The effect of resistance versus aerobic training on metabolic control in patients with type-1 diabetes mellitus

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Received 25 April 2005; received in revised form 4 November 2005; accepted 11 November 2005

Abstract

This study evaluated the effect of aerobic versus resistance training on metabolic control in type-1 diabetes patients. Thirteen non-active patients, ranging in age from 13–30, were submitted to a 12-week aerobic exercise (Group A, n = 7) or resistance training (Group B, n = 6) period. Group A training consisted of a 40 min walk or run and Group B training consisted of resistance exercises three times a week. Blood samples were obtained before and after the 12-week training period. When these samples were compared, results showed that in Group A there were no changes in glycated hemoglobin, lipid profile, fast glucose level or body mass index (BMI). There was, however, a reduction in waist circumference and in average self-monitored blood glucose levels, measured after each exercise session. In Group B, there were no changes in the parameters evaluated. In both groups the total insulin dosage was reduced. As other authors have shown, resistance/aerobic training did not improve glycated hemoglobin in type-1 diabetes patients.

Keywords: Diabetes; Aerobic exercise; Resistance exercise; Glycated hemoglobin

1. Introduction

Although physical activity has been associated with a reduction in cardiovascular mortality in type-1 diabetes patients [1], contradictory data have been reported regarding the benefits of physical activity on metabolic control in these patients.

Mosher et al. showed beneficial effects on glycated hemoglobin in eleven type-1 diabetes patients after a 12-week period of both aerobic exercise and resistance training [2]. Similar beneficial results were also demonstrated by Campagne et al. in adolescents with type-1 diabetes after 12 weeks of vigorous games and recreational activities [3]. In contrast, no decrease in glycated hemoglobin levels was reported by Laaksonen et al. after a 12-week training program in twenty type-1 diabetes patients, compared to a control group [4]. Improvements in maximal oxygen uptake (VO₂ max) with no associated changes in glycemic control have been reported by Rowland [5] and Zinman et al. [6] after 12 weeks of bicycle and treadmill exercise, respectively.

Apart from the controversy surrounding the beneficial effects of exercise on glycemic control in type-1 diabetes patients, the question remains about which type
of activity is better: aerobic exercise or resistance training. Studies that evaluated the effect of exercise on metabolic control in type-1 diabetes patients used aerobic training or aerobic exercise associated with resistance training [2–4]. Information is lacking about the effect of resistance training without aerobic exercise on metabolic control in type-1 diabetes. Taking into account that today type-1 diabetes is more prevalent in young people who frequent gyms for resistance training, this evaluation becomes even more important.

The unanswered question as to whether exercise should be encouraged in subjects with type-1 diabetes in order to achieve better glycemic control has important implications for these patients. Better glycemic control is associated with a reduced risk of diabetic complications, as shown in the DCCT trial [7]. At present, the relationship between physical activity and glycemic control in type-1 diabetes patients has yet to be fully established. The aim of this study was to evaluate the effect of 12 weeks of aerobic exercise and resistance training on metabolic control in type-1 diabetes patients.

2. Materials and methods

2.1. Subjects

Sixteen patients with type-1 diabetes mellitus ranging in ages from 13 to 30, who exercised less than twice a week, were chosen from outpatients at a public hospital in Salvador, Bahia, Brazil. Patients with ketosis, chronic complications, such as proliferative retinopathy and peripheral neuropathy, as determined by the monofilament test (Semmes–Weinstein 5.07/10 g), were excluded. At baseline, treatments were administered in the morning and at bedtime using NPH insulin and regular, lispro or aspart insulin, before meals. The study was approved by the Hospital Ethics Committee and all patients gave their informed written consent.

2.2. Anthropometric measurements

The anthropometric measurements consisted of weight (calibrated scale-Filizola), height (nearest cm-stadiometers-Standard), waist circumference measured at the level of umbilicus and the waist/hip ratio was calculated. The body mass index (BMI) was calculated as the ratio of weight (kg) to the square of height (m) (kg/m²).

2.3. Exercise testing

Before and after 12 weeks of training, all subjects underwent a maximal treadmill-graded exercise test to estimate maximal oxygen consumption (VO₂ max), using the Bruce protocol [8].

