretching for at least 5 min (phase 1). During this 6 week period the group trained together under direct supervision. In phase 2 the patients trained at home individually, with frequent encouragement by means of direct contact or phone calls (once every 2 weeks) over 6 weeks. All patients received personal training advice, based on their preference and capabilities.

In the last phase the patients trained at home, without being contacted by the investigators.

Classification of physical activity

A validated standardized physical activity questionnaire for elderly subjects was used [29]. Briefly, the questionnaire consisted of scores in household activities, sporting activities, and other physically active leisure-time activities (e.g. cycling, gardening) performed in the previous 12 months. These scores, classified by an intensity code, together with data on the number of hours spent on the activity and the season of the year in which the activity was performed, resulted in a total activity score.

Feasibility of intervention

The feasibility of physical training was determined on the basis of three criteria: (1) attendance of participants at the exercise sessions; (2) number of drop-outs after randomization; (3) following of training advice in the third and fourth phase. Each patient of the training group received a training record book, in which they noted down their physical activities during these phases.
Insulin tolerance test and laboratory measurements

All patients were instructed not to take their oral agents at least 24 h before the insulin tolerance test and C-peptide measurements. Patients on insulin therapy were instructed to postpone the morning dose of insulin until after the test; when patients used intermediate acting insulin at night, they were asked to do the same. There were no patients on long-acting insulin.

The insulin tolerance test was carried out between 07.45 and 10.00 hours and performed as follows: after a 12 hour overnight fast a bolus of 0.1 units/kg body weight of regular insulin (Actrapid®, Novo Nordisk, Denmark) was injected in an antecubital vein. Venous blood sampling for glucose was carried out at -4 min, -2 min, just before and every 2 min after injection of insulin until 16 min. The percentage rate of decline in plasma glucose concentration per minute was determined from plasma glucose concentrations at 4–14 min after insulin injection. After the test a breakfast was provided. If necessary, glucose was injected before leaving the hospital. Blood samples for glucose were analysed by a glucose-dehydrogenase method.

HbA1c levels were measured by HPLC (Bio-Rad Laboratories, Richmond, CA, U.S.A.; reference range 4.5%–6.5%). Lipoproteins were isolated by sequential ultracentrifugation. EDTA-plasma (3 ml) was layered with 0.15 mol/l saline and centrifuged for 20 h at 105 000 g, according to the Lipid Research Clinics Programme [32]. Lipids were measured in the 3 ml bottom fraction. HDL-cholesterol was measured in the supernatant of the bottom fraction after precipitation of LDL with phosphotungstate/MgCl2 reagents [33]. Cholesterol and triacylglycerols were measured using Boeringer (Mannheim, Germany) reagents.

C-peptide was measured using the human C-peptide RIA kit (NOVO Research Institute, NOVO Biolabs, Bagsvared, Denmark). The method is a competitive RIA after precipitation of endogenous antibodies, with an inter-assay variation of 1.26 ± 8.1%.

Statistical analysis

Multivariate analysis of variance (MANOVA), with repeated measures design, was used to test differences within (time) and between groups. P < 0.05 was considered to be significant.

RESULTS

Clinical characteristics

The patients’ data on age, sex, duration of diabetes, body mass index, mode of therapy, smoking habits and physical activity score at the start of the study did not differ between groups (Table 1). Fifty-eight patients entered the study. In the end, data from 51 patients could be used for analysis. The drop-outs did not differ from the patients studied in any variable.

In the training group, 22 patients used antihypertensive drugs from the start until the end of the study. In the control group, 16 patients used antihypertensive medication at the start and 19 patients at the end. The median blood pressure (mmHg) did not change with time in the training group [157/88 (phase 0), 154/87 (phase 1), 145/90 (phase 2), 144/87 (phase 3)] or control group [155/90 (phase 0), 160/90 (phase 1), 153/90 (phase 2), 153/89 (phase 3)].

In both groups ten patients were on insulin therapy. Two more patients of the control group were using insulin at the end of the study. The total number of units of insulin in the basal state in the training group was 48.7 and in the control group 49.6 (P not significant between groups) and did not change significantly during the study. Seven patients used simvastatine (3 in the training group, 4 in the control group).

