Physical Fitness and Exercise Endurance Measured by Oxygen Uptake Kinetics in Patients with Type 2 Diabetes Mellitus

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Abstract. Exercise testing was used to examine 38 type 2 diabetes mellitus (DM) patients without cardiovascular complications, aged 47–74 years (body mass index [BMI], 23.8 ± 1.6 kg/m²), and 18 healthy volunteers, aged 45–68 years (BMI, 22.5 ± 1.5 kg/m²). A graded cycling exercise test was performed, monitoring gas exchange to evaluate physical fitness and exercise endurance by oxygen uptake (VO2) kinetics. The following results were obtained. (1) Oxygen deficit (O2deficit) and time constant (τ on) at the onset of exercise were significantly higher in subjects with type 2 DM compared with controls (p<0.01). (2) Maximum oxygen uptake (VO2max) and maximum work load were lower by 12% and 15%, respectively (p<0.05). These data suggest a notable abnormality in the cardiopulmonary response at the onset of exercise and a lower exercise endurance in subjects with type 2 DM. These findings may reflect impaired cardiac response to exercise, although an additional defect in skeletal muscle oxygen diffusion or oxygen utilization is also possible.

Key words: Type 2 diabetes mellitus, Exercise endurance, Oxygen uptake kinetics.

INTRODUCTION

It has previously been observed that persons with type 2 diabetes mellitus (DM), even in the absence of clinical cardiovascular disease, have a reduced maximum oxygen uptake (VO2max) compared with non-diabetic persons1–3). In addition, it has been reported that oxygen uptake (VO2) kinetics are impaired in women with type 2 DM4). The causes of exercise impairment are unknown, and thus their physiological and clinical significance warrants further study.

In this study, we investigated patients with uncomplicated type 2 DM by asking them to perform bouts of exercise with constant load and thereafter exercise with incremental loading to evaluate their physical fitness and exercise endurance by VO2 kinetics.

MATERIALS AND METHODS

Subjects

Thirty-eight type 2 DM patients (29 male and 9 female), aged 47 to 74 years (58 ± 10 years), participated in this study. None of the patients showed clinical evidence of cardiovascular complications. Fifteen of them were taking treatment by diet, 13 by oral agents and 10 by insulin. Their mean body mass index was 23.8 ± 1.6 kg/m². They were accepted for this study only if
they had total HbA1c levels <9% on therapy.

Control subjects (12 male and 6 female), aged 45 to 68 years (55 ± 8 years) were screened identically to the subjects with type 2 DM. These subjects were taking no medication, had normal HbA1c, and had no history of any active medical problems.

The exercise testing system

This study used an exercise stress test including an electromagnetically controlled cycle ergometer (Lode Corival WLP-400, Groningen, Netherlands) as reported previously5).

Each test began with 3 min of resting baseline measurement. After this period, a preselected workload (30 W) was imposed with a motor-driven flywheel and the subject maintained pedaling at 60 rpm for 3 min at the start of exercise (constant load exercise). Thereafter, incremental loading of 20 W/min was started. The heart rate was monitored continuously with an electrocardiograph Fukuda ML-600 (Japan). The dynamic exercise test continued until the individual’s maximal effort was achieved.

Kinetics measurement during exercise

VO2 was continuously determined during the graded exercise test using breath-by-breath respiration gas analysis equipment with a gas analyzer (Minato RM-300, Japan). Oxygen deficit (O2 deficit) and time constant (τ on) during the constant load exercise were calculated from actual VO2 changes using a statistical program6), which was used to fit a single exponential data curve from the onset of exercise to the end of the constant load exercise (Fig. 1). VO2 max and maximum loads were measured as parameters of endurance ability and subjects were urged to maximal effort in the incremental load exercise.

Table 1. Physical fitness and exercise endurance measured by oxygen uptake kinetics in type 2 diabetes mellitus

<table>
<thead>
<tr>
<th></th>
<th>Type 2 DM</th>
<th>Control</th>
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<tbody>
<tr>
<td>Time constant (sec)</td>
<td>39.7 ± 12.1</td>
<td>28.7 ± 8.6**</td>
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<tr>
<td>O2 deficit (ml)</td>
<td>325.1 ± 122.4</td>
<td>218.7 ± 62.2**</td>
</tr>
<tr>
<td>VO2max (ml/min/kg)</td>
<td>21.3 ± 5.1</td>
<td>24.1 ± 5.8*</td>
</tr>
<tr>
<td>Maximum work load (watt)</td>
<td>110.2 ± 35.9</td>
<td>128.4 ± 43.6*</td>
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*p<0.05, **p<0.01.

RESULTS

The results of this study are summarized in Table 1. O2 deficit and τ on at the onset of constant load exercise were significantly higher in subjects with type 2 DM compared with controls (p<0.01). VO2max and maximum work load were lower by 12% and 15%, respectively, on the incremental load (p<0.05).

DISCUSSION

Physically untrained people with type 2 DM have been shown to have a reduced VO2max compared with nondiabetic people1–3). In this study, we found that type 2 DM patients had impaired maximal and submaximal cardiopulmonary responses to exercise, even though they had no evidence of clinical cardiovascular diseases or diabetic complications.

VO2max is the classic measure of overall cardiorespiratory fitness and describes the highest oxygen uptake obtainable by an individual for a given form of exercise in respect of increased effort and increased work rate7).

In contrast, VO2 kinetics measure the efficiency of the cardiorespiratory response to an imposed demand. Specifically, VO2 kinetics describe the rate at which the cardiorespiratory system is able to deliver oxygen to skeletal muscle and the rate at
which oxygen is consumed by skeletal muscle at the
beginning of exercise. The rise to steady state is
described by $\tau_{on}$, and is determined by fitting an
exponential curve to VO2 kinetics data. A rapid
increase of VO2 to steady state is seen in healthy,
physically trained individuals$^8)$. In contrast, a
delayed rise in VO2 to steady state is observed in
patients with decreased cardiac function or in
chronic obstructive pulmonary diseases$^9)$. 

In the present study O2 deficit and $\tau_{on}$ at the
onset of exercise were significantly higher in
subjects with type 2 DM compared with controls.

Oxygen uptake kinetics is influenced by a
combination of cardiovascular and peripheral
factors. Studies are currently underway to determine
whether cardiac output, arteriovenous oxygen
difference, aspects of skeletal muscle metabolism, or
a combination of factors play a role in low
endurance in exercise. These findings may reflect
impaired cardiac response to exercise, although an
additional defect in skeletal muscle oxygen diffusion
or oxygen utilization is also possible.

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