2.4. Blood chemistry

Venous blood samples were collected after a 12 h overnight fast. Samples were taken before and after the 12-week exercise program of: glycated hemoglobin (HbA1c) (enzymatic colorimetry, Biorad, reference range 4.0–6.3%), plasma glucose and lipid profile (total cholesterol and fractions-HDL, VLDL, triglyceride) (enzymatic colorimetry, Merck-selectra ll). LDL was calculated according to Friedewald’s formula [9], which has been validated in type-1 diabetes [10].

2.5. Pre- and post-exercise self-monitored blood glucose levels

Self-monitored blood glucose levels were determined using a Roche glucometer (Active) before and after each exercise session, using blood drawn from a finger prick. Subjects with pre-exercise self-monitored blood glucose levels higher than 250 mg/dl, had their urine examined for the presence of ketosis, and if positive, the exercise session was canceled as recommended [11]. The session was also canceled if self-monitored blood glucose levels were higher than 300 mg/dl even without ketosis, if the subject had measured this glucose level over the previous 2-day period. When the subject began the exercise session with a self-monitored blood glucose level of >250 mg/dl, the level was monitored again after 20 min; if the level increased, the session was interrupted.

Subjects consumed a carbohydrate supplement based on pre-exercise self-monitored blood glucose levels. If the level was between 70 and 140 mg/dl, they consumed 15–20 g of carbohydrates before exercise. If the level was between 140 and 180 mg/dl, no carbohydrates were consumed before exercise. Subjects who had a self-monitored blood glucose level of less than 70 mg/dl during or after training, stopped the exercise and received 30 g of carbohydrates, and the dose of regular, lispro or aspart insulin for the pre-exercise meal was reduced by 2 units. If patients experienced hypoglycemia in the evening after the exercise session, the insulin NPH night dose was reduced by 20%. At the end of the study, each patient’s final insulin dose was compared to the dose used before the study began, and the percentage change in NPH, regular, aspart and lispro insulin was verified.
2.6. Exercise training

Patients were randomized into two groups: Group A patients participated in an aerobic exercise program \((n = 8)\) and Group B patients in a resistance training program \((n = 8)\). Both groups trained three times a week for 12 weeks, doing either aerobic exercise or resistance training, supervised by a physical trainer and an endocrinologist. Each exercise session began and finished with a 10 min warm-up or cool-down and stretching period. The intensity and duration of the exercise program were progressively increased throughout the 12-week period, according to the tolerance of each individual patient.

2.7. Aerobic training

Patients in Group A were submitted to a 40 min aerobic session on a treadmill, either walking or running, based on heart rate, until the target heart rate was reached, according to American College of Sport Medicine guidelines [12]. The program began with 10 min of stretching and was conducted using the maximal heart rate index (HRmax) estimated by: 220-age [13]. First 2 weeks = 60–70\% of HRmax, 3rd to 6th weeks = 70–80\% of HRmax, 7th to 12th weeks = 70–90\% of HRmax.

2.8. Resistance training

Patients in Group B were submitted to a 40 min session of resistance training. The program began with 10 min of stretching and was conducted with exercises done on nine resistance machines. The resistance machines used were: chest press, bicep curl, triceps extension, lower back, abdominals, leg press, leg curl and leg extension. Subjects performed three sets of 8–12 repetitions, with 60 s of rest between each set. Resistance was increased by five pounds after the subject was able to complete three sets of eight repetitions on three consecutive days. Subjects were trained using between 60 and 80\% of their one maximal repetition weight (1-RM).

2.9. Statistical methodology

The Student’s \(t\)-test was used to compare means, and, when necessary, Wilcoxon statistical significance was defined at \(p < 0.05\) with a 95\% confidence interval. SPSS/PC Windows software version 9.0 was used for statistical analyses.

3. Results

One patient in Group A and two in Group B did not complete the study, the former because of an infectious disease, and the latter two because of personal problems. Group A consisted of seven patients (five women and two men), with an average age of 19.8 \(\pm\) 5.1 years who had had diabetes for 7.0 \(\pm\) 5.9 years. Group B consisted of six patients (five women and one man) with an average age of 20.8 \(\pm\) 4.7 who had had diabetes for 7.8 \(\pm\) 4.8 years.

