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# Efficacy of a pedometer-based physical activity program on parameters of diabetes control in type 2 diabetes mellitus

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**Abstract**

The aim of the study was to determine whether a recommendation to walk 10 000 steps per day would result in significant improvements in glycemic control, insulin sensitivity, and cardiovascular risk in patients with type 2 diabetes mellitus. The study was a 6-week randomized controlled trial that included 30 patients with type 2 diabetes mellitus. After 10 days of baseline activity, patients were randomized into 2 groups: control and active. The control group (n = 15) was instructed to continue with their baseline activity for 6 weeks. The active group (n = 15) was instructed to walk at least 10 000 steps per day 5 or more days per week, for 6 weeks. Data relevant to glycemic control and other parameters of health were collected at study weeks 0 and 6. There were no differences in the baseline activity between groups ($P$ = .36). Subjects in the active group significantly increased physical activity by 69% during the intervention phase of the study ($P$ = .002), whereas there was no change in the physical activity of the control group ($P$ > .05). High-density lipoprotein cholesterol and resting energy expenditure significantly increased in the active group ($P$ < .05). Finally, plasminogen activator inhibitor 1 (PAI-1) activity was reduced by exercise relative to the control group ($P$ = .03). There were no differences in any other study parameters during the 6-week study. In conclusion, short-term intervention with a pedometer increased physical activity and positively affected plasminogen activator inhibitor 1 activity in previously inactive patients with type 2 diabetes mellitus. The use of a pedometer may prove to be an effective tool for promoting healthy lifestyle changes that include daily physical activity and self-monitoring of therapeutic goals.


## 1. Introduction

Regular physical activity is an important component in the prevention and management of type 2 diabetes mellitus. Recent evidence suggests that participation in nonvigorous physical activity significantly improves insulin sensitivity in patients at high risk for diabetes [1]. The Diabetes Prevention Program found that a lifestyle modification incorporating a minimum of 150 min/wk of moderate-intensity physical activity, such as brisk walking, was more effective in preventing type 2 diabetes mellitus in individuals with prediabetes than was either with metformin or with placebo [2]. Furthermore, Heimrich and colleagues [3] reported an inverse relationship between energy expenditure in leisure-time physical activity and the development of type 2 diabetes mellitus in former college students.

Regular exercise has been demonstrated to have positive effects on glycemic control, weight reduction, and insulin resistance in patients with type 2 diabetes mellitus [4-7]. Regular physical activity is also correlated with decreases in all-cause and cardiovascular disease mortality in diabetic patients [8]. Conversely, impaired insulin action can lead to elevated triglycerides, reduced high-density lipoprotein cholesterol (HDL-C), increased secretion of very low-density lipoprotein cholesterol, and hypertension [9]. In nondiabetic subjects, regular physical activity has been found to raise HDL-C, reduce triglyceride levels, reduce blood pressure, decrease body weight, and increase insulin sensitivity [10-20].

The Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) have recommended that every adult accumulate at least 30 minutes of moderate-intensity physical activity on most days of the week [21]. Another popular recommendation is the accumulation of 10 000 steps per day on most days of the week. According to Tudor-Locke and Bassett [22] and Le Masurier and colleagues [23], the amount of physical

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activity achieved by walking 10 000 steps per day is in agreement with the recommendations of the CDC and ACSM. However, whether the achievement of moderate-intensity physical activity goals translate into favorable changes in glycemic control, insulin sensitivity, and/or cardiovascular risk in patients with type 2 diabetes mellitus over the short-term remains to be established.

Despite the known health benefits of moderate physical activity in patients with type 2 diabetes mellitus, compliance with exercise prescriptions is notoriously poor. The recent availability of low-cost pedometers may improve exercise compliance in patients with type 2 diabetes mellitus by providing a motivational and monitoring tool that offers immediate feedback about physical activity levels. The purpose of this study was therefore to determine whether a recommendation to accumulate 10 000 steps per day, as documented by use of a pedometer, would result in significant improvements in parameters of glycemic control, insulin sensitivity, cardiovascular risk, lipid profile, and oxidative stress in sedentary patients with type 2 diabetes mellitus.

