Cost-sparing effect of twice-weekly targeted endurance training in type 2 diabetics: A one-year controlled randomized trial

J.-F. Brun\textsuperscript{a,b,c,*}, S. Bordenave\textsuperscript{a,b,c}, J. Mercier\textsuperscript{a,b,c}, A. Jaussent\textsuperscript{d}, M.-C. Picot\textsuperscript{d}, C. Préfaut\textsuperscript{a,b,c}

\textsuperscript{a} ER125, Inserm, 34000 Montpellier, France
\textsuperscript{b} EA 4202, UFR de médecine, université Montpellier-1, 34000 Montpellier, France
\textsuperscript{c} Service de physiologie clinique (CERAMM), hôpital Lapeyronie, CHU de Montpellier, avenue du doyen Gaston-Giraud, 34295 Montpellier cedex 5, France
\textsuperscript{d} Département de l’Information médicale (DIM), hôpital Arnaud-de-Villeneuve, 34295 Montpellier cedex, France

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Abstract

Objective. – We evaluated the effects of targeted, moderate endurance training on healthcare cost, body composition and fitness in type 2 diabetes patients routinely followed within the French healthcare system.

Design and methods. – A total of 25 type 2 diabetic patients was randomly assigned to one of two groups: 13 underwent a training programme (eight sessions, followed by training twice a week for 30–45 minutes at home at the level of the ventilatory threshold \(V_T\)); and 12 received their usual routine treatment. Both groups were followed for one year to evaluate healthcare costs, exercise effectiveness and a six-minute walking test.

Results. – The training prevented loss of maximum aerobic capacity, which decreased slightly in the untrained group (\(P=0.014\)), and resulted in a higher maximum power output (\(P=0.041\)) and six-minute walking distance (\(P=0.020\)). The Voorrips activity score correlated with both \(V_{O_{2\max}}\) (\(r=0.422, P<0.05\)) and six-minute walking distance (\(r=0.446, P<0.05\)). Changes in \(V_{O_{2\max}}\) were negatively correlated with changes in body weight (\(r=0.608, P<0.01\)). Training decreased the insulin-resistance index (HOMA-IR) by 26% (\(P<0.05\)). Changes in percentages of fat were correlated to changes in waist circumference (\(r=0.436, P<0.05\)). The total healthcare cost was reduced by 50% in the trained group (\(\€1.65\pm\€1.47\) per day versus \(\€3.00\pm\€1.47\) per day in the untrained group; \(P<0.02\)) due to fewer hospitalizations (\(P=0.05\)) and less use of sulphonylureas (\(P<0.05\)).

Conclusion. – Endurance training at \(V_T\) level prevented the decline in aerobic working capacity seen in untrained diabetics over the study period, and resulted in a marked reduction in healthcare costs due to less treatments and fewer hospitalizations.

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Résumé

Effets bénéfiques d’un entraînement en endurance ciblé, bihebdomadaire sur les coûts de santé dans le diabète de type 2 : étude randomisée d’un an.

Objectif. – Nous avons évalué les effets d’un entraînement en endurance modéré et ciblé sur les dépenses de santé, la composition corporelle et l’aptitude physique chez des diabétiques de type 2 suivis médicalement dans le système de santé français.

Matériel et méthode. – Vingt-cinq diabétiques de type 2 ont été randomisés et répartis en deux groupes : 13 ont suivi un programme d’entraînement physique (huit séances d’éducation à l’hôpital poursuivies à domicile par deux séances hebdomadaires de 30–45 minutes à une intensité correspondant au premier seuil ventilatoire \(V_T\)) et les 12 autres poursuivaient leur traitement habituel. Les deux groupes ont été suivis pendant un an avec une évolution des coûts de santé, des tests d’effort et un test de marche de six minutes.

