Original Article

Effect of Walking with a Pedometer on Serum Lipid and Adiponectin Levels in Japanese Middle-aged Men

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Objective: **To clarify the effects of walking with a pedometer on metabolic parameters, including adiponectin (APN).**
Methods: **We recruited 44 male Japanese volunteers (age, 37 ± 9 yrs; body mass index (BMI), 24.2 ± 2.9 kg/m^2; fasting plasma glucose (FPG), 96 ± 11 mg/dL; total cholesterol (TC) 190 ± 26 mg/dL; triglycerides (TG) 119 ± 80 mg/dL; HDL-C56 ± 14 mg/dL). Subjects were instructed to walk with a pedometer and record the number of steps they walked every day for 50 days. Serum adiponectin (APN) levels were measured by enzyme immunoassay. Treatment effects were examined by Wilcoxon's rank test.**
Results: **The average number of steps was 8211 ± 2084 per day. There were significant reductions in BMI, sBP, TG and TNF-α levels after 50 days, but no changes in adiponectin levels. We then divided the subjects into 2 groups according to the steps walked per day, namely, more than 8000 steps (MT group, n=22) and less than 8000 steps (LT group, n=22) and found that the reduction in TG and BP was observed only in the MT group.**
Conclusions: **Walking with a pedometer is effective for improving metabolic parameters, such as TG and blood pressure, but is not sufficient to increase adiponectin levels in Japanese men.**

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Key words; Waist circumference, Percent body fat, Triglycerides, HOMA-R, Adiponectin

Introduction

To prevent lifestyle-related disease, such as dyslipidemia, hypertension, type 2 diabetes (T2DM) and cardiovascular disease, it is important to exercise daily. Walking with a pedometer is easy and can be incorporated in to daily life even for individuals with a busy schedule. It is generally accepted that regular exercise, including walking, is beneficial for preventing life-related disease, such as type 2 diabetes, hypertension and hyperlipidemia[1-3].

Adiponectin (APN), an adipocytokine, is a plasma protein expressed exclusively in adipose tissue[4-6], the plasma levels of which are linked to insulin sensitivity[7-13]. APN mRNA and its plasma concentrations are known to be reduced in T2DM and atherosclerotic disease[14, 15]. Several studies in humans, monkeys and rodents have shown that APN is an insulin-sensitizing cytokine and exhibited anti-atherogenic moieties[16].

Several studies have been conducted on the effects of exercise using a bicycle ergometer and treadmill walking on plasma APN levels in obese or overweight subjects[17-19], and they showed that exercise did not change APN levels. However, to our knowledge, no study has investigated the effects of walking with a pedometer, a practical form of daily exercise, on APN levels in individuals of normal body weight.

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With this background, the aim of this study was to clarify the effects of daily walking with a pedometer on APN levels as well as other metabolic parameters connected to life-style-related disease.

Subjects and Methods

We recruited 44 male volunteers (age, 37 ± 9 yrs) with a sedentary lifestyle who were instructed to wear a pedometer (TANITA FB-714) from the time they got up until they went to bed for 50 consecutive days and to record the number of steps they walked every day. All subjects were employees of a food company in Kanazawa city, Japan. We did not perform dietary therapy. Exclusion criteria included: abnormal liver or muscle enzymes, creatinemia, habitual alcohol intake $>$3 standard drinks/day or endocrinological disorder. Subjects who already walked daily using a pedometer were also excluded. Two subjects were on medication for hypertension (A-II receptor antagonist), three for hyperlipidemia (statins) and one for hyperuricemia (allopurinol). The dosage for these drugs did not change during the study period, and they had been on those medications for at least a few months before starting this study. Drinkers (consuming more than 30 grams of alcohol per day) and smokers (smoking more than 10 cigarettes) were also excluded from this study, because these factors are known to considerably affect plasma lipoprotein metabolism. Percent body fat (PBF) was determined from bioelectrical impedance analyses (BIA) using TANITA BC-118D (TANITA Corporation, Tokyo, Japan). Venous blood was obtained after a 12-h overnight fast. Serum total- and high-density lipoprotein (HDL) cholesterol and triglyceride levels were determined before and after 50 days. Serum cholesterol and triglyceride levels were measured by enzymatic methods. HDL-cholesterol was measured by a polyanion-polymer/detergent (PPD) method (Daiichi, Tokyo). Serum insulin concentrations were determined using a commercial enzyme immunoassay kit (Eiken, Tokyo, Japan). The homeostasis model assessment of insulin resistance (HOMA-R), a surrogate measure for insulin sensitivity[20], was calculated as fasting insulin X PG (mmol/L)/22.5. Serum levels of adiponectin [Otsuka Chemical] and TNF-α [R&D Systems] were measured by ELISA. A statement of institutional approval was granted for this study in accordance with the Declaration of Helsinki and informed consent was obtained from all participants.