## 2. Materials and methods

### 2.1. Subjects

A total of 30 subjects with type 2 diabetes mellitus participated in the study. All study subjects were between 33 and 69 years of age, had a diagnosis of type 2 diabetes mellitus for at least 1 year, were treated with oral therapy, and were free from advanced secondary complications of diabetes. Oral therapies included sulfonylureas (n = 25), metformin (n = 14), thiazolidinediones (n = 3), and statins (n = 4). Medications and doses were not changed during the study period, and there were no group differences in oral therapies ($P$ = .51). Study exclusion criteria included pregnant or lactating women, anemia (hemoglobin <11 g/100 mL for males, hemoglobin <10 g/100 mL for females), cardiovascular disease, hypertension (systolic blood pressure >180 mm Hg and/or diastolic blood pressure >110 mm Hg), or orthopedic limitations for walking. The study was approved by the University of New Mexico Human Research Review Committee, and all participants provided verbal and written consent.

### 2.2. Experimental design

The protocol consisted of a 10-day baseline period during which the participants were asked not to change their physical activity habits, followed by a 6-week intervention period. Subjects were randomized into 1 of 2 groups (control and active) that were matched with respect to age, hemoglobin $A_{1c}$ ($HbA_{1c}$), body mass index (BMI), and percentage of body fat. The control group was instructed to maintain their normal activity habits throughout the 6-week intervention. The active group was instructed to walk 10 000 steps on 5 or more days of the week for 6 weeks.

Each subject wore a Yamax Digiwalker step counter (SW-701, New Lifestyles, Kansas City, MI) throughout the day, except for sleeping and bathing, and was trained regarding proper placement and use of the pedometer. The pedometers were positioned on the waist, in-line with the right mid-thigh. Each morning the pedometer was reset to zero, and each evening the subject recorded the steps accumulated during the day in an activity log.

Participants were asked to follow their usual eating habits throughout the study. All participants completed a 24-hour dietary recall at baseline (week 0) and at week 6. Data from the 24-hour recall were analyzed using NutritionistPro Nutrition Analysis Software (FirstData Bank, San Bruno, CA).

### 2.3. Measurements

Screening data were collected during fasting outpatient visits to the General Clinical Research Center (GCRC). Week 0 and week 6 data were collected in the morning after overnight hospitalization at the University of New Mexico GCRC. All measurements were taken at the same time of the morning.

### 2.4. Anthropometric measures

Body mass index, percentage of body fat, blood pressure, waist circumference, and resting energy expenditure (REE) were measured at study weeks 0 and 6. Body height and weight were measured with subjects wearing light clothing and without shoes. Body mass index was calculated as the weight in kilograms divided by the square of height in meters. Percentage of body fat was estimated with bioelectrical impedance analysis (RJL Systems, Quantum Series, Clinton Township, MI). Blood pressure was measured with subjects in the seated position with an automated monitor (Critikon Vital Answers, Dinamap Pro Series, Tampa, FL). Standing waist circumference was measured in duplicate at the narrowest part of the torso between the rib cage and the iliac crest, after a normal expiration using a Gulick fiberglass measuring tape with a tension handle (Creative Health Products, Plymouth, MI). Resting energy expenditure was measured using indirect calorimetry in the morning after overnight hospitalization and 12-hour fast (SensorMedics, VMax 29, Yorba Linda, CA).

### 2.5. Sample analyses

Hemoglobin $A_{1c}$, fructosamine, fasting glucose, fasting insulin, fasting lipids, total radical antioxidant parameter (TRAP), malondialdehyde (MDA), plasminogen activator inhibitor 1 (PAI-1), homocysteine, and lipoprotein(a) [Lp(a)] were measured at study weeks 0 and 6. Insulin resistance was calculated using the homeostasis model of assessment (HOMA-IR) [24].

Study measurements were performed in the University of New Mexico GCRC Core Laboratory. Plasma was separated from blood elements by centrifugation immediately after sampling and frozen at −70°C for later determination.

Table 1
Baseline participant characteristics

| Characteristic | Control group (n = 15) | Active group (n = 15) |
|---|---|---|
| Age (y) | 51 ± 10 | 49 ± 11 |
| $HbA_{1c}$ (%) | 8.4 ± 1.7 | 8.5 ± 1.9 |
| BMI (kg/m$^2$) | 33.5 ± 6.6 | 30.0 ± 4.4 |
| Body fat (%) | 36.7 ± 8.7 | 38.0 ± 10.4 |

Data are expressed as means ± SD. $P > .05$ for all comparisons.

