The Effect of Daily Walking on Body Fat Distribution

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Abstract

The effect of daily walking on body fat distribution was investigated using an electronic pedometer and ultrasonography. Subjects were 77 women, aged 31 to 72 years. They were divided into four groups according to the average number of steps they walked per day ($I < 7,500$, $7,500 \leq II < 10,000$, $10,000 \leq III < 12,500$, $12,500 \leq IV$). Subcutaneous fat in the trunk and limbs, and the minimum thickness of subcutaneous fat (Smin) and the maximum thickness of preperitoneal fat (Pmax) below the xiphoid process were measured by ultrasonography. Abdominal wall fat index (AFI) reflecting the intra-abdominal fat accumulation was obtained by dividing Pmax by Smin. Fat distribution was analyzed by ANCOVA, controlled for age, body mass index (BMI), percent body fat, and menopausal status. Energy and macronutrient intake were obtained through a nutritional survey. There were no significant differences in anthropometric variables, energy and macronutrient intake, and subcutaneous fat thickness in trunk and limbs. Pmax of Group I was significantly higher than Group IV. Furthermore, Group I showed significantly higher AFI than the other three Groups (II, III, IV). The results of this study suggested that women who walked less than 7,500 steps per day tend to have significantly increased intra-abdominal fat accumulation.

Key words: fat distribution, walking, intra-abdominal fat, B-mode ultrasonography, abdominal wall fat index

Introduction

It is now well established that body fat distribution is more closely related with complications of obesity than excess body weight¹⁾. Intra-abdominal fat accumulation in particular is associated with a cluster of metabolic abnormalities contributing to increase the risk of diabetes and cardiovascular diseases^{2,3)}. Therefore, factors relating to fat distribution, such as smoking, food intake, alcohol consumption, and physical activity have been investigated^{4,5,6)}. However, levels of physical activity have been assessed only by questionnaire in most studies. Several studies have indicated that some physical activity questionnaires yield imprecise estimates of daily walking distance^{7,8)}. Bassett et al.⁹⁾ reported, however, that the new electronic pedometers could prove to be useful in epidemiological studies of daily walking. Pedometers have the advantage of avoiding the potential bias of physical activity questionnaires and diaries; electronic pedometers especially have a greater absolute accuracy than the old-style

mechanical pedometers.

On the other hand, variety of techniques have been used to classify individuals by their fat distribution patterns. The measurement of waist and hip circumferences is easy, but evaluating fat distribution by the waist-hip ratio (WHR) is considered questionable because both waist and hip circumferences include many tissues and organs in addition to adipose tissue. Interpretation of the literature concerning the WHR is difficult because waist and hip circumferences have been measured at various points in different studies¹⁰⁾. Ultrasonography has been employed to measure fat distribution. The lack of radiation exposure and good precision with mean observer differences are advantages of the ultrasonography method¹¹⁾. Recently, Suzuki et al.¹²⁾ reported that both the minimum thickness of subcutaneous fat (Smin) and the maximum thickness of preperitoneal fat (Pmax) below the xiphoid process could be determined by ultrasonography; the Pmax to Smin ratio was termed the abdominal wall fat index (AFI) and was utilized as a new index to abdominal fat distribution.

The main purpose of the present cross-sectional study was to investigate the relationship between daily walking and body fat distribution using an electronic pedometer and ultrasonography.

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Methods

Subjects

Seventy-seven women aged 31 to 72 years who attended health education class held in Midori Ward in Nagoya, Japan, were included in this study. The study was approved by the appropriate institutional review boards at Nagoya University, and each subject gave written consent after a full explanation of the procedures and risks. Women with hypertension, diabetes, or undergoing hormone replacement therapy, and who had regular exercise habits (for example, jogging, aerobic dance, or swimming) were excluded. Information on smoking status and menopausal status, was obtained by personal interview. Measurements described below were made 7 to 10 days before the class began.

Anthropometry

Anthropometry measurements were made with the subjects in their underwear, without shoes, and in the standing position. Height was measured to the nearest 0.1 cm with an electric stadiometer and body weight was measured to the nearest 0.1 kg on a clinical scale. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Percent body fat was measured using a bioelectric impedance analysis device (TBF-102, Tanita, Japan). This instrument operates at a single frequency of 50 kHz, and a two-electrode approach is used; measurements were taken at a minimum of 3 hours after breakfast.