Statistical Analysis

Statistical evaluation was performed using StatView-J 5.0 software (SAS Institute, Cary, NC, on a Macintosh Computer). All results are presented as the mean ± SD. Wilcoxon's rank test was used for evaluation of the significance of differences between before and after 50 days of walking with a pedometer.

Table 1. Baseline characteristics and changes in metabolic parameters in all subjects (n = 44)

Variables	Before	After	*P* value
Body mass index, kg/m^2	24.2 ± 2.9	23.9 ± 2.9	0.0009
Percent body fat, %	22.7 ± 5.3	22.4 ± 5.4	0.21
Waist, cm	85.1 ± 7.7	84.7 ± 8.1	0.27
sBP, mmHg	122 ± 11	117 ± 10	0.0089
dBP, mmHg	77 ± 9	75 ± 9	0.176
TC, mg/dL	190 ± 26	189 ± 24	0.99
TG, mg/dL	119 ± 80	101 ± 52	0.019
HDL-C, mg/dL	56 ± 14	57 ± 13	0.25
FPG, mg/dL	96 ± 11	95 ± 11	0.36
Glycoalbumin, %	14.4 ± 1.0	14.3 ± 1.1	0.091
HOMA-R	1.87 ± 1.20	1.68 ± 1.15	0.19
TNF-α, pg/mL	1.58 ± 0.49	1.48 ± 0.51	0.023
Adiponectin, μg/mL	6.8 ± 2.3	6.6 ± 2.3	0.32

sBP, systolic blood pressure; dBP, diastolic blood pressure
TC, total cholesterol; TG, triglycerides; HDL-C, HDL-cholesterol
FPG, fasting plasma glucose; HOMA-R, homeostasis model assessment of insulin resistance

Results

Baseline Characteristics and Changes in Metabolic Parameters in All Subjects (Table 1)

The average number of steps of the 44 men over the 50-day period was 8211 ± 2084 steps per day. There was a subtle but significant reduction in body mass index (BMI), but no significant changes in PBF and waist circumference. There were significant reductions in systolic blood pressure (sBP), serum triglycerides (TG) and TNF-α levels; however, APN did not show a significant change during this period.

Changes in Metabolic Parameters in MT and LT Groups (Tables 2 and 3)

We divided the subjects into 2 groups according to the steps they walked per day, namely, more than 8000 steps (MT group, n = 22) and less than 8000 steps (LT group, n = 22). The average number of steps in the MT and LT groups was 9960 ± 1100 and 6462 ± 1128 steps per day, respectively. In the MT group, TG and sBP levels fell considerably after 50 days, wheseas in the LT group none of these metabolic parameters showed a considerable change after 50 days of walking.