Serum total cholesterol and HDL-C were measured by enzymatic methods (TriCore Reference Laboratory, Albuquerque, NM). Triglycerides were measured with an oxidative method (TriCore Reference Laboratories). Plasma glucose was measured with a glucose oxidase method (Analox Microstat GM7, Analox Instruments, Lulenburg, MA). Insulin was measured by a radioimmunoassay (Linco, St Charles, MO). Hemoglobin $A_{1c}$ was assayed with a spectrophotometric method (Bayer DCA 2000 Analyzer, Kernersville, NC), as was fructosamine (Specialty Laboratories, Santa Monica, CA). Homocysteine concentrations were determined using automated immunoassay (IMMULITE Chemiluminescence System, Diagnostic Products, Los Angeles, CA). Total radical antioxidant parameter was determined using an immunoactivity assay read on a microplate reader at 590 nm (Randox Laboratories, Oceanside, CA). Free MDA was determined using selected ion monitoring gas chromatography-mass spectrometry (Agilent Technologies, Palo Alto, CA). Plasminogen activator inhibitor 1 was assayed with a "sandwich-type" enzyme linked immunosorbent assay (BioPool US, Ventura, CA) and read on a microplate reader at 490 nm. Lipoprotein (a) was assayed with an enzyme-linked immunosorbent assay (Esoterix Endocrinology, Calabasas Hills, CA).

### 2.6. Statistical analysis

Paired Student $t$ tests were conducted to compare all glycemic, anthropometric, oxidative stress, and cardiovascular risk factor variables at baseline and week 6. For baseline analysis between groups, Bonferroni corrections for multiple tests were performed, and significance was taken at $P < .008$ for body composition variables and $P < .004$ for metabolic variables. All comparisons were repeated using a nonparametric Wilcoxon-Mann-Whitney test. Repeated-measures analysis of variance (ANOVA) was performed to compare all variables using the assigned activity level as the grouping variable and time as the repeated factor. Significance was taken at $P < .05$ for all ANOVA analyses. All analyses were performed using SAS (SAS Institute, Cary, NC). Data are presented as mean ± SD.

### 2.7. Power analysis

A post hoc power analysis of $HbA_{1c}$, based on an SD of paired differences equal to 0.88 in our data, revealed 15 subjects per group were adequate to demonstrate a statistically significant reduction in $HbA_{1c}$ of 0.7% within the treatment group with 80% power and $\alpha = .05$ by paired $t$ test.

## 3. Results

At baseline, there were no significant differences in BMI, $HbA_{1c}$, or percentage of body fat between the 2 groups ($P > .05$, Table 1). Both groups were classified as overweight or obese (BMI, >25.0 kg/m$^2$).

Changes in physical activity data from baseline to week 6 are presented in Fig. 1. Baseline activity levels (steps per day) were similar between the control and active groups, 6239 ± 2985 vs 7220 ± 2792 steps per day, respectively ($P = .36$). Participants in the active group increased their total steps per day by an average of 69% to 10 410 ± 4162 steps per day during the intervention period ($P = .002$). Activity levels for the control group did not change during the intervention period (6240 ± 2769 steps per day, $P > .05$).

Changes in anthropometric measures, metabolic control, lipid profiles, and cardiovascular risk factors at baseline and week 6 are presented in Table 2. There were no significant changes in BMI, percentage of body fat, blood pressure, or waist circumference after the 6-week intervention in either group ($P > .05$). There was a trend for decreasing systolic blood pressure and waist circumference in the active group after the 6-week intervention, but statistical significance was not reached in either variable ($P > .05$).

Measured REE significantly increased from baseline to week 6 in the active group (6856 ± 1451 vs 6996 ± 1343 kJ/d, $P = .014$). No significant change in REE was noted in the control group (8546 ± 1928 vs 8914 ± 2123 kJ/d, $P > .05$).

Repeated-measures ANOVA demonstrated a significant main effect over time for HDL-C ($P = .022$). Post hoc analyses revealed HDL-C significantly increased in the active group after the 6-week intervention ($P = .049$) with no change in the control group (.093).