Food intake

Dietary energy and macronutrient intake were determined by a 7-day self-reported nutritional diary. Subjects noted the kinds and quantities of foods consumed in each meal. Energy, carbohydrate, protein, and fat intake were calculated from these data. All subjects agreed not to change their usual diet.

Walking

The number of steps walked per day was counted by an electronic pedometer (Select2®, Suzuken, Japan). This device is accurate to within $\pm 1\%$. It was 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. The Japanese Industrial Standards Committee has established a strict set of standards for electronic pedometers¹³⁾. The device was used to count steps per day and record the data for 7 days. The sum of 7 days' data was divided by 7 to obtain the average number of steps per day. All subjects wore the electronic pedometer in their upper iliac region all day except while sleeping, and they were instructed not to change their usual lifestyle during the measurement period.

Fat distribution

Fat distribution was assessed by B-mode ultrasonography (SSD-500, ALOKA, Japan) with a linear-array probe (5 MHz). The probe was applied as lightly as possible so that the fat layers were not compressed. Measurements were carried out by a single experienced operator. Subcutaneous fat thickness at the side of the umbilicus and subscapula as part of the trunk, and triceps, front thigh and posterior calf as part of the limbs, were measured on the right side of the body. The minimum thickness of subcutaneous fat (Smin) and the maximum thickness of

preperitoneal fat (Pmax) below the xiphoid process were measured as abdominal fat distribution. The scheme for assessing intra-abdominal fat distribution is shown in Figure 1. A subject was lying in the supine position; the probe was kept perpendicular to the skin on the upper median abdomen, and scanning was performed below the xiphoid process, and the surface of the liver was kept almost parallel to the skin by breath holding. The Smin and the Pmax were measured, and the abdominal wall fat index (AFI) was obtained by dividing Pmax by Smin. Ultrasonograms of two types of abdominal fat distribution are shown in Figure 2.

Statistical analysis

The effect of the number of steps walked on anthropometric variables, energy, and macronutrient intake was analyzed using ANOVA. The difference in fat distribution according to the steps walked per day was analyzed using a covariance (ANCOVA) controlled for age, BMI, percent body fat, and menopausal status. Post hoc analysis was completed with Sheffe's multiple

Figure 1 Procedure for assessing intra-abdominal fat distribution by B-mode ultrasonography. Smin is the minimum thickness of subcutaneous fat and Pmax is the maximum thickness of preperitoneal fat below the xiphoid process. Abdominal wall fat index (AFI) = $P_{\max}/S_{\min}$.

Figure 2 Ultrasonograms of two types of abdominal fat distribution. (a): Subject with thickened subcutaneous fat compared to preperitoneal fat. (b): Subject with thickened preperitoneal fat compared to (a).

comparisons test. Data were analyzed using the PROC GLM option LSMEANS procedure in the Statistical Analysis System version 6.12 (SAS institute, Cray, NC); statistical tests were two-tailed, and P values below 0.05 were regarded as statistically significant. All data are reported as means $\pm$ standard error (SE).

Results

The study population consisted of middle-aged and elderly Japanese women; the mean age was 48 years. Based on the personal interviews, 28 women were classified as pre menopausal and 46 as post menopausal. We could not determine the data of three women. All subjects were non-smokers. The average number of steps walked per day ranged from 4,737 to 18,302, and the subjects were divided into four groups on the basis of steps walked per day. (Group I < 7,500, 7,500 $\leq$ Group II < 10,000, 10,000 $\leq$ Group III < 12,500, 12,500 $\leq$ Group IV). We found no differences between pre menopausal and post menopausal women in anthropometric measurements, fat distribution, or the average number of steps walked per day.

Characteristics of the subjects

The anthropometric characteristics in the four groups are shown in Table 1. As expected, the most inactive Group I showed greater weight, BMI, and percent body fat than the other three groups. In contrast, the most active Group IV tended toward lower weight, BMI, and percent body fat. However, there were no significant differences among the four groups.

Food intake

Table 2 shows energy, carbohydrate, protein, and fat intake in the four groups. A similar pattern was found with respect to all

food intake values in the four groups, and no significant inter group differences were found.