Résultats. – L’entraînement a permis de conserver la capacité maximale aérobie qui a diminué significativement dans le groupe non entraîné (\(P=0.014\)), la puissance maximale (\(P=0.04\)) et la distance parcourue au test de marche de six minutes (\(P=0.02\)) étant plus élevées chez les sujets

* Corresponding author.
\textit{E-mail address: drjfrbrun@dixinet.com} (J.-F. Brun).
1. Introduction

As a sedentary lifestyle is a major determinant of the occurrence and progression of type 2 diabetes [1,2], exercise training has therefore emerged over the past few decades as a key factor in diabetes management. A recent meta-analysis of 87 studies of the effects of exercise programmes in patients with type 2 diabetes [3] carried out between 1988 and 2004 showed that exercise moderately improves HbA1c and VO2max, and exerts a small positive effect on fasting blood glucose and cholesterol, while effects on HDL- and LDL-cholesterol subfractions is less evident. The meta-analysis also showed that aerobic exercise is more beneficial than resistance exercise for HbA1c. In general, exercise appears to be beneficial for patients with overt type 2 diabetes, and these results support the idea that exercise is an essential adjunct to diabetes treatment that can both reduce the need for antidiabetic drugs and work in synergy with them. However, making diabetics take regular exercise is always a challenge [4–6] and so, in everyday medicine, it is easier for physicians to simply prescribe drugs rather than long-term lifestyle changes.

Most studies of an exercise programme for diabetics apply an exercise intensity based on a fixed percentage of the VO2max, usually ranging from 40 to 75%. In other fields of medicine, more specific targeting that takes into account individual patient characteristics has been shown to improve the efficiency of training. For example, in patients with chronic airways limitation, targeting the level of the ventilatory threshold (VT) has proved to be more efficient than training at 50% of the maximum heart rate [7]. Such targeting has, until now, rarely been investigated in type 2 diabetes. Furthermore, due to marked differences in diet and exercise across different countries, there is a need for specific studies to investigate this issue on a national basis. This is particularly the case for France, where the relationship between lifestyle and disease exhibits a relatively atypical picture [8,9].

For these reasons, this controlled randomized trial was undertaken to evaluate the effects of one year of “realistic” (twice weekly) endurance training targeting the VT, on health-care costs to the French healthcare system and, as explanatory variables, on fitness outcomes, body composition, diabetes treatments and metabolic balance.

2. Materials and methods

2.1. Study participants

Twenty-five patients with type 2 diabetes routinely followed by their general practitioner were recruited into the study. Diabetes was defined according to the 1997 American Diabetes Association diagnostic criteria [10]. Patients were eligible for the study if they were aged 40–85 years and if they fulfilled the following criteria:

- treatment with oral hypoglycaemic agents or diet alone, and not with insulin therapy;
- HbA1c level between 8 and 10%;
- no change in any medication for the past three months;
- no history of ketoacidosis.

Patients with congestive heart failure, a recent episode of ischaemic heart disease, peripheral vascular disease, current malignancy, chronic renal failure, severe proliferative diabetic retinopathy or any physical and mental conditions that may have an influence on the ability of the patient to participate in the intervention were excluded. The study protocol was approved by the institutional review board of the University Hospital of Montpellier. All patients gave their informed consent to participate in the study.

2.2. Body composition

The patients were measured, weighed on a Sartorius F1505-F2 balance scale and had their waist circumference measured at the umbilicus. Body composition was assessed with a four-terminal impedance plethysmograph (Dietosystem Human IM-Scan, Milan, Italy), which minimizes contact impedance and skin-electrode interactions. Measurements were taken in fasting patients after 15 minutes of rest in a supine position. A low-intensity (100–800 μA) current was introduced at various frequencies (1, 5, 10, 50 and 100 kHz), and measurement of the voltage drop allowed determination of the total body impedance rate. These values are then used with specially designed software to calculate body water (intra- and extracellular), fat mass, fat-free mass and body cell mass.
2.3. Exercise testing

The patient’s $V_{O2\text{max}}$ was measured during 8–12 minutes of exercise performed on an electronically braked cycloergometer (550 ERG, Bosch, Germany). During exercise, gas exchanges were measured breath by breath, using a mass spectrometer (Marquette MGA 1100, France). The calibration of the mass spectrometer was checked before each test with standard calibration gases. A 3-L syringe was used to calibrate the volume turbine, using flow rates similar to the patient’s ventilation. Heart rate was monitored throughout the exercise test, which started with a six-minute warm-up at 20% of the theoretical maximum power output. The workload was then increased by steps of 8% of $P_{max}$ per minute until the maximum exercise level was reached, which was then evaluated in terms of maximum heart rate, respiratory exchange ratio (RER) (> 1.15) and $O_2$ consumption ($V_{O2}$) stability. The results of this test were used to determine the ventilatory threshold according to the method used by Beaver et al. [11,12]. The maximum theoretical oxygen consumption ($V_{O2\text{max},th}$) and, thus, the theoretical $P_{max}$ were also calculated, according to Wasserman’s equations [13]. Criteria for defining $V_{O2\text{max}}$, and $V_{T}$ were taken from the standardization consensus guidelines of the French Society of Sports Medicine [12,14], downloadable at http://www.sfms.asso.fr.