Repeated-measures ANOVA demonstrated a significant group-vs-time interaction in PAI-1 ($P = .03$), as PAI-1 values decreased in the active group and increased in the

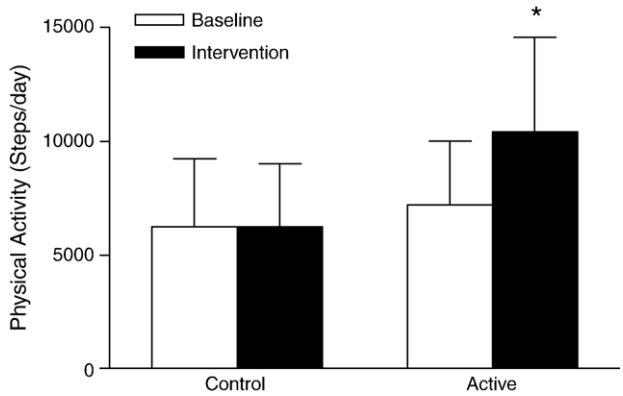


Fig. 1. Average steps per day at baseline and intervention period ($P = .002$). Data are expressed as means ± SD.

Table 2
Change in anthropometric measures, metabolic control, lipid profiles, and cardiovascular risk factors at baseline and week 6

| Parameter | Control (n = 15) | | Active (n = 15) | | Wilcoxon *P* | |
|---|---|---|---|---|---|---|
| | Baseline | Week 6 | Baseline | Week 6 | Baseline | Week 6 |
| BMI (kg/m$^2$) | 33.5 ± 6.6 | 33.2 ± 6.6 | 30.0 ± 4.4 | 29.3 ± 4.4 | .14 | .10 |
| Body fat (%) | 36.7 ± 8.7 | 36.8 ± 9.1 | 38.0 ± 10.4 | 37.4 ± 10.2 | .64 | .85 |
| SBP (mm Hg) | 136.6 ± 19.3 | 143.6 ± 18.6 | 140.6 ± 21.4 | 135.5 ± 16.9 | 1.00 | .20 |
| DBP (mm Hg) | 77.6 ± 8.9 | 80.2 ± 10.7 | 80.7 ± 12.2 | 82.6 ± 10.9 | .50 | .75 |
| Waist (cm) | 109.5 ± 19.3 | 110.5 ± 20.6 | 102.3 ± 15.6 | 101.5 ± 12.1 | .29 | .12 |
| REE (kJ/d) | 8546 ± 1928 | 8914 ± 2123 | 6856 ± 1451 | 6996 ± 1343* | .03 | .06 |
| $HbA_{1C}$ (%) | 8.6 ± 1.7 | 8.7 ± 1.4 | 8.5 ± 1.6 | 8.7 ± 1.9 | .81 | .65 |
| Glucose (mg/dL) | 186.3 ± 57.2 | 184.2 ± 60.9 | 193.6 ± 60.2 | 192.3 ± 67.0 | .97 | .93 |
| Insulin ($\mu$U/mL) | 14.2 ± 9.9 | 13.9 ± 8.8 | 14.9 ± 16.0 | 12.9 ± 8.0 | .76 | .84 |
| Fructosamine ($\mu$mol/L) | 337.4 ± 93.2 | 338.3 ± 96.3 | 327.7 ± 54.4 | 335.3 ± 63.8 | .60 | .72 |
| HOMA-IR | 5.9 ± 4.8 | 5.3 ± 2.6 | 6.7 ± 3.8 | 6.1 ± 3.3 | .87 | .68 |
| Triglycerides (mg/dL) | 237.1 ± 137.0 | 246.6 ± 142.4 | 244.7 ± 141.6 | 268.5 ± 195.6 | .93 | .95 |
| Total Cholesterol (mg/dL) | 200.9 ± 47.4 | 191.5 ± 28.6 | 189.9 ± 45.9 | 198.0 ± 48.9 | .76 | .73 |
| HDL-C (mg/dL) | 44.7 ± 9.4 | 45.6 ± 7.3 | 42.0 ± 9.4 | 45.9 ± 11.7* | .37 | .98 |
| LDLC (mg/dL) | 117.5 ± 37.4 | 104.6 ± 28.2 | 105.4 ± 38.4 | 114.6 ± 37.1 | .52 | .65 |
| Lp(a) (mg/dL) | 40.9 ± 40.2 | 42.4 ± 42.2 | 44.8 ± 68.4 | 45.9 ± 61.9 | .26 | .56 |
| PAI-1 (IU/mL) | 23.9 ± 11.8 | 32.5 ± 22.9 | 38.9 ± 36.8 | 28.4 ± 20.2† | .38 | .87 |
| TRAP (mmol/L) | 3.9 ± 0.2 | 3.9 ± 0.5 | 3.7 ± 0.3 | 3.4 ± 1.0 | .04 | .77 |
| Homocysteine ($\mu$mol/L) | 8.3 ± 2.4 | 8.8 ± 2.8 | 9.1 ± 4.8 | 8.9 ± 3.6 | .82 | .77 |
| MDA ($\mu$mol/L) | 0.07 ± 0.05 | 0.09 ± 0.03 | 0.07 ± 0.03 | 0.11 ± 0.05 | .57 | .23 |

