Correlations between Pedometric Measurement in Daily Physical Activity and Cardiorespiratory Fitness in Patients with Type 2 Diabetes Mellitus

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Abstract. The purpose of this study was to investigate the relationship between daily physical activity and physical fitness in 10 type 2 diabetes mellitus (DM) patients without cardiovascular complications, aged 43–72 years (body mass index [BMI], 23.7 ± 2.2 kg/m²). The pedometric measurement was made using a calorie counter (CAL-D) in daily life at home, and was compared with oxygen uptake (VO₂) and work load with gas analysis obtained using a bicycle ergometer. The mean number of gait steps recorded with CAL-D, and energy expenditure in exercise per day were 8,202 ± 1,966 steps/day and 231 ± 70 kcal/day respectively. The mean number of gait steps per day was positively correlated with VO₂ (r=0.44, p<0.05). These results suggest that gait performance of daily physical activity at home is generally related with exercise endurance in DM patients.

Key words: Diabetes mellitus, Physical activity, 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). The causes of exercise impairment are unknown, and thus the physiological and clinical significance of this warrants further study.

The purpose of this investigation was to (1) measure the number of gait steps made in daily physical activity by DM patients and (2) assess whether it was related to exercise endurance described by VO₂ kinetic responses with gas analysis obtained while using a bicycle ergometer in DM patients.

MATERIAL AND METHODS

Subjects

Ten type 2 DM patients (7 male and 3 female), aged 43 to 72 years (59 ± 9 years) living in the community participated in this study. None of the patients showed clinical evidence of cardiovascular complications. Four of them were being treated by diet and 6 by oral anti-hyperglycemic agents. Their mean body mass index was 23.7 ± 2.2 kg/m². They
were accepted for this study only if they had total HbA1c <8.5% on therapy.

Pedometric analyses of daily physical activity
In the present study, a compact ambulatory calorimeter (CAL-D: Suzuken Co., Nagoya, Japan) equipped with an acceleration sensor was used. It is designed to detect the acceleration rate along the vertical axis at the waist during body movements and automatically calculate walking steps and energy expenditure from the product of the acceleration rate and body velocity. The number of gait steps and amount of energy expenditure during daily physical activities were measured continuously from the time it was put on at 7:30 a.m. (wear on) to the time it was taken off at 9:30 p.m. (wear off). To minimize day-to-day variation in daily gait, steps for 16 ± 10 consecutive days were obtained in this study. During the measurement period, subjects were instructed to continue their ordinary daily routine.

Oxygen kinetics measurement during exercise testing
In this study we used a symptom-limited ramp exercise test with a load test system including an electromagnetically controlled cycle ergometer (Lode Corival WLP-400, Groningen, Netherlands). Each test began with 3 min. of resting baseline measurement. After the constant load work exercise at 20 W for 3 min., incremental loading of 20 W/min. was started. The electrocardiogram and heart rate were monitored continuously with a Fukuda ML-600 (Japan). At the stage of constant load, O2 deficit and time constant (τon) were calculated from actual VO2 changes using a statistical program, which was used to fit a single exponential data curve from the onset of exercise to end of the steady-state exercise. Exercise metabolic parameters such as VO2 and work rate were continuously determined during the graded exercise test using a breath-by-breath respiration gas analysis assembly with a gas analyzer (Minato RM-300, Japan). The VO2max and maximal work load were measured as parameters of endurance abilities, forcing individuals to maximal effort exercise on the incremental load.

Statistical analysis
Data are shown as mean ± SD. Linear regression analysis was used to correlate data which were considered statistically significant at p<0.05.

RESULTS
Table 1 shows physical characteristics, number of gait steps recorded with CAL-D, and energy expenditure of the subjects. The mean number of gait steps, maximum number of gait steps, energy expenditure in exercise, and total energy expenditure per day were 8,202 ± 1,966 steps/day, 13,284 ± 3,217 steps/day, 231 ± 70 kcal/day, and 1,789 ± 191 kcal/day, respectively.

On exercise tests, the O2 deficit and τon under fixed loading during warm-up were 243 ± 39 mL and 33 ± 8 seconds, respectively, and VO2max, VO2max/W, and maximal work load under ramp loading were 1,282 ± 222 mL/min, 20 ± 4 mL/min/kg, and 118 ± 25 watts, respectively.

Figure 1 shows the relationship between the mean number of gait steps per day and VO2max. The mean number of gait steps per day was positively

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correlated with VO₂max \( (r=0.44, p<0.05) \). Also, the maximum number of gait steps per day was positively correlated with the energy expenditure in exercise \( (r=0.40) \), maximum total energy expenditure \( (r=0.69) \).

**DISCUSSION**

To maintain and improve the effectiveness of exercise therapy for DM patients, an exercise for each patient must be designed, and guidance and follow-up to encourage the patients to practice and continue it in their daily living are necessary. Calorimetry by expired gas analysis and time study to estimate the energy expenditure from actions and their percent energy metabolism are used for the assessment of physical activities based on energy metabolism in daily living.

CAL-D used in this study is easy to carry and use, indicates the energy expenditure in terms of calories, and its data has been reported to be correlated with those obtained by VO₂ measurements. Activity is detected by a built-in acceleration sensor with a piezo-electric device, and the energy expenditure is calculated with a microprocessor by the following formula:

\[
E = 1.11 \times KaW \times 0.444 + 1.11 \times KbW
\]

\([E, \text{ energy expenditure}; W, \text{ body weight}; Ka, \text{ coefficient of basal metabolism}; Kb, \text{ coefficient of exercise (calculated from the relationship between the treadmill exercise load and the oxygen expenditure)})\].

In this study, we assessed the physical activity in daily living and systemic endurance capacity in DM patients treated on an outpatient basis at our center and evaluated their relationship. The results obtained in this study concerning the mean number of gait steps per day and maximum number of gait steps were similar to those reported by Yokochi et al.\(^\text{10}\).

In the exercise test, the O₂ deficit and \( \tau \text{on} \), which are indices of the state at the beginning of exercise, were measured under a fixed load of 20 W during 3-minute warm-up, and changes in the oxygen uptake at the beginning of exercise were examined. Katoh et al. reported decreases in the oxygen uptake at the beginning of exercise in DM patients even when they had no heart disease. Also, as the mean number of gait steps was positively correlated with VO₂max, the association between the physical activity and the systemic endurance capacity (e.g., VO₂max) was reconfirmed.

Generally, exercise is considered to be effective for controlling the blood glucose level, improving hyperinsulinemia associated with a decrease in insulin sensitivity, and cardiovascular risk factors such as abnormal carbohydrate and lipid metabolism, hypertension, and clotting abnormalities. To make exercise therapy effective primary and secondary preventive measures against DM, the establishment of a method for the assessment of the compliance with exercise therapy is needed. The use of CAL-D, which allows easy calculation of physical activity, may contribute to the maintenance of exercise education and exercise habit, alleviation of lifestyle-related disorders, control of DM, and prevention of the progression of its complications.

Lastly, the positive correlation between the physical activity in daily living and VO₂max during exercise in DM patients observed in this study suggests the effectiveness of exercise guidance and exercise prescriptions using the number of gait steps as a parameter. The clinical application of exercise guidance using CAL-D for DM patients is anticipated.

**REFERENCES**


