ORIGINAL ARTICLE

Daily Walking Combined With Diet Therapy Is a Useful Means for Obese NIDDM Patients Not Only to Reduce Body Weight But Also to Improve Insulin Sensitivity

KUNIO YAMANOUCHI, MD, PHD
TAKASHI SHINOZAKI, MD, PHD
KIWAMI CHIKADA, MD, PHD
TOSHIHIKO NISHIKAWA, MD
KATSUNORI ITO, MD
SHOJI SHIMIZU, MD
NORIHITO OZAWA, MD
YOICHIRO SUZUKI, MD
HITOSHI MAENO, MD, PHD
KATSUMI KATO, MD, PHD
YOSHIHARU OSHIDA, MD, PHD
YUZO SATO, MD, PHD

OBJECTIVE — To evaluate the effects of walking combined with diet therapy (1,000–1,600 kcal/day) on insulin sensitivity in obese non-insulin-dependent diabetes mellitus (NIDDM) patients.

RESEARCH DESIGN AND METHODS — Subjects were divided into two groups: 10 patients were managed by diet alone (group D), and 14 patients were placed in the diet and exercise group (group DE). Group DE was instructed to walk at least 10,000 steps/day on a flat field as monitored by pedometer (19,200 ± 2,100 steps/day), and group D was told to maintain a normal daily routine (4,500 ± 290 steps/day). A glucose clamp procedure at an insulin infusion rate of 40 $mU \cdot m^{-2} \cdot min^{-1}$ was performed before and after the 6- to 8-week training program. Mean serum insulin concentrations ranged from 720 to 790 pmol/l.

RESULTS — While body weight (BW) in groups D and DE decreased significantly ($P < 0.01$) during the study, the amount of BW reduction in group DE was greater than that in group D (7.8 ± 0.8 vs. 4.2 ± 0.5 kg, $P < 0.01$). After training, glucose infusion rate (GIR) and metabolic clearance rate (MCR) in group D did not significantly increase; however, GIR and MCR increased significantly in group DE, from 17.21 ± 1.11 to 26.09 ± 1.11 $\mu mol \cdot kg^{-1} \cdot min^{-1}$ ($P < 0.001$) and from 3.0 ± 0.3 to 5.3 ± 0.4 $ml \cdot kg^{-1} \cdot min^{-1}$ ($P < 0.001$), respectively. The analysis of variance showed significant effects of exercise (time × exercise, $P = 0.0005$) for the improvement of MCR. Significant correlations were also observed between ΔMCR and average steps per day ($r = 0.7257$, $P < 0.005$) in group DE.

CONCLUSIONS — Walking, which can be safely performed and easily incorporated into daily life, can be recommended as an adjunct therapy to diet treatment in obese NIDDM patients, not only for BW reduction, but also for improvement of insulin sensitivity.

From the First Department of Internal Medicine (K.Y., T.S., K.C., T.N., K.I., S.S., N.O., Y. Suzuki, H.M., K.K.), Aichi Medical University, Aichi; and the Research Center of Health, Physical Fitness and Sports (Y.O., Y. Sato), Nagoya University, Nagoya, Japan.
Address correspondence and reprint requests to Yuzo Sato, MD, PhD, Research Center of Health, Physical Fitness and Sports, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464–01, Japan.
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BMI, body mass index; BW, body weight; GIR, glucose infusion rate; MCR, metabolic clearance rate; NIDDM, non-insulin-dependent diabetes mellitus.

It is known that reduced insulin-mediated glucose uptake due to insulin resistance is one of the major characteristics of both obesity (1) and non-insulin-dependent-diabetes mellitus (NIDDM) (2,3). Physical exercise improves insulin action (4), yet the effects of physical training disappear within days when discontinued (5,6). Continued regular exercise is, therefore, recommended as an adjunct therapy to specific diet treatment for obese and/or NIDDM patients. Exercise, however, may cause motor-joint disturbances in obese individuals, but low-intensity exercise, such as walking, can be well managed by such individuals and easily incorporated into their daily lives. This study demonstrated the effects of walking combined with diet therapy on body weight (BW) reduction and improvement of insulin sensitivity in obese NIDDM patients.