Wilcoxon *P* values represent comparisons between groups at baseline to test for randomization error and week 6. SBP indicates systolic blood pressure; DBP, diastolic blood pressure.

* $P < .05$ for comparison of baseline (week 0) vs week 6 ($P < .05$), within group by ANOVA.

† $P < .05$ for week-group interaction by ANOVA.

control group during the 6-week intervention. As shown in Table 2, there were no significant changes in total cholesterol, homocysteine, fasting triglycerides, low-density lipoprotein cholesterol (LDL-C), $HbA_{1c}$, fasting serum glucose, insulin, fructosamine, TRAP, MDA, HOMA-IR, or Lp(a) during the 6-week intervention ($P > .05$).

## 4. Discussion

Only 2 studies to date have evaluated the use of a pedometer for increasing physical activity and insulin sensitivity in patients with type 2 diabetes mellitus [6,25]. Yamanouchi and colleagues [6] reported that walking an average of 19 200 steps per day combined with diet therapy increased insulin sensitivity among 24 obese, type 2 diabetic patients who were hospitalized for the duration of the study. The authors reported that combining walking and dietary restriction was more effective at improving insulin sensitivity and reducing body weight than diet alone. However, this study did not address the effects of walking on glycemic control, oxidative stress, or cardiovascular risk factors. Furthermore, this study demonstrated changes in insulin sensitivity and body weight with walking an average of 19 200 steps per day (approximately 8.4 miles) while supervised, which may be an unattainable goal for most diabetic patients. Katsuki and colleagues [24] reported a significant increase in physical activity after a 16-week intervention in sedentary patients with type 2 diabetes mellitus. However, there were no reported changes in resting blood pressure, fasting blood glucose, insulin sensitivity, $HbA_{1c}$, lipids, or triglycerides after the intervention. Although this study used a pedometer, a specific goal of 10 000 steps per day of physical activity was not used.

The main finding of the current study was that a recommendation to walk 10 000 steps per day among sedentary patients with type 2 diabetes mellitus was effective at improving daily physical activity by an average of 69%. In addition, subjects assigned to the active group experienced a beneficial decrease in PAI-1 relative to patients in the control group. Our data also demonstrated a significant increase in HDL-C and REE in the active group after the intervention. However, the change in these variables was not significant when compared with the control group by repeated-measures ANOVA. In addition, other lipid parameters (triglycerides, total cholesterol, and LDL-C) showed a trend to increase in both groups, making it difficult to interpret a significant increase in HDL-C in the active group.

The increase in HDL-C observed in the active group after the 6-week intervention is in agreement with past studies [10,11]. Hardman and Hudson [10] reported an increase in HDL-C after 12 weeks of brisk walking in sedentary women. Similarly, Huttunen and colleagues [11] reported an increase in HDL-C after 16 weeks of mild to moderate physical activity in middle-aged men, independent of changes in body weight. Our data suggest some improvement in HDL-C with walking 10 000 steps per day, but no comparison can be made to the control group.

Resting energy expenditure was significantly elevated in the active group after the 6-week intervention. Long-term

changes in REE are associated with an increase in lean body mass after exercise training. Resting energy expenditure can also be temporarily increased for up to 24 hours after a single bout of exercise [26]. This increase in REE has been termed the *excess post-exercise oxygen consumption* (EPOC) and can account for a 5% to 10% increase in REE above normal values [26]. Because there was no change in body composition in the present study, our data suggest that the significant increase in REE in the active group was not a long-term training effect of the 6-week intervention, but rather most likely the detection of excess post-exercise oxygen consumption after the last exercise event.