The six-minute walking shuttle test (6 MWT) was conducted as described by Guyatt et al. [15]. Using a corridor in the outpatients clinic, a 15-meter course was marked out, placing a chair at each end. The decision whether the patient was fit enough to take the 6 MWT was made by the attending cardiologist. Patients were instructed to walk at their own pace from end to end while attempting to cover as much ground as possible in the allotted six-minute time period. A physiotherapist clocked the walking and called out the time every two minutes, while also encouraging the patient on. Patients were allowed to rest, but were instructed to carry on walking as soon as they were able to do so. After six minutes, patients were instructed to stop walking, and their total distance was measured to the nearest meter. Any symptoms experienced by the patient during this test were also recorded. Blood pressure was measured before and after the test.

2.4. Questionnaires and cost evaluation

Physical activity level was assessed using the Voorrips questionnaire [16]. Questionnaires of quality of life were also applied — namely, a French translation of the Nottingham Health Profile (NHP) [17], and a French translation of the Diabetes Quality of Life (DQOL) questionnaire [18], adapted into a useful tool by Renard et al. [19,20]. This has been shown to be suitable for people with type 2 diabetes [21], and consists of 46 items divided into three subsections: patient satisfaction, diabetes impact and diabetes-related worries, including anticipated diabetic effects and social considerations. Answers are given according to a 5-point Likert scale, ranging from 1 (very satisfied, not affected, no worries) to 5 (very dissatisfied, very affected, very worried) [18,20].

Healthcare costs were measured over the study period (one year), based on the number and duration of hospitalizations, number of outpatient consultations with the family physician or specialists, drugs prescribed and analyses performed. This information was obtained from the patients as well as hospital healthcare files. There was also the intention to measure indirect costs (such as periods of not working, job loss and unemployment), but none of these events occurred to any patient in the study period. However, this cost analysis did not include the educational expenses incurred by the patients’ training.

2.5. Training intervention

This was a parallel-group, randomized trial. On Day 1, patients were randomly assigned to one of two groups using a computer-generated list of random numbers. In the intervention group, patients were told to follow the training programme while, in the control group, the intervention consisted of repeated evaluation of fitness, healthcare cost assessment and metabolic parameters. Patients in both groups continued to be managed by their own primary-care physician, and there was no study interference with the physicians’ therapeutic choices. The only modification from the study was the addition of structured exercise training in the intervention group. All treatments, health events and hospitalizations were recorded by the investigators at each visit for calculation of the healthcare costs.

The structured training programme comprised of an educational period of one month, followed by training at home. The educational period involved eight two-hour sessions over four weeks, when a trained professional, during the first hour, explained to the patient the purpose of the training and how it should be performed. The second hour was devoted to actually learning the exercise that the patient had to perform — in this case, cycling at the level of the ventilatory threshold for 30–45 minutes at a time. After this learning session, the patient had to train at home twice a week at a level defined by heart rate. All participants performed, at their own convenience, brisk walking, jogging or gymnastics for 45 minutes at this target heart rate, as determined by a heart-rate monitor.

To ensure “realistic” conditions of training, the actual practice of the physical activity was recorded: everyday, patients had to keep track of all their activity in a notebook, and fill in Voorrips questionnaires on Days 120, 240 and 365.

Both study groups were followed over the course of the year by evaluations at 30, 120, 240 and 365 days to determine healthcare costs, blood pressure, spirometry, glycaemic and lipid equilibrium, 6 MWT, and exercise [16] and QOL questionnaires. A further maximum-level exercise test to determine $V_{O2\text{max}}$ and ventilatory threshold was performed at Day 0 and Day 365 as described above.