Fat distribution

The most active Group IV showed the lowest values in subcutaneous fat in the trunk (side of umbilicus and subscapula) and limbs (triceps, thigh, and calf), but the differences between the four groups were not significant when the data were controlled for age, BMI, percent body fat, and menopausal status (Table 3). As illustrated in Figure 3, the Smin in Group I was significantly lower than it was in Group III or Group IV ($P < 0.05$) after being controlled for age, BMI, percent body fat, and menopausal status. However, the Pmax was the highest in Group I as shown in Figure 4, and there was a significant difference between that in Group I and Group IV ($P < 0.001$). Figure 5 shows a comparison of the AFI values in the four groups after adjustment for age, BMI, percent body fat, and menopausal status. The most inactive Group I showed the highest AFI among the four groups. There were significant differences between Group I and Group II ($P < 0.05$), and Group III ($P < 0.001$), and Group IV ($P < 0.001$), and between Group II and Group IV ($P < 0.05$). The mean AFI in Group I, Group II, Group III, and Group IV was 0.82, 0.66, 0.54 and 0.47, respectively.

Discussion

We found that preperitoneal fat thickness was relatively reduced compared to subcutaneous fat thickness below the xiphoid process, as the steps walked per day increased. In this study, there were no significant differences in food intake between the four groups. Neither were there any significant differences in anthropometric measurements, fat distribution, or

Table 1 Anthropometric characteristics

Group	I	II	III	IV	F Value
Number of Subjects	23	27	13	14	(Probability)
Age (year)	49.4 $\pm$ 1.8	48.2 $\pm$ 1.7	45.5 $\pm$ 2.5	49.6 $\pm$ 2.4	0.62 (NS)
Height (cm)	153.1 $\pm$ 1.2	154.3 $\pm$ 1.1	154.8 $\pm$ 1.5	153.7 $\pm$ 1.5	0.33 (NS)
Weight (kg)	57.0 $\pm$ 1.6	55.4 $\pm$ 1.5	57.4 $\pm$ 2.1	54.2 $\pm$ 2.0	0.58 (NS)
BMI (kg/m ²)	24.3 $\pm$ 0.6	23.2 $\pm$ 0.5	23.9 $\pm$ 0.8	22.9 $\pm$ 0.7	0.99 (NS)
% Fat	31.5 $\pm$ 1.0	29.7 $\pm$ 1.0	30.7 $\pm$ 1.4	28.5 $\pm$ 1.3	1.23 (NS)

Group I subjects walked fewer than 7,500 steps/day; Group II subjects walked more than 7,500 steps/day but fewer than 10,000 steps/day; Group III subjects walked more than 10,000 steps/day but fewer than 12,500 steps/day; Group IV subjects walked more than 12,500 steps/day. Values are means $\pm$ SE; they were compared using ANOVA. All subjects were non-smokers and did not have regular exercise habits. NS (Not Significant)

Table 2 Energy and macronutrient intake

Group	I	II	III	IV	F Value
					(Probability)
Energy (kcal/day)	1678 $\pm$ 76	1713 $\pm$ 72	1667 $\pm$ 99	1658 $\pm$ 96	0.99 (NS)
Carbohydrate (g/day)	227 $\pm$ 13	233 $\pm$ 12	221 $\pm$ 17	222 $\pm$ 16	0.15 (NS)
Protein (g/day)	64 $\pm$ 3	64 $\pm$ 3	62 $\pm$ 4	59 $\pm$ 4	0.35 (NS)
Fat (g/day)	50 $\pm$ 3	53 $\pm$ 3	51 $\pm$ 4	53 $\pm$ 4	0.29 (NS)

Values are means $\pm$ SE; they were compared using ANOVA. NS (Not Significant)

Table 3 Subcutaneous fat thickness of the trunk and limbs

Group	I	II	III	IV	F Value
					(Probability)
Umbilicus (mm)	21.5 $\pm$ 1.1	21.9 $\pm$ 1.0	22.0 $\pm$ 1.4	19.5 $\pm$ 1.4	9.50 (NS)
Subscapula (mm)	10.0 $\pm$ 0.3	10.6 $\pm$ 0.3	10.1 $\pm$ 0.4	9.7 $\pm$ 0.4	8.55 (NS)
Triceps (mm)	11.6 $\pm$ 0.6	11.4 $\pm$ 0.6	11.5 $\pm$ 0.8	10.7 $\pm$ 0.7	2.78 (NS)
Thigh (mm)	13.8 $\pm$ 0.5	13.6 $\pm$ 0.5	13.6 $\pm$ 0.6	12.8 $\pm$ 0.6	2.71 (NS)
Calf (mm)	10.1 $\pm$ 0.3	10.0 $\pm$ 0.3	10.0 $\pm$ 0.4	9.7 $\pm$ 0.4	2.45 (NS)

Values are means $\pm$ SE; they were compared using ANCOVA, controlled for age, BMI, percent body fat and menopausal status. NS (Not Significant)

steps walked per day between pre and post menopausal subjects. All subjects were non-smokers, and they did not have regular exercise habits. It follows from these findings that the number of steps walked could reflect the daily activity, and it was one of the factors influencing abdominal fat distribution in our subjects.