RESEARCH DESIGN AND METHODS

— A total of 24 obese NIDDM patients (23–59 years old), whose characteristics are given in Table 1, participated in this study after giving informed consent. Diabetes mellitus was confirmed according to the criteria established by the World Health Organization Study Group (7). Diabetes was diagnosed in all subjects within 1 year before this study and good control had been achieved by diet alone. No patients had diabetes-related complications, and no medications were administered. No subjects had participated in athletics or regular exercise before this study. Subjects were assigned to one of two groups that were matched with respect to age, sex, and body mass index (BMI).

A total of 10 obese NIDDM patients (group D) were managed by diet alone; another 14 obese NIDDM patients (group DE) were managed by a program incorporating diet and walking. All subjects were hospitalized and ingested the following diet for 6–8 weeks under supervision: 1,000–1,600 kcal/day (54–58% carbohydrates, 17–20% protein, and 25–

Table 1—*Characteristics of subjects*

	Sex (M/F)	Age (years)	Height (cm)	Weight (kg) Before	Weight (kg) After	BMI (kg/m^2) Before	BMI (kg/m^2) After	75-g OGTT (2-h) Glucose (mmol/l)	HbA_{1c} (%)
Group D (n = 10)	8/2	41.3 ± 1.8	163.1 ± 2.7	83.9 ± 5.8	79.7 ± 6.5*	31.6 ± 1.8	29.8 ± 2.3*	13.6 ± 0.3	7.0 ± 0.5
Group DE (n = 14)	11/3	41.6 ± 3.5	162.8 ± 2.5	82.1 ± 4.1	74.3 ± 3.4*†	31.2 ± 1.2	27.9 ± 2.0*†	13.8 ± 0.3	7.2 ± 0.6

Data are means ± SE. Normal value for HbA_{1c} is 4.0–6.5%. *$P < 0.01$ vs. before training; †$P < 0.01$ vs. group D.

26% fat), determined by subtracting 1,000 kcal from the patient's usual self-reported daily average caloric intake. The subjects in group DE were instructed to walk a minimum of 10,000 steps/day on a flat field while being monitored by pedometer (HJ-7, OMRON Industries). The accuracy of this device was to within ±3%, calibrated by the regulator of the experiment to 100 steps after the subjects had walked their first 100 steps (a mean of 0.0435 miles) on a flat surface. Patients in group D were instructed to walk roughly the same distance as in their normal daily life before hospitalization. During hospitalization, patients in group D and group DE walked a mean of 4,500 ± 290 steps/day (~2.0 miles) and 19,200 ± 2,100 steps/day (~8.4 miles), respectively.

Glucose clamp procedure

The euglycemic insulin clamp procedure was performed at an insulin infusion rate of 40 $mU \cdot m^{-2} \cdot min^{-1}$ for 120 min in the postabsorptive state, after an overnight fast, before and after the training program as previously reported (8). The glucose infusion rate (GIR) and the glucose metabolic clearance rate (MCR) (9), averaged for each 10-min value from 60 to 120 min, were used as an indicator of whole-body insulin sensitivity because of the stability in GIR during this period (8). The subjects in group DE were asked not to engage in any extraordinary exercise but to follow their normal daily routine for 2 days before the glucose clamp procedure. Blood samples were taken before and at 30, 60, 90, and 120 min during the clamp procedure to determine mean plasma insulin concentrations by radioimmunoassay.

Statistical analysis

All data are expressed as means ± SD. Statistical analyses were performed by paired or unpaired Student's t tests: $P < 0.05$ was considered to be statistically significant. Furthermore, repeated-measures analysis of variance was used to compare the changes in MCR in the two groups. Multiple regression was performed to determine which factor, exercise or BW reduction, correlated with the changes in MCR.

RESULTS

Changes in BW after training periods

While BW in groups D and DE decreased significantly ($P < 0.01$), the amount of BW reduction during this study in group DE was greater than that in group D (7.8 ± 0.8 vs. 4.2 ± 0.5 kg, $P < 0.01$).