2.6. Statistical analyses

Data are shown as means ± S.E.M. As variables derived by the Shapiro–Wilk test appeared to display a non-normal distribution, comparisons were made using non-parametric tests (Wilcoxon’s). Results were considered statistically significant if the $P$ value was less than 0.05. All analyses were performed with SAS software, version 6.11.
Anthropometric, ergometric and metabolic parameters measured in the untrained versus trained diabetic patients at the beginning and end of the study

<table>
<thead>
<tr>
<th>Untrained</th>
<th>Trained</th>
<th>Intra- and intergroup comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 0</td>
<td>Day 365</td>
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<tr>
<td></td>
<td>Day 0</td>
<td>Day 365</td>
</tr>
<tr>
<td>Gender ratio F/M</td>
<td>5/7</td>
<td>4/9</td>
</tr>
<tr>
<td>Duration of diabetes (years)</td>
<td>10.3 ± 1.7</td>
<td>10.3 ± 1.7</td>
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<tr>
<td>Age (years)</td>
<td>60.6 ± 1.8</td>
<td>58.9 ± 3.6</td>
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<tr>
<td>Height (cm)</td>
<td>167.56 ± 12.16</td>
<td>168.17 ± 8.13</td>
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<tr>
<td>Weight (kg)</td>
<td>94.96 ± 25.09</td>
<td>90.13 ± 29.5</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>32.76 ± 6.19</td>
<td>32.82 ± 7.65</td>
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<tr>
<td>Fat-free mass (kg)</td>
<td>63.44 ± 8.87</td>
<td>64.03 ± 11.5</td>
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<tr>
<td>Fat mass (kg)</td>
<td>35.4 ± 7.8</td>
<td>36.13 ± 11.6</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>8.83 ± 1.38</td>
<td>8.56 ± 1.5</td>
</tr>
<tr>
<td>Waist circumference</td>
<td>110.65 ± 16.3</td>
<td>112.54 ± 12.9</td>
</tr>
<tr>
<td>Hip circumference</td>
<td>111.32 ± 12.9</td>
<td>108 ± 17.7</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>130 ± 22</td>
<td>134.4 ± 16.7</td>
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<tr>
<td>BP diastolic</td>
<td>76.15 ± 11.39</td>
<td>66.11 ± 22.3</td>
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<tr>
<td>Fasting insulin (µU/mL)</td>
<td>6.66 ± 3.2</td>
<td>10.6 ± 13</td>
</tr>
<tr>
<td>Fasting blood glucose (g/L)</td>
<td>1.68 ± 0.4</td>
<td>1.73 ± 0.56</td>
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<tr>
<td>HOMA-IR</td>
<td>2.75 ± 0.59</td>
<td>4.34 ± 12.2</td>
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<tr>
<td>Triglycerides (g/L)</td>
<td>1.36 ± 0.63</td>
<td>1.25 ± 0.66</td>
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<tr>
<td>HDL cholesterol (g/L)</td>
<td>0.51 ± 0.14</td>
<td>0.61 ± 0.15</td>
</tr>
<tr>
<td>LDL cholesterol (g/L)</td>
<td>1.04 ± 0.31</td>
<td>1.14 ± 0.64</td>
</tr>
<tr>
<td>V̇O₂max (mL/min/kg)</td>
<td>15.5 ± 1.2</td>
<td>12.7 ± 2.0</td>
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<tr>
<td>V̇O₂max (mL/min/kg fat-free mass)</td>
<td>24.1 ± 2.2</td>
<td>20.1 ± 2.1</td>
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<tr>
<td>V̇O₂max (% theoretical value)</td>
<td>78.41 ± 14.6</td>
<td>65.52 ± 18</td>
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<tr>
<td>V̇O₂ (% theoretical V̇O₂max)</td>
<td>49.35 ± 11.7</td>
<td>49.87 ± 14.2</td>
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<tr>
<td>VO2max score</td>
<td>3.57 ± 2.31</td>
<td>4.34 ± 3.3</td>
</tr>
<tr>
<td>Difference in VO2max score</td>
<td>99.8 ± 47.7</td>
<td>69.7 ± 33.5</td>
</tr>
<tr>
<td>Maximum power</td>
<td>1247 ± 278</td>
<td>1247 ± 278</td>
</tr>
<tr>
<td>Difference in maximum power reached</td>
<td>–22.6 ± 30.06</td>
<td>–22.6 ± 30.06</td>
</tr>
<tr>
<td>Walking distance</td>
<td>461 ± 26</td>
<td>458 ± 23</td>
</tr>
<tr>
<td>Total cost (€/day)</td>
<td>3 ± 1.47</td>
<td>1.65 ± 1</td>
</tr>
<tr>
<td>Number of days of hospitalization</td>
<td>1.27 ± 2.2</td>
<td>0</td>
</tr>
<tr>
<td>Total cost of hospitalization (€)</td>
<td>1102.56 ± 2010.29</td>
<td>0</td>
</tr>
</tbody>
</table>