After the exercise program, five in Group A (5/7) and five in Group B (5/6) showed a reduction in the NPH insulin dose. The rapid and ultra-rapid insulin dose was reduced in one patient (1/7) in Group A and in four (4/6) in Group B. The average pre- and post-training program total insulin doses are shown in Table 1.

There was a slight increase in cardio-respiratory endurance in both groups, based on VO2max (ml/kg/min): 34.5–36.5 in Group A and 31.7–36.8 in Group B.

A significant reduction in waist/hip ratio \((p = 0.017)\) and in waist circumference \((p = 0.009)\) was observed in Group A, while no difference was observed in these parameters in Group B (Fig. 1). Nor was there any alteration in BMI for either of the groups (22.2 \(\pm\) 2.3 to 22.15 \(\pm\) 2.2 kg/m\(^2\) in Group A and 20.6 \(\pm\) 1.4 to 20.6 \(\pm\) 1.8 kg/m\(^2\) in Group B).

In Group A there was no difference in lipid profile or fasting blood sugar before and after the exercise program, while the HbA1c increased. In Group B there were no significant alterations in these parameters. (Table 2).

<table>
<thead>
<tr>
<th>Daily insulin dosage (units/kg/day)</th>
<th>Pre-training</th>
<th>Post-training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>0.84</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>0.78</td>
<td>0.62</td>
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<tr>
<td></td>
<td>0.59</td>
<td>0.50</td>
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<tr>
<td></td>
<td>1.30</td>
<td>1.27</td>
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<tr>
<td></td>
<td>0.89</td>
<td>0.56</td>
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<tr>
<td></td>
<td>0.75</td>
<td>0.88</td>
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<tr>
<td></td>
<td>0.98</td>
<td>1.05</td>
</tr>
<tr>
<td>Group B</td>
<td>1.70</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>1.01</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>1.16</td>
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<tr>
<td></td>
<td>1.20</td>
<td>0.51</td>
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<td></td>
<td>0.46</td>
<td>0.64</td>
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<td></td>
<td>0.60</td>
<td>0.48</td>
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<tr>
<td>Total mean</td>
<td>0.95 (\pm) 0.34</td>
<td>0.79 (\pm) 0.28*</td>
</tr>
</tbody>
</table>

* \(p < 0.05\).
Self-monitored blood glucose levels, measured before and after each session, showed a significant reduction in Group A and a less significant reduction in Group B (Fig. 2). The average number of hypoglycemic episodes during the 12-week training program was 3.4 in Group A and 3.8 in Group B.

4. Discussion

Evidence that regular exercise can improve metabolic control in type-1 diabetes is lacking. As is the case with non-diabetic subjects, the insulin sensitivity of type-1 diabetic patients improves [14], but this does not translate into an improvement in long-term glucose control, according to glycated hemoglobin levels [14–17].

Most studies that evaluated the effect of exercise on metabolic control in type-1 diabetes used aerobic exercise. Some of them showed an improvement in metabolic control [2,6], but others did not [14–17]. Few studies exist that evaluate the effect of resistance training on metabolic control in type-1 diabetes, and most of those that do exist evaluated resistance associated with aerobic exercise in the same patient [2]. In this study, no improvement in glycated hemoglobin was found after either aerobic exercise or resistance training programs. In fact, in the aerobic exercise group there was a slight increase in glycated hemoglobin.

The lack of improvement in glycated hemoglobin can, in part, be explained by the reduction of insulin doses related to the hypoglycemic episodes that frequently occur in these patients. As no generally accepted guidelines to adapt insulin and food intake to exercise exist, the insulin dose was reduced based on each patient’s response to exercise, as determined by