Blood glucose and plasma insulin concentrations at basal levels and during glucose clamp procedure

Basal blood glucose and plasma insulin concentrations were similar for the two groups with no statistically significant differences before training (Table 2). After training, basal blood glucose concentra-

Table 2—*Blood glucose and plasma insulin concentrations at basal and during euglycemic insulin clamp before and after training in group D and group DE.*

	Blood glucose (mmol/l)				Plasma insulin (pmol/l)			
	Before		After		Before		After	
	Basal	Steady-state	Basal	Steady-state	Basal	Steady-state	Basal	Steady-state
Group D	5.9 ± 0.3	5.6 ± 0.3	5.1 ± 0.3*	5.0 ± 0.4	129 ± 15	740 ± 113	95 ± 20	753 ± 146
Group DE	6.1 ± 0.4	6.1 ± 0.5	5.2 ± 0.3*	5.3 ± 0.2	125 ± 11	788 ± 38	68 ± 7*	737 ± 42

Data are means ± SE. *$P < 0.05$ vs. before training.

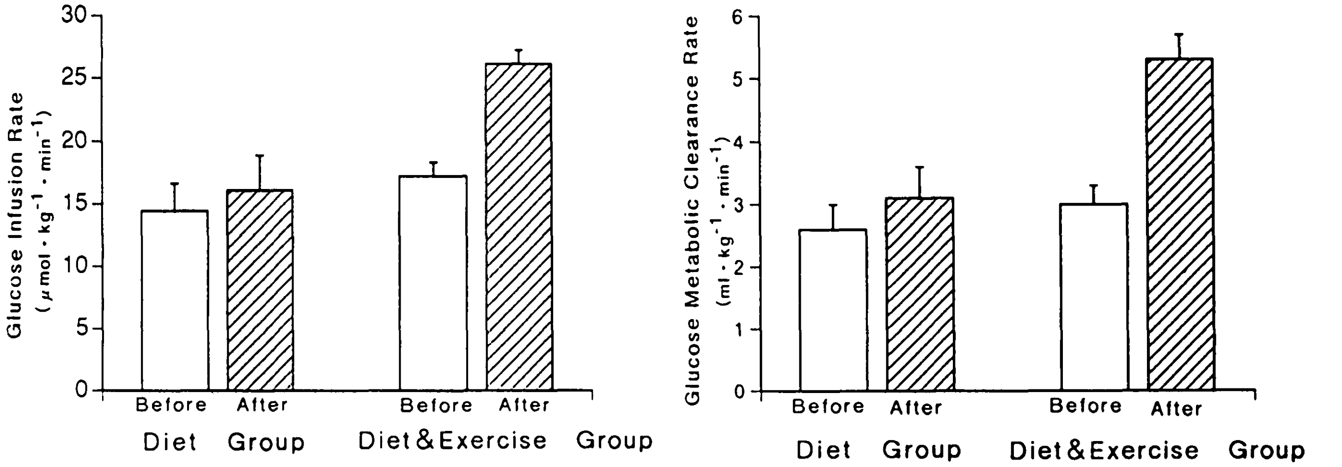

Figure 1—*GIR and glucose MCR before and after training periods in group D and DE. A 2 × 2 repeated-measure analysis of variance showed significant effects of exercise (time × exercise, P = 0.0005) in the improvement of MCR.*

tions were slightly but significantly ($P < 0.05$) reduced in the two groups, while basal plasma insulin concentrations were significantly reduced ($P < 0.05$) in group DE only. Steady-state blood glucose concentrations during the glucose clamp procedure were maintained at basal levels in the two groups. Steady-state plasma insulin concentrations during glucose clamp at insulin infusion rates of 40 $mU \cdot m^{-2} \cdot min^{-1}$ ranged from 720 to 790 pmol/l. No other significant differences were observed between the two groups.

GIR and glucose MCR after training periods

After training, GIR and MCR in group D did not significantly increase (from 14.43 ± 2.22 to 16.10 ± 2.78 $\mu mol \cdot kg^{-1} \cdot min^{-1}$ and from 2.6 ± 0.4 to 3.1 ± 0.5 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively) (Fig. 1). GIR and MCR in group DE, however, increased significantly, from 17.21 ± 1.11 to 26.09 ± 1.11 $\mu mol \cdot kg^{-1} \cdot min^{-1}$ ($P < 0.001$) and from 3.0 ± 0.3 to 5.3 ± 0.4 $ml \cdot kg^{-1} \cdot min^{-1}$ ($P < 0.001$), respectively. The analysis of variance showed significant effects of exercise (time × exercise, $P = 0.0005$) for the improvement of MCR.