ns: not significant.

3. Results

3.1. Baseline characteristics

Baseline clinical and demographic characteristics did not differ significantly between the intervention and control groups (Table 1). Overall, patients had a mean age of 59.7 ± 2 years, diabetes duration of 10 ± 4 years and an HbA1c of 8.86 ± 0.27%. Also, 26% of the participants were women, 60% were obese (defined as a body mass index [BMI] greater than 30 kg/m²), and 32% were overweight (BMI of 25–30 kg/m²).

On entering the study, the participants appeared to have similar values of HbA1c (8.8% ± 1.38 versus 8.77 ± 0.98%), fasting blood glucose, weight, height, BMI, waist circumference and blood pressure.

3.2. Lifestyle and fitness outcomes

There were training-related differences in parameters assessing the level of physical activity and the ability to exercise. The V̇o2max score (Fig. 1A), which was similar between the two groups at baseline, increased (5.25 ± 3.3, P < 0.001) two-fold in the trained patients compared with the untrained controls (9.5 ± 4.20 versus 4.26 ± 2.38, respectively; P = 0.001).

The maximum power achieved during the exercise test (Pmax) did not differ at baseline, but tended to decrease in the untrained subjects and to increase in the trained patients; the differences in both its evolution (P = 0.041) and absolute values on Day 365 (P = 0.018) were significant (Fig. 1C).

The V̇o2max exhibited the same pattern, which was not significant on looking at the raw data, but became significant when expressed as a percentage of the theoretical value expected according to age and anthropometric data (V̇o2max (% theor)). This parameter decreased in the untrained subjects (P = 0.014), but was maintained in the trained group, so that values on Day 365 were higher in trained versus untrained subjects (85.8 ± 14.7% versus 65.52 ± 18%, respectively; P = 0.015) (Fig. 1B). The six-minute walking distance was also higher in the trained versus control group (472.2 ± 98.9 m versus 547.6 ± 56.7 m, respectively; P = 0.020) at the end of the study (Fig. 1D). In addition, there was a significant correlation between the V̇o2max and both the V̇O₂max (r = 0.44, P < 0.05; Fig. 2A) and six-minute walking distance (r = 0.446, P < 0.05; Fig. 2B).
3.3. Body composition and metabolic outcomes

As shown on Table 1, there was no significant change in body composition (body weight, body fat, waist circumference, waist-to-hip ratio) in the trained group, whose values remained statistically similar to those of the controls. Changes in \( V_{O2\text{max}} \) were negatively correlated with changes in body weight \( (r = -0.46, P < 0.05; \text{Fig. 2C}) \) and changes in the percentages of fat were correlated with those for abdominal fat, as evaluated by waist circumference \( (r = 0.44, P < 0.05) \).

Blood pressure, lipid profile and glycaemic control did not significantly improve during the study in either group. The only significant physiological result was the 26% decrease in insulin resistance (HOMA-IR), from \( 3.39 \pm 0.76 \) to \( 2.58 \pm 0.47 \) \( (P < 0.05) \), in the intervention group, while this index tended (non-significantly) to increase in the controls \( (r = 4.4, P < 0.05) \).

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3.4. Quality of life (QOL)

QOL assessment by the NHP revealed no significant changes, despite a non-significant tendency towards a higher NHP score for mobility \( (P = 0.81) \). In contrast, the DQOL revealed an increase in well-being with physical training \( (2.846 \pm 0.38 \text{ versus } 2.250 \pm 0.75, P = 0.019) \).