Table 2. Changes in metabolic parameters in subjects walking more than 8000 steps per day (n=22)

	Before	After	*P* value
Body mass index, kg/m^2	23.9 ± 2.3	23.7 ± 2.2	0.0018
Percent body fat, %	22.0 ± 4.5	21.9 ± 4.1	0.52
Waist, cm	84.4 ± 7.3	84.0 ± 7.2	0.41
sBP, mmHg	124 ± 11	114 ± 11	0.0005
dBP, mmHg	78 ± 10	74 ± 9	0.085
TC, mg/dL	189 ± 26	187 ± 25	0.71
TG, mg/dL	125 ± 75	102 ± 61	0.034
HDL-C, mg/dL	53.0 ± 9.8	53.1 ± 10.6	0.45
FPG, mg/dL	96 ± 10	95 ± 8.5	0.42
Glycoalbumin, %	14.4 ± 1.0	14.3 ± 1.0	0.15
HOMA-R	1.78 ± 1.06	1.46 ± 0.64	0.11
TNF-α, pg/mL	1.5 ± 0.31	1.38 ± 0.26	0.09
Adiponectin, μg/mL	6.7 ± 2.3	6.4 ± 2.3	0.21

sBP, systolic blood pressure; dBP, diastolic blood pressure
TC, total cholesterol; TG, triglycerides; HDL-C, HDL-cholesterol
FPG, fasting plasma glucose; HOMA-R, homeostasis model assessment of insulin resistance

Table 3. Changes in metabolic parameters in subjects with less than 8000 steps per day (n=22)

	Before	After	*P* value
Body mass index, kg/m^2	24.4 ± 3.5	24.2 ± 3.5	0.17
Percent body fat, %	23.3 ± 6.1	24.2 ± 6.5	0.24
Waist, cm	85.8 ± 8.2	85.5 ± 9.0	0.47
sBP, mmHg	119 ± 11	119 ± 8.7	0.86
dBP, mmHg	77 ± 7.8	77 ± 9.2	0.95
TC, mg/dL	191 ± 27	191 ± 24	0.73
TG, mg/dL	114 ± 86	99 ± 44	0.22
HDL-C, mg/dL	59 ± 17	60 ± 15	0.47
FPG, mg/dL	96 ± 13	96 ± 13	0.64
Glycoalbumin, %	14.4 ± 1.1	14.3 ± 1.3	0.37
HOMA-R	1.97 ± 1.34	1.89 ± 1.48	0.76
TNF-α, pg/mL	1.7 ± 0.6	1.6 ± 0.6	0.12
Adiponectin, μg/mL	7.0 ± 2.4	6.9 ± 2.4	0.77

sBP, systolic blood pressure; dBP, diastolic blood pressure
TC, total cholesterol; TG, triglycerides; HDL-C, HDL-cholesterol
FPG, fasting plasma glucose; HOMA-R, homeostasis model assessment of insulin resistance

Table 4. Correlations of waist circumference, BMI and % fat (PBF) versus several metabolic parameters at baseline

	Waist		BMI		% fat	
Variables	r	p	r	p	r	p
Age	0.203	0.187	0.111	0.472	0.214	0.163
BMI	0.878	<0.0001	–	–	0.901	<0.0001
PBF	0.893	<0.0001	0.901	<0.0001	–	–
Waist	–	–	0.878	<0.0001	0.893	<0.0001
sBP	0.315	0.0373	0.306	0.0433	0.299	0.049
dBP	0.409	0.0058	0.287	0.0588	0.434	0.0033
TC	−0.047	0.760	−0.031	0.841	−0.017	0.914
TG*	0.165	0.285	0.085	0.583	0.201	0.192
HDL-C	−0.336	0.0256	−0.384	0.0101	−0.324	0.032
FPG	0.400	0.0071	0.374	0.0124	0.434	0.0032
HOMA-R*	0.662	<0.0001	0.596	<0.0001	0.667	<0.0001
Adiponectin*	−0.417	0.0049	−0.300	0.0477	−0.384	0.0102