Correlation between ΔMCR and average steps per day and between ΔMCR and ΔBW in group DE

Significant correlations were observed between ΔMCR (ΔMCR represents the positive changes in MCR after training) and average steps per day ($r = 0.7257$, $P < 0.005$) (Fig. 2*A*). Significant correlations between ΔMCR and ΔBW (ΔBW represents BW reduction after training) ($r = 0.5410$, $P < 0.05$) were also observed in group DE but not in group D ($r = 0.024$, $P = 0.9462$) (Fig. 2*B*). We also used multiple regression (general linear models procedure) to evaluate the effect of ΔBW and number of steps on MCR and found that the effect of ΔBW was not significant ($P = 0.962$) but the effect of walking was ($P = 0.0005$).

CONCLUSIONS— Most previous studies in which physical training effects have been demonstrated used high-intensity exercise, such as bicycle ergometer or running, graded up to 70–90% of Vo_{2max} (10–12). Only a few studies have addressed the results of walking intervention in obese NIDDM patients (13,14). Wing et al. (14) reported that in obese NIDDM patients, the diet plus exercise group (walking 3 miles/day, four times a week) had significantly better weight

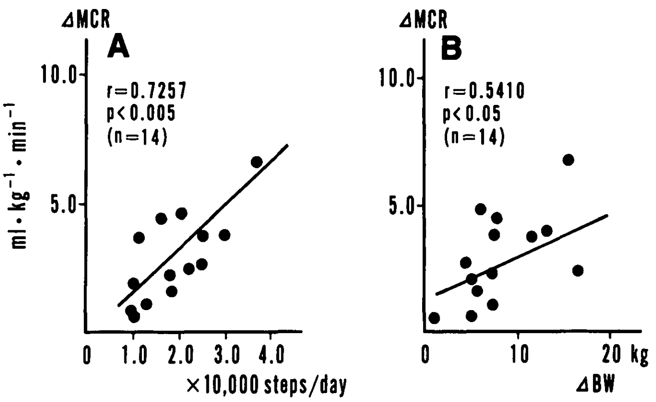

Figure 2—*Correlation between ΔMCR and mean steps/day (A) and between ΔMCR and ΔBW (B).*

losses than the diet-only group at the end of the 10-week program (−9.3 vs. −5.6 kg). At 1-year follow-up, self-reported exercise was related to weight loss and to improvements in glycosylated hemoglobin even after adjusting for weight loss. However, these studies did not address the effect of exercise on insulin sensitivity.

In our present study, group DE showed a significant improvement in GIR and MCR after training for 6–8 weeks (Fig. 1) and achieved a greater BW reduction than did group D (−7.8 vs. −4.2 kg, $P < 0.01$). These results indicate that the combination of walking and dietary restrictions is more effective in improving insulin sensitivity and reducing BW than diet alone. In addition, our analysis by multiple regression of the effect on MCR of weight loss or walking showed that only the effect of walking was significant ($P = 0.0005$). Moreover, there was a positive correlation in group DE between the improvement in MCR and the number of steps walked each day (Fig. 2*A*), again suggesting that physical exercise is an essential factor in improving insulin sensitivity. Bogardus et al. (11) reported similar results. They divided obese diabetic subjects into two groups: the first was placed on dietary restrictions only, and the second was treated by diet and exercise at 75% Vo_{2max}. A comparison of the groups showed that, although weight loss was the same, the GIR measured by the glucose clamp procedure remained unchanged in the diet-only group but improved in the diet-exercise group. These results support the contention that even when patients succeed in weight reduction, they may remain unable to improve insulin sensitivity if they are not placed on a regimen of regular exercise.

We can also remark on another finding: only in group DE did basal insulin levels significantly drop after training. This might indicate that production of glucose in the liver was being suppressed at lower basal insulin concentrations. In other words, exercise might also affect the insulin action in the liver itself. Finally, despite similar dietary restrictions in both groups D and DE, striking differences in clinical outcomes were observed between the groups. From the clinical viewpoint, it is important to know that walking, which can be safely performed and easily incorporated into daily living, can be an effective means of treatment in obese NIDDM patients not only for BW reduction but also for improvement of insulin sensitivity.

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