\( V_{O2\max} \)

All patients met the requirements for maximal oxygen uptake testing. Two patients did not perform the final test: one male of the control group because of a painful hip due to an activation of M. Paget and one female of the training group because of a painful knee.

The data for \( V_{O2\max} \) measurements and maximum work load during the cyclometer test are presented in ml/min and watts in Figures 1a and 1b. After 6 weeks of training, a significant difference in \( V_{O2\max} \) levels emerged between the training group and the control group (P ≤ 0.01). The difference remained significant until the end of the study (Figure 1a), although the training group relapsed to pre-study values and the control group values showed a decrease. The results for \( V_{O2\max} \) per kg body weight (ml min\(^{-1}\) kg\(^{-1}\)) were as follows: training group: 21.0 (prestudy), 22.0 (after 6 weeks) and 21.0 (after 26 weeks) and control group: 20.8 (prestudy), 19.6 (after 6 weeks) and 18.2 (after 26 weeks). The mean maximum work load increased in the training group, whereas the control group showed decreasing values after 6 weeks of training (P ≤ 0.001); the difference

<p>| Table 1. Patients characteristics of training and control group at the start of the study; means ± SD are given (except for smoking habits) |</p>
<table>
<thead>
<tr>
<th>Training group</th>
<th>Control group</th>
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<tbody>
<tr>
<td>Number (female/male)</td>
<td>30 (20/10)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>63 ± 5</td>
</tr>
<tr>
<td>Duration of diabetes (years)</td>
<td>6.6 ± 4.6</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>30.8 ± 4.0</td>
</tr>
<tr>
<td>Mode of therapy (oral/insulin)</td>
<td>20/10</td>
</tr>
<tr>
<td>Physical activity score</td>
<td>8.7 ± 5.2</td>
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<tr>
<td>Smoking habit (number of patients)</td>
<td>9</td>
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</table>
between the groups increased even more after 26 weeks ($P \leq 0.01$, Figure 1b).

**Blood glucose control**

Fasting blood glucose levels remained unchanged in both groups during the study (Table 2). Changes in HbA1c level did not differ significantly between groups after 6 or 26 weeks of training, although the training group tended to have a lower HbA1c after 26 weeks.

Significant differences in HbA1c levels were found between previous more active and previous less active patients: 8.6±1.2% and 9.1±1.3% (prestudy, $P \leq 0.05$) and increased after 6 weeks of training: 8.4±1.5% and 9.5±2.1% ($P \leq 0.05$) respectively (Figure 2).

**Insulin sensitivity and C-peptide levels**

The percentage rate of decline in plasma glucose concentration between 4 and 14 min after insulin injection did not change after 6 weeks of training in either group. The mean decline in blood glucose was 1.8±1.3%/min in the training group and 1.5±1.0%/min in the control group before training, 2.0±1.3%/min and 1.8±1.2%/min after 6 weeks, and 1.8±1.2%/min and 1.8±1.1%/min after 26 weeks respectively. The unbiased estimate of reliability of the three insulin tolerance test measurements together was 0.98 with a non-significant non-additivity.

Mean fasting C-peptide values in the two groups were not significantly different at baseline nor after 6 weeks (Table 2). The range of fasting C-peptide levels was 1.6 (0.0–1.6) ng/ml for the control group and 2.1 (0.0–2.1) ng/ml for the training group.

**Lipid profile**

Values of the lipid profile are presented in Table 2. After 6 weeks of training, significant differences between groups were measured for the total amount of triacylglycerols, VLDL-triacylglycerols and apolipoprotein B ($P \leq 0.01$, $P \leq 0.05$ and $P \leq 0.05$ respectively). These differences disappeared at the end of 26 weeks.

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**Table 2. Laboratory measurements in training group (TG, n = 25) and control group (CG, n = 26); means±SD are given. *$P \leq 0.05$, **$P \leq 0.01$ training compared with control group (MANOVA); #P$\leq 0.05$ compared with prestudy (MANOVA)**