*These values were logarithmically transformed before correlation analysis.
BMI, body mass index; PBF, percent body fat; sBP, systolic blood pressure; dBP, diastolic blood pressure; TC, total cholesterol; TG, triglycerides; HDL-C, HDL-cholesterol; FPG, fasting plasma glucose; HOMA-R, homeostasis model assessment of insulin resistance

Correlation of BMI, Percent Body Fat (PBF) and Waist Circumference with Metabolic Parameters at the Baseline (Table 4)

Significant associations were noted between BMI, PBF and waist circumference versus serum APN levels, among which the association between waist circumference and serum adiponectin levels was most pronounced. Similarly, there were considerable associations between BMI, PBF and waist circumference, and HOMA-R.

Correlation between the Number of Steps Per Day with % Changes in Metabolic Parameters During the Study Period

Among the metabolic parameters investigated, % changes in sBP showed a significant correlation ($r=-0.401$, $p=0.0069$) and BMI tended to show a correlation ($r=-0.276$, $p=0.068$) with the number of steps per day, whereas no other metabolic parameters showed a significant correlation.

Discussion

In this study we found that walking with a pedometer had a favorable effect on conventional metabolic parameters, such as blood pressure and serum triglycerides levels when the steps per day were greater than 8000. Meta-analysis of the effect of walking on serum lipids in 46074 subjects in 8 populations have shown that walking 6000 steps or more lowered TG by 10 mg/dL and increased HDL-C by 3 mg/dL compared to subjects walking less than 2000 steps per day[21)]. In our study we did not find a significant effect of walking 6000 steps on lipid levels. Since our study subjects did not wear a pedometer before this study and thus we did not know the changes in the steps they walked between before and after this study, it was impossible to exactly explain the reason underlying this inconsistency between our study and their meta-analysis. This point might be a limitation of our study.

In our study, we measured several cytokines as well as conventional metabolic parameters. There was a significant reduction in plasma TNF-α levels after 50 days of walking, which could have a favorable effect on insulin sensitivities; however, there was no significant change in APN levels. There have been several studies conducted on the effects of exercise on plasma APN levels in obese or overweight subjects[17-19)]. Yokoyama *et al.* reported that a 3-week intervention consisting of exercise, including walking and a bicycle ergometer, and diet therapy did not produce significant changes in APN levels in type 2 diabetic overweight individuals[17)], which was consistent with previous findings[18, 19)]. Our study differs from theirs in that we investigated the effect of walking with a pedometer. Also, we were able to compare the effects of walking on metabolic parameters between LT and MT groups. There is a report showing that considerable weight loss produces a significant increase in APN levels[22)]. Yang *et al.* showed that 21% BMI reduction by gastric partition produced a 46% increase in plasma APN levels[22)]. We presume that we did not observe significant changes in APN levels in our study because the weight loss produced by walking was too subtle.

In addition to the effect of walking on metabolic parameters, we also investigated the association between BMI, PBF and waist circumference versus various metabolic parameters. To our knowledge, there has been no previous study comparing the clinical significance of BMI, PBF and waist circumference versus metabolic parameters. Significant attention has been given to waist circumference, which is an important component for diagnosing metabolic syndrome[23)]. In our study, there was a stronger association with APN levels than with BMI and PBF; thus, we presume that waist circumference could a better predictor of adiponectin levels than BMI or PBF.

It is intriguing that there was a positive correlation of % changes in sBP with the number of steps walked per day, indicating how important it is to walk with a pedometer to lower systolic blood pressure.

For the accuracy and reliability of PBF by BIA, which was applied in this study, Tsui *et al.*[24)] showed a high correlation between PBF by BIA and that by DXA ($r=0.89$, $p<0.0001$) in 96 (48 men and 48 women) type 2 diabetic subjects. This is in line with the data previously shown in healthy individuals[25)].

In conclusion, we have reported that walking with a pedometer considerably improved blood pressure and TG levels but had no effect on serum APN levels in Japanese middle-aged men.

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