The significant group-vs-time interaction for PAI-1 indicates that the short-term exercise intervention had positive effects on PAI-1 levels. There was a decreasing trend in PAI-1 in the active group and an increasing trend in PAI-1 in the control group. Interventions combining exercise with diet modification have reported improvements in PAI-1 [27]. Only one study to date supports a decrease in PAI-1 after exercise [28]. In that study, Szymanski and colleagues [28] showed a significant decrease in PAI-1 after a single maximal exercise bout in inactive, regularly active and highly active men. Conversely, Bodary and colleagues [29] reported that 10 days of moderate-intensity exercise did not change PAI-1 levels in healthy men and women. Janand-Delenne and colleagues [30] have suggested that changes in PAI-1 are mediated primarily through changes in visceral fat. Interestingly, cross-sectional studies indicate that physically active individuals have lower resting PAI-1 activity [28]. These findings suggest that regular physical activity may be an important determinant of PAI-1 activity, but that there may be a dose-response relationship between exercise intensity and duration with PAI-1 activity. The current study demonstrates that walking 10 000 steps per day has beneficial effects on PAI-1 activity in sedentary patients with type 2 diabetes mellitus.

This study was limited by the duration of the intervention and the relatively small number of subjects. A longer intervention would be appropriate to determine if exercise compliance is maintained for greater than 6 weeks. All of the subjects who were admitted into the current study returned for all study visits and complied with the exercise recommendations. A longer intervention would also provide more information on the effects of habitual walking on parameters of glycemic control, insulin sensitivity, and cardiovascular risk in type 2 diabetic patients. In addition, the study entrance criteria limit the generalizability of the findings to type 2 diabetic patients receiving oral therapy and cannot be extrapolated to type 2 diabetic patients receiving insulin.

One might speculate that baseline differences in PAI-1 and REE reflect a chance failure of randomization and a subsequent regression to a common mean. Unfortunately, the current design does not allow us to further examine this possibility. Although there is an appearance of randomization failure with waist circumference, REE, and PAI-1, Bonferroni corrections for body composition variables would require $P$ values of less than .05/6 = .008, and for metabolic variables, .05/14 = .004. No baseline differences rise to this level of significance. All comparisons were repeated using a nonparametric Wilcoxon-Mann-Whitney test (Table 2).

In summary, intervention with a simple pedometer significantly increased physical activity, but did not improve the metabolic or cardiovascular risk profile in previously sedentary type 2 diabetic patients aside from a modest reduction in PAI-1. Future research should include longer interventions to better quantify the effects of walking on glycemic control, insulin sensitivity, and cardiovascular risk factors in these patients. The significant increase in daily physical activity in the active group supports the use of pedometer-based exercise prescriptions when working with diabetic patients. Our data also suggest that providing patients with a specific physical activity goal of 10 000 steps per day results in a significant increase in physical activity levels and may improve exercise compliance.

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## References

[1] Mayer-Davis EJ, D'Agostino Jr R, Karter AJ, et al. Intensity and amount of physical activity in relation to insulin sensitivity. JAMA 1988;279:669-74.
[2] Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002;346:393-403.
[3] Helmrich SP, Ragland DR, Leung RW, et al. Physical activity and reduced occurrence of non–insulin-dependent diabetes mellitus. N Engl J Med 1991;325:147-52.
[4] Boule NG, Haddad E, Kenny GP, et al. Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus. JAMA 2001;286:1218-27.
[5] Schneider SH, Amorosa LF, Khachadurian AK, et al. Studies on the mechanism of improved glucose control during regular exercise in type 2 diabetes. Diabetologia 1984;26:355-60.
[6] Yamanouchi K, Shinozaki T, Chikada K, et al. 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. Diabetes Care 1995;18:775-8.
[7] Bruce CR, Kriketos AD, Cooney GJ, et al. Disassociation of muscle triglyceride content and insulin sensitivity after exercise training in patients with type 2 diabetes. Diabetologia 2004;47:23-30.
[8] Gregg EW, Gerzoff RB, Caspersen CJ. Relationship of walking to mortality among US adults with diabetes. Arch Intern Med 2003;163:1440-7.
[9] Beller GA. Coronary heart disease in the first 30 years of the 21st century: challenges and opportunities. Circulation 2001;103:2428-35.
[10] Hardman AE, Hudson A. Brisk walking and serum lipid and lipoprotein variables in previously sedentary women—effect of 12 weeks of regular brisk walking followed by 12 weeks of detraining. Br J Sports Med 1994;28:261-6.
[11] Huttunen JK, Lansimies E, Voutilainen E, et al. Effect of moderate physical exercise on serum lipoproteins. A controlled clinical trial

with special reference to serum high-density lipoproteins. Circulation 1979;60:1220-9.