<table>
<thead>
<tr>
<th></th>
<th>TG</th>
<th>CG</th>
<th>TG</th>
<th>CG</th>
<th>TG</th>
<th>CG</th>
<th>6 weeks</th>
<th>12 weeks</th>
<th>26 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1c (mean of duplicates) (%)</td>
<td>8.9±1.0</td>
<td>8.8±1.5</td>
<td>8.9±1.4</td>
<td>9.1±1.9</td>
<td>9.2±1.4</td>
<td>9.4±1.8</td>
<td>8.7±1.1</td>
<td>9.0±1.6</td>
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<tr>
<td>C-Peptide fasting (ng/ml)</td>
<td>0.93±0.64</td>
<td>0.97±0.39</td>
<td>0.88±0.52</td>
<td>0.86±0.44</td>
<td>0.9±0.7</td>
<td>0.9±0.7</td>
<td>0.9±0.2</td>
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<tr>
<td>Total cholesterol (mmol/l)</td>
<td>5.9±1.2</td>
<td>5.7±1.0</td>
<td>5.6±1.3</td>
<td>5.7±1.0</td>
<td>5.7±1.1</td>
<td>6.0±1.1</td>
<td>6.0±1.2</td>
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<tr>
<td>VLDL-cholesterol (mmol/l)</td>
<td>1.2±0.9</td>
<td>1.1±0.7</td>
<td>1.1±1.1</td>
<td>1.2±0.7</td>
<td>1.1±0.8</td>
<td>1.4±0.9</td>
<td>1.2±1.1</td>
<td>1.3±0.7</td>
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<tr>
<td>LDL-cholesterol (mmol/l)</td>
<td>3.7±0.9</td>
<td>3.7±1.1</td>
<td>3.5±0.9</td>
<td>3.6±0.9</td>
<td>3.6±0.8</td>
<td>3.7±1.1</td>
<td>3.7±1.1</td>
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<tr>
<td>HDL-cholesterol (mmol/l)</td>
<td>0.93±0.2</td>
<td>0.87±0.1</td>
<td>1.0±0.2</td>
<td>0.97±0.2</td>
<td>0.94±0.2</td>
<td>0.90±0.2</td>
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<tr>
<td>Total triacylglycerols (mmol/l)</td>
<td>2.4±2.4</td>
<td>2.5±1.3</td>
<td>2.2±2.9</td>
<td>2.5±1.5*</td>
<td>2.7±1.7</td>
<td>3.1±1.7</td>
<td>2.6±2.2</td>
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<tr>
<td>VLDL-triacylglycerols (mmol/l)</td>
<td>1.8±2.3</td>
<td>1.8±1.2</td>
<td>1.6±2.8</td>
<td>1.9±1.4*</td>
<td>2.2±1.6</td>
<td>2.5±1.6</td>
<td>1.9±2.0</td>
<td>1.8±1.1</td>
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</tr>
<tr>
<td>LDL- and HDL- triacylglycerols (mmol/l)</td>
<td>0.61±0.2</td>
<td>0.63±0.2</td>
<td>0.62±0.2</td>
<td>0.7±0.2</td>
<td>0.57±0.2</td>
<td>0.64±0.2</td>
<td>0.73±0.2</td>
<td>0.72±0.2</td>
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<tr>
<td>Apolipoprotein A-I (mmol/l)</td>
<td>1.4±0.2</td>
<td>1.3±0.2</td>
<td>1.4±0.2</td>
<td>1.4±0.2#</td>
<td>1.5±0.2</td>
<td>1.4±0.2</td>
<td>1.5±0.2</td>
<td>1.4±0.2</td>
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</tr>
<tr>
<td>Apolipoprotein B (mmol/l)</td>
<td>0.66±0.2</td>
<td>0.66±0.1</td>
<td>0.65±0.2</td>
<td>0.68±0.1*</td>
<td>0.65±0.2</td>
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<td>0.67±0.2</td>
<td>0.71±0.2</td>
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</table>
the study. After 12 weeks a significant difference appeared between groups concerning total cholesterol ($P \leq 0.05$), whereas the subfractions of cholesterol did not show any differences. The difference faded away after 26 weeks.

**Anthropometric measurements and energy intake**

Neither the mean waist circumference nor the waist/hip ratio changed significantly during the study (results not shown). Men showed a higher waist/hip ratio than women during the whole study ($P \leq 0.01$). No changes could be detected in the sum of four skin-fold thicknesses in either group during the study. Men had lower total scores than women ($P \leq 0.000$).