3.5. Healthcare costs

While the trained group required no hospitalizations, the controls spent \( 1.27 \pm 2.20 \) days in hospital \( (P = 0.047) \) (range: 0–5 days, corresponding to a mean total cost of €1102.56 ± 2010.29). The total cost of healthcare over the study year dropped by 50% in the trained group \( (€1.65 \pm 1 \text{ per day versus } €3 \pm 1.47 \text{ per day; } P = 0.018) \), as shown on Table 1. The difference in disease-related costs after versus before the study was \( €0.23 \pm 0.33 \) per day in the untrained group versus \( €0.008 \pm 0.27 \) per day in the trained group \( (P = 0.002) \).

Although the decrease in total cost could be quantitatively, almost entirely explained by the lack of hospitalizations, another additional cause of cost-savings is that fewer courses of various treatments were prescribed by the patients’ physicians. However, the only significant reduction was a decrease in sulphonylurea treatments \( (−13.7 \pm 6\%, P < 0.05) \), although the intervention group did enjoy other reductions of treatment (metformin, acarbose, insulin) to account for the overall positive result.

This treatment reduction, in addition to explaining some of the cost-lowering effects of the intervention, also explains the HbA1c and blood pressure stability (considered satisfactory by
the physicians, which led to less treatment when the exercise training made it unnecessary).

4. Discussion

This study is part of a wider study investigating the effects of exercise training at the level of $V_T$ on healthcare costs for chronic diseases that included 112 patients: 45 with chronic obstructive pulmonary disease (COPD), 32 with chronic heart failure, and the 25 with type 2 diabetes (on whom we focused in the present study). Preliminary results from the 80 patients in the three subgroups have already revealed an overall cost-savings effect of the targeted training [22]. Also, the comprehensive results from the diabetic subgroup presented here confirm the initial findings. They show, for the first time within the French healthcare system, that endurance training at the level of $V_T$ results in significant reductions in healthcare costs, and prevents the rapid progressive decline in aerobic working capacity seen in the untrained diabetics over the year-long period of observation.

As part of the study protocol, there was no interference with the blood pressure and glycaemic control that was routinely followed by the patients’ own physicians. Although glycaemic control failed to achieve the targets given in the current guidelines, it was considered satisfactory by the physicians; for example, HbA1c remained within the 8–9% range. When blood pressure, blood glucose or serum lipid values appeared to further decrease, treatments were often reduced or withdrawn, as shown by the results in the section above. This explains, on one hand, why there was no significant improvement in glycaemic control, blood lipids or blood pressure, yet it does, on the other hand, explain the reduction in costs.

Indeed, the main finding of the present study was the marked reduction in healthcare costs. This was due to a reduction in treatment (mostly of sulphonylurea) and the lack of hospitalization. Although a true explanation of the cost reduction is multifactorial, this finding, which was also the primary endpoint of the study, is highly significant.

It may be that the picture of type 2 diabetes is changing, and that type 2 diabetics treated according to the current guidelines would benefit from tighter glycaemic control aimed at maintaining their HbA1c to less than 7%, with most patients treated by insulin analogues. In fact, a similar study performed in 2007 is likely to yield similar findings despite the use of novel treatments and more aggressive therapeutic targets. Moreover, the wider use of more expensive treatments (glitazones, rimonabant, incretins and DDP4 inhibitors) would certainly increase...
the costs of non-exercising patients, making exercise even more beneficial in terms of cost-savings.

Nevertheless, the costs of the exercise testing and the training follow-up have not been included in our calculations. In addition, in patients with coronary heart disease or autonomic neuropathy, closer medical supervision of the training may be required, and such an additional cost has also not been included in our calculations.

In 2004, a survey involving 1,136,172 diabetics across France [23] concluded that €5910 per year — or €16.2 per day — was the healthcare cost of the average diabetic (lumping types 1 and 2 together). In 1999, a similar study had determined this cost to be €3780 per year — or €10.3 per day [24]. A similar study in the United States in 2002 yielded an almost two-fold higher cost of $13,243 per year — or $36.3 per day [25]. When comparing these costs with those of the patients in our present study, it is clear that our diabetics were less expensive than the average patient with diabetes. This means that our patient selection for the study excluded the most costly ones. The protocol included two maximum-level exercise tests that eliminated diabetics with severe complications such as neuropathy, nephropathy or CHD. Nevertheless, an easier protocol, performed with great care, might also be beneficial in terms of improving general health and, therefore, healthcare costs in more severe cases of type 2 diabetes.