When the difference in fat distribution according to the steps walked per day was analyzed, interaction factors, such as age, BMI, percent body fat, and menopausal status, were controlled by statistical procedures. The most active Group IV showed the

lowest preperitoneal fat thickness and abdominal wall fat index among the four groups. In contrast, the most inactive Group I showed higher preperitoneal fat thickness and abdominal wall fat index than the other three groups. It might be indicated that the preperitoneal fat was more sensitive to daily walking than the subcutaneous fat.

Preperitoneal fat is anatomically covered by the peritoneum, like omental fat or retroperitoneal fat, and is considered part of the intra-abdominal fat. As such, it shares properties with intra-abdominal fat and reflects the amount of intra-abdominal fat¹²⁾. Previous studies have reported that the decrease in adipose tissue caused by low-to moderate-intensity activities is more striking with respect to intra-abdominal fat than subcutaneous fat. These activities have beneficial effects on reducing intra-abdominal fat, independent of changing body mass^{14, 15)}. An explanation for this could provide evidence of a difference in metabolic characteristics between intra-abdominal adipose tissue, and subcutaneous adipose tissue¹⁶⁾.

Another way to assess the fat distribution has been proposed: the ratio of intra-abdominal visceral fat area to subcutaneous fat area (V/S ratio) by radiographic computer tomography (CT). The V/S ratio can be used as an indicator for various disabilities, for example, glucose intolerance, hyperinsulinemia, hyperlipidemia, hypertension, and coronary heart disease^{17, 18)}. The AFI (P/S ratio) showed the highest positive correlation with the V/S ratio ($r=0.75$). Furthermore, AFI correlates positively with plasma triglyceride levels, atherogenic index and basal insulin levels, and correlates negatively HDL-cholesterol levels¹²⁾. A cut-off point AFI for women is determined over 0.70 because the frequency of coronary stenosis as well as the coronary stenosis score is highest in women with an AFI over 0.70¹⁹⁾. Our Group I showed the lowest pedometer scores and a significantly high AFI ($=0.82$) in comparison to there in the other three groups, which implies that Group I might be a potential high-risk group.

Walking is a popular form of daily activity that has been

Figure 3 Minimum subcutaneous fat thickness (Smin) below the xiphoid process in the four study groups. Analysis of covariance was used to examine differences between the four groups, controlled for age, BMI, percent body fat, and menopausal status. Sheffe's multiple comparisons test was completed. Values are means $\pm$ SE. * significant difference, $P < 0.05$.

Figure 4 Maximum preperitoneal fat thickness (Pmax) below the xiphoid process in the four study groups. Analysis of covariance was used to examine differences between the four groups, controlled for age, BMI, percent body fat, and menopausal status. Sheffe's multiple comparisons test was completed. Values are means $\pm$ SE. # significant difference, $P < 0.001$.

Figure 5 Abdominal wall fat index (AFI) in the four study groups. $AFI = Pmax/Smin$. Analysis of covariance was used to examine differences between the four groups, controlled for age, BMI, percent body fat, and menopausal status. Sheffe's multiple comparisons test was completed. Values are means $\pm$ SE. * significant difference, $P < 0.05$. # significant difference, $P < 0.001$.

linked to a variety of health benefits. Regular walking has been associated with decreased overall mortality rate, and reduced risk of death from coronary heart disease and stroke^{20, 21)}. The American Heart Association has said the greatest benefits obtained through physical activity toward reducing mortality from cardiovascular disease can be attained through daily low-to-moderate-intensity activities such as walking²²⁾.

The results of this cross-sectional study suggest that daily walking can influence abdominal fat distribution in Japanese women. When the number of steps walked per day was fewer than 7,500, the accumulation of intra-abdominal fat increased. We propose that it is necessary to walk a minimum of 7,500 steps per day in order to prevent increasing intra-abdominal fat accumulation.

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