Body weight did not change in either group during the whole study period, but the total energy intake between the training group and the control group was significantly different after 6 weeks of training [training group: $7.95 \pm 3.0$ kJ (prestudy) and $8.27 \pm 1.7$ kJ (after 6 weeks) compared with control group: $7.17 \pm 1.7$ kJ (prestudy) and $6.66 \pm 1.8$ kJ (after 6 weeks); $P \leq 0.01$]. Significant changes were found between groups concerning the intake of protein [training group: $80.5 \pm 27.5$ g/day (prestudy) and $81.6 \pm 17$ g/day (after 6 weeks) compared with control group: $72 \pm 16.5$ g/day (prestudy) and $66.0 \pm 19.6$ g/day (after 6 weeks); $P \leq 0.01$], and carbohydrates [training group: $180.3 \pm 70$ g/day (prestudy) and $187.3 \pm 52.2$ g/day (after 6 weeks) compared with control group: $167.2 \pm 50.5$ g/day (prestudy) and $153.5 \pm 59.3$ g/day (after 6 weeks); $P \leq 0.05$]. The differences in dietary intake were related to exercise-induced hypoglycaemia and its prevention. No changes were found concerning fat composition, cholesterol content etc. after 6 weeks and at the end of the study within and between groups (results not shown).

**Physical activity score and feasibility of intervention**

The mean physical activity scores in the training group and control group did not differ from scores in elderly healthy subjects [29]. The mean physical activity score increased in the training group from $8.7 \pm 5.2$ (prestudy) to $13.2 \pm 5.5$ (after 6 weeks) and $12.6 \pm 6.2$ (after 26 weeks). In the control group the physical activity score did not change: $10.6 \pm 6.8$ (prestudy), $11.9 \pm 6.3$ (after 6 weeks) and $11.0 \pm 6.3$ (after 26 weeks).

Patients attended 97% of the training sessions (range 80–100%) during phase 1. After 26 weeks 16 of the 25 patients (64%) had followed the training advice. Twelve of them (75%) had become members of already existing exercise groups (e.g. fitness school, gymnastics for the elderly, swimming club).

**Somatic events during training**

During the training period 50% of the insulin-treated patients experienced post-exercise hypoglycaemia. Patients were instructed to decrease by 10% their dose of insulin preceding the activity session. Thereafter no patient experienced a further episode
of hypoglycaemia. As mentioned above, two patients had to leave the study, one because of progressive back pain and one patient because of vascular problems. No patient experienced clinically evident visual, renal or neurological deterioration.

At the end of the study one patient in the training group had a deterioration of his diabetes so that insulin therapy was started after the last measurements.

DISCUSSION

We studied the effects of physical training in elderly, obese type 2 diabetic patients, but did not find any short-term improvements in fitness, glucose tolerance or insulin sensitivity. Differences in lipid profile were found only after a period of intensive training on a regular and supervised basis. After the less intensive training period without supervision this difference was lost again.

Concerning the effects of physical training on glycaemic control we observed only a small, but not significant, difference in HbA1c levels between the training and control groups at the end of the study. From studies in physically trained healthy [34] and type 2 diabetic subjects [12] it was concluded that cumulative effects of individual bouts of exercise are responsible for a blunted insulin response to a glucose load, or lower plasma glucose levels after a glucose load (i.e. a better glucose tolerance). The beneficial effects of exercise on glycaemic control in these studies disappeared within 3 days after the cessation of exercise, although there were no changes as yet in VO2max and body fat. So, physiological changes such as in VO2max and muscle enzyme profiles may persist for weeks in trained individuals, whereas the effects on glucose tolerance are rapidly lost with a lower frequency of exercise. To achieve a continuous improvement in glycaemic control among type 2 diabetic patients a training programme consisting of at least three sessions a week was therefore suggested [12]. An explanation for the unaltered HbA1c levels in our training group, despite the use of such a training programme and despite the transient beneficial changes in VO2max, may be the duration of the intensive training period being only 6 weeks. The subsequent period of home training could have changed the HbA1c levels in a positive direction, if the type 2 diabetic patients had continued intensive training at a frequency of three times a week. From the activity record booklets we know that most patients trained only once or twice a week.