[12] Kokkinos PF, Fernhall B. Physical activity and high density lipoprotein cholesterol levels what is the relationship? Sports Med 1999;28:307-14.

[13] Angelopoulos TJ, Lewis R, Jamurtas T, et al. Significant changes in VLDL-triacylglycerol and glucose tolerance in obese subjects following ten days of training. Eur J Appl Physiol Occup Physiol 1998;77: 556-9.

[14] Dumortier M, Brandou F, Perez-Martin A, et al. Low intensity endurance exercise targeted for lipid oxidation improves body composition and insulin sensitivity in patients with the metabolic syndrome. Diabetes Metab 2003;29:509-18.

[15] Iwane M, Arita M, Tomimoto S, et al. Walking 10,000 steps per day or more reduces blood pressure and sympathetic nerve activity in mild essential hypertension. Hypertens Res 2000;23:273-580.

[16] Swartz AM, Strath SJ, Bassett Jr DR, et al. Increasing daily walking improves glucose tolerance in overweight women. Prev Med 2003;37: 356-62.

[17] Walker KZ, Piers LS, Putt RS, et al. Effects of regular walking on cardiovascular risk factors and body composition in normoglycemic women and women with type 2 diabetes. Diabetes Care 1999;22: 555-61.

[18] Zinman B, Ruderman N, Campaigne BN, et al. Physical activity/ exercise and diabetes. Diabetes Care 2004;27(Suppl 1):S58-S62.

[19] Houmard JA, Tanner CJ, Slentz CA, et al. Effect of the volume and intensity of exercise training on insulin sensitivity. J Appl Physiol 2004;96:101-6.

[20] Nishida Y, Tokuyama K, Nagasaka S, et al. Effect of moderate exercise training on peripheral glucose effectiveness, insulin sensitivity, and endogenous glucose production in healthy humans estimated by a two-compartment–labeled minimal model. Diabetes 2004;53: 315-20.

[21] Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 1995;273:402-7.

[22] Tudor-Locke C, Bassett Jr DR. How many steps per day are enough? Sports Med 2004;34:1-8.

[23] LeMasurier GC, Sidman CL, Corbin CB. Accumulating 10,000 steps: does this meet current physical activity guidelines? Res Q Exerc Sport 2003;74:389-94.

[24] Katsuki A, Sumida Y, Gabazza E, et al. Homeostasis model assessment is a reliable indicator of insulin resistance during follow-up of patients with type 2 diabetes. Diabetes Care 2001;24:362-5.

[25] Tudor-Locke C, Bell RC, Myers AM, et al. Controlled outcome evaluation of the first step program: a daily physical activity intervention for individuals with type II diabetes. Int J Obes 2004; 28:113-9.

[26] Maehlm S, Grandmontagne M, Newsholme EA, et al. Magnitude and duration of excess post exercise oxygen consumption in healthy young subjects. Metabolism 1986;35:425-9.

[27] Lindahl B, Nilsson TK, Asplund K, et al. Intense nonpharmacological intervention in subjects with multiple cardiovascular risk factors: decreased fasting insulin levels but only a minor effect on plasma plasminogen activator inhibitor activity. Metabolism 1998;47: 384-90.

[28] Szymanski LM, Pate RR, Durstine JL. Effects of maximal exercise and venous occlusion on fibrinolytic activity in physically active and inactive men. J Appl Physiol 1994;77:2305-10.

[29] Bodary PF, Yasuda N, Watson DD, et al. Effects of short-term exercise training on plasminogen activator inhibitor (PAI-1). Med Sci Sports Exerc 2003;35:1853-8.

[30] Janand-Delenne B, Chagnaud C, Raccah D, et al. Visceral fat as a main determinant of plasminogen activator inhibitor 1 level in women. Int J Obes Relat Metab Disord 1998;22:312-7.