Although the therapeutic efficacy of an aggressive lifestyle intervention in diabetes has been well demonstrated, our study focused instead on a more realistic training programme, consisting of only one month of education (eight sessions) followed by home-based activity twice a week. The results showed, however, that even this rather minimal programme was effective, as reflected by the reduction in healthcare costs.

An interesting finding was the significant decrease in fitness outcomes seen over the study year in the controls. $O_{2\text{max}}$ decreased during this time by 16.4%, and $P_{\text{max}}$ by 30%. Although it is well accepted that diabetes is a progressive disease [26], such a rapid decline serves to highlight the “vicious circle” of a sedentary lifestyle not only evident in respiratory diseases, but in all chronic diseases [27], and characterized by rapid deterioration even at the stage of disease where patients are comparatively healthy. In this regard, it is noteworthy that our “realistic” lifestyle intervention, albeit not particularly aggressive, was nonetheless able to prevent such a decline.

Although training-induced modifications in body composition did not reach statistical significance in our study, correlations between fitness outcomes and fatness were in agreement with previous studies showing the benefits of endurance training on abdominal obesity [28]. We found that changes in $O_{2\text{max}}$, were negatively correlated, and so, inversely proportional to body weight, with variations due to fat mass — apparently mostly involving abdominal fat, as measured by waist circumference. These correlations might be explained as follows. As the moderate training in the present study did not significantly increase $O_{2\text{max}}$, it did not significantly affect fat mass, which remained unchanged. In contrast, the decrease in $O_{2\text{max}}$ as seen in the untrained group, was paralleled by changes in body composition that led to increased abdominal fat.

In addition, the 26% decrease seen in both fasting insulin and HOMA-IR index may suggest to some extent that, in accord with other studies, the training protocol we used enhanced insulin sensitivity. However, our patients were overt diabetics, and the HOMA, which is a reasonable index of insulin resistance in non-diabetic sedentary individuals [29], becomes less reliable in such patients [30]. Therefore, no definitive conclusions as to the effects of this moderate training protocol on insulin resistance can be drawn from this observation. Interestingly, however, the improvement in fasting insulin and HOMA-IR appears to contradict the non-significant tendency towards worsening in the controls, which may have been a further sign of the worsening of various physiological parameters such as $O_{2\text{max}}$ over the short study period.

This was the first training protocol to target the $V_T$. None of the studies included in the meta-analysis by Snowling and Hopkins [3] used such a target. Usually, a fixed percentage of the theoretical $V_{2\text{max}}$ and/or maximum heart rate is used. In other fields of medicine, the superiority of more personalized targeting after exercise-testing is well established. $V_T$, as a “threshold of dyspnoea”, is the level chosen for cardiac and respiratory patients [7]. Because this study was part of a larger one that also included patients with COPD and heart failure, the target level was set at the $V_T$. Apparently, few studies have used such a level for type 2 diabetics, although it has been proposed by several teams of researchers [31–34]. This means that the present study is probably the first to report on the effects of training at the $V_T$ in diabetics. In fact, the choice of the $V_T$ for diabetics is questionable as dyspnoea is not a prominent symptom of type 2 diabetes. Targeting on a metabolic basis with exercise calorimetry is a procedure that appears to be more logical for such patients, and the preliminary evidence so far is worthy of consideration [35].

Overall, our randomized one-year interventional study showed that realistic, moderate exercise training (30–45 minutes twice a week, following one month of education) can counteract the progressive decline in aerobic working capacity seen in type 2 diabetics, thereby leading to significant savings in healthcare costs. These results support the increasingly more widely accepted idea that lifestyle interventions are a fundamental part of the treatment of type 2 diabetes. Relatively simple exercise programmes can be effective within a healthcare system such as is used in France to improve both the patient’s health and the cost-effectiveness of treatment.

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References