<table>
<thead>
<tr>
<th></th>
<th>Pre-training</th>
<th>Post-training</th>
<th>Pre-training</th>
<th>Post-training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fasting glycemia (mg/dl)</td>
<td>229.8 ± 118.0</td>
<td>270.0 ± 109.0</td>
<td>141.5 ± 117.0</td>
<td>180.6 ± 87.2</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>8.7 ± 1.6</td>
<td>9.8 ± 1.8*</td>
<td>8.2 ± 2.9</td>
<td>7.6 ± 1.6</td>
</tr>
<tr>
<td>Fructosamine (mmol/L)</td>
<td>4.0 ± 0.7</td>
<td>3.8 ± 0.4</td>
<td>3.6 ± 0.8</td>
<td>3.4 ± 0.5</td>
</tr>
<tr>
<td>Total cholesterol (mg/dl)</td>
<td>176.4 ± 35.0</td>
<td>181.0 ± 36.1</td>
<td>156.6 ± 29.9</td>
<td>165.0 ± 44.2</td>
</tr>
<tr>
<td>HDL-c (mg/dl)</td>
<td>62.6 ± 9.1</td>
<td>64.4 ± 8.2</td>
<td>53.5 ± 9.2</td>
<td>54.3 ± 10.9</td>
</tr>
<tr>
<td>LDL-c (mg/dl)</td>
<td>98.1 ± 33.4</td>
<td>100.7 ± 31.8</td>
<td>89.3 ± 23.1</td>
<td>94.8 ± 40.6</td>
</tr>
<tr>
<td>Triglycerides (mg/dl)</td>
<td>81.4 ± 26.2</td>
<td>75.8 ± 17.5</td>
<td>69.2 ± 15.9</td>
<td>79.0 ± 23.2</td>
</tr>
</tbody>
</table>

* p < 0.05.
self monitoring blood glucose levels. The American Diabetes Association [18], based on Wasserman and Zima’s general recommendations [11], states that these adaptations are based on blood glucose monitoring in order to avoid hypoglycemia and does not provide specific values.

After 12 weeks, patients in both aerobic exercise and resistance training programs showed a reduction in their NPH insulin dose, which was related to hypoglycemic episodes. Probably, the 20% reduction in the NPH dose was higher than necessary, and this could explain the fact that there was no reduction in glycated hemoglobin in either group, and that there was even a slight increase in the aerobic group.

In patients with type-1 diabetes, as in individuals without diabetes, exercise increases insulin sensitivity and muscle glucose uptake [14]. This effect can last more than 12 h after exercise, as shown by Mikines et al. [19] and could explain the hypoglycemic episodes and the subsequent reduction in insulin doses observed in the patients in the present study.

Ligtenberg et al. [20] showed a significant decrease in glycated hemoglobin in type-2 diabetes patients, but only after 1 year of training, and not within 6 months. This suggests that a longer period of regular activity is necessary before any difference in glycemic control can be observed. In the present study, a 3-month training program was carried out, which may have been too short to modify metabolic control, although some authors found no improvement, even when evaluating a long-term training program in type-1 women [16].

The effect of exercise on the lipid profile is controversial. Mosher et al. showed a reduction of LDLC in adolescents with type-1 diabetes, who underwent endurance and resistance training [2]. Conversely, no alterations of lipoprotein profiles were observed after 10 weeks of either running, weight training or a combination of both in adolescent men [21].

The lipid profile did not change in this type-1 diabetes group. In fact, they had normal pre-training lipid levels, and the greatest improvement was observed in individuals with the highest lipid levels [22]. A tendency was observed for an increase in HDL-c levels in both groups, which could be considered significant if the number of subjects were higher. Furthermore, this study did not evaluate other lipid parameters such as LDL-a or Apo B levels, which may have changed as shown by Laaksonen et al. [4].

The present study has some limitations. It is possible that no significant difference in metabolic control was detected because of the small sample size, the length of the training program and the lack of guidelines to adapt the insulin dose.

Although this study provides no evidence that regular exercise improves glycemic control in type-1 diabetes patients, insulin sensitivity and muscle glucose uptake are altered by exercise training [19]. Reassessment of the insulin dose, diet and prescriptive exercise characteristics (frequency, duration, intensity and mode) should be done to obtain more conclusive results.

The lack of an improvement in glycemic control shown in this and other studies should not discourage type-1 diabetes patients from exercising. A reduction in waist circumference in the aerobic exercise group associated with a tendency for increased HDL-c levels shown in this study may indicate a reduction of visceral fat, with an improvement in insulin resistance, which could have an impact on cardiovascular risk, thereby reducing mortality.

Acknowledgements

We would like to thank the group who helped us with the patients at the gym: Luciano Vidal, João Marcelo, David Teixeira, Fábio Castro, Humberto Santos, João Paulo, Marcos Paulo, Marli Batista, Paulo Cezar, Tiago Neto, Vinicius David, Flávia Costa and Nixon Fernandes.

References