The idea that long-term training may be beneficial is supported by the fact that we found in already active diabetic patients significantly lower HbA1c levels at the start of the study. After 6 weeks of training the difference significantly increased between the groups. Nevertheless, we are aware of possible confounding factors, e.g. better diet and better compliance with treatment. In addition, this was not the end-point of our study. Previous studies have shown conflicting data about the effect of physical training on glucose tolerance [9–24]. A critical assessment of these studies was published recently [35]. Studies showing beneficial effects have high drop-out rates [12] or contain only small numbers of patients [10, 11, 13, 15, 16, 20]. People who are willing to influence their disease beneficially will be more eager to join a study than those who are not. Differences in disease progression could also influence the different outcomes. Finally, a publication bias could play a role. Nevertheless, in spite of conflicting results of studies which are difficult to compare, the benefit of the doubt lies with an improved glucose tolerance.

The VO2max and maximum load levels differed significantly between the training group and the control group after training. This small difference remained significant until the end of the study. However, this difference seems irrelevant, because no significant changes occurred within the training group. The study period was too short for age-related changes to occur. These results, combined with the above-mentioned results on glucose tolerance, suggest that the transient beneficial changes induced by intensive regular exercise in the first 6 weeks, as expressed in VO2max, probably need more time to attain and consolidate metabolic adaptations in obese elderly patients with a rather advanced type 2 diabetes. In patients who were 15 years younger and had only a mild glucose intolerance, periods of up to 6 months of supervised training were needed to secure improvement in fitness and, concomitantly, in glucose tolerance [36].

Although several studies have been published concerning the effects of physical training in type 2 diabetic patients, in only a few of them are the effects on lipid profiles reported [9, 14, 18–22, 24]. Most studies failed to detect a significant difference in total cholesterol or triacylglycerols. Wing et al. [21] demonstrated an improved lipid profile in elderly obese diabetic patients, but combined the physical training programme with dietary adjustments. Therefore, the beneficial effect could be due to changes in body weight or an altered food intake, instead of to the training itself.

In our study, significant differences were found between the two groups in levels of triacylglycerols, VLDL-triacylglycerols and apolipoprotein B after 6 weeks of training, and in total cholesterol after 12 weeks of training, although the change in absolute values was not impressive. HDL-cholesterol and the other subfractions did not change. The disappearance of the beneficial changes in the levels of lipids in the last phase of our study could be due to the fact that the patients were advised to train on their own. With less attention and encouragement, the motivation to exercise at least three times a week diminished, and consequently the levels of triacylglycerols and cholesterol returned to their initial.
values as was seen in the levels of \( V_{O_{2\text{max}}} \) at the end of the study.

In general, training studies performed in type 2 diabetic patients in the past 15 years are difficult to compare due to many differences in study design, in particular the duration and intensity of training. Because of these differences, it is difficult to make an unambiguous statement about the effects of training. It is known that long-term adherence to a regular exercise regimen for the elderly is generally poor [18, 23], although two Scandinavian studies reported a better compliance in middle-aged subjects [24, 37]. In our study, the attendance was high during the entire supervised part of the study. There were only a few drop-outs during the training, due to physical problems. It is noticeable that in the last phase, two-thirds of the patients continued with regular exercise and some of them became members of some kind of activity club. However, the frequency of the activity sessions became less in that period, suggesting that encouragement by health workers or physicians is important. Intensive contact with the investigators could have influenced the attendance score. Therefore, regular training under supervision is feasible in this particular group and may be effective when it is performed on a long-term basis. Without supervision compliance is likely to be low.

Should physical training be recommended for type 2 diabetic patients? Although this study illustrates the difficulties in introducing physical training at an advanced age in type 2 diabetes, and ultimately only some of the elderly patients are eligible for training, we would advocate, although with caution, physical training in this group of patients. Moreover, with diabetes mellitus itself being a risk factor for cardiovascular disease, in combination with obesity and a sedentary life-style, physical training may be of special importance in reducing the risk of cardiovascular disease.

In conclusion, our study has shown that physical training in obese type 2 diabetic patients over 55 does not change glycemic control in the short- and medium-term, although significant lower HbA1c levels in previously active type 2 diabetic patients suggest a beneficial role for physical training in the long-term. Besides, physical activity may reduce levels of triacylglycerols and cholesterol when performed on a regular basis, thus contributing to a reduced risk of cardiovascular disease. Finally, increasing physical training in motivated elderly type 2 diabetic patients without major cardiovascular or musculoskeletal disorders is feasible, but only when incorporated in a supervised programme.

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