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Original Article

Anthropometric and Clinical Findings in Obese Japanese: The Saku Control Obesity Program (SCOP)

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Abstract

BACKGROUND: Japan has entered the epidemic of obesity. To clarify the contributing factors to the development of metabolic syndrome triggered by visceral fat obesity and to investigate the effectiveness of a weight-loss program, we launched a new intervention program for obese people.

METHODS: Japanese subjects with high body mass index (BMI > 28.3 kg/m^2) were selected for a weight-loss program from those who had undergone a medical checkup at the Saku Central Hospital. The baseline anthropometric and clinical findings of the participants were analyzed.

RESULTS: At baseline, 235 subjects (116 men and 119 women) participated in this program. The mean weight, waist circumference, and visceral fat area were 86.4 ± 11.8 kg, 101.5 ± 8.7 cm, and 159.0 ± 54.1 cm^2 in men and 75.2 ± 9.5 kg, 103.7 ± 8.3 cm, and 129.8 ± 47.0 cm^2 in women, respectively. Using the Japanese diagnostic criteria, the prevalence of metabolic syndrome was 62.9% in men and 51.3% in women. Leptin, c-peptide, and insulin levels tended to increase with increasing numbers of metabolic risk factors in men. In women, c-peptide and free fatty acid levels tended to increase with increasing numbers of these factors, but adiponectin decreased dose-dependently with increasing numbers of factors.

CONCLUSIONS: More than half the subjects were founded to meet the criteria for metabolic syndrome. Immediate intervention to lose weight and to improve other risk factors of metabolic syndrome is necessary in such seriously obese people.

KEY WORDS: obesity, metabolic syndrome, visceral fat area, adipocytokine

Introduction

Japan has entered the escalating epidemic of obesity.[1] Obesity may trigger many serious illnesses, including type 2 diabetes and cardiovascular diseases. In particular, visceral fat obesity is thought to be associated with many metabolic disorders.

The metabolic syndrome is an important cluster of metabolic abnormalities linked with insulin resistance and cardiovascular diseases.[2,3] Insulin resistance had long been considered to have a central role in the development of metabolic disorders[4]; however, several clinical studies have demonstrated intra-abdominal visceral fat accumulation to have a crucial, direct role in this development.[5,6] According to the new definition released by the Japanese examination committee for the criteria of metabolic syndrome, the presence of abdominal obesity is necessary for the diagnosis.[7]

Recently, it has been shown that adipocytes secrete several proteins called adipocytokines, including adiponectin, leptin, and tumor necrosis factor-α (TNF-α); these may be related to the development of obesity-mediated adverse effects in glucose and lipid metabolism.[8] Thus, along with weight reduction in obese patients, changes in the concentrations of biochemical parameters including these adipocytokines should be surveyed.

To prevent the development of metabolic syndrome, weight reduction in obese patients is clearly necessary.[9] However, it is not well understood how much reduction is appropriate and which method of weight control is the most effective for prevention of metabolic syndrome. In addition, it is unclear whether visceral fat can be reduced effectively by modification of diet and exercise habits.

To clarify the contributing factors to the development of metabolic and cardiovascular disorders and to investigate the effectiveness of a weight-loss program, we launched a new intervention program for obese people.[10] In this report, we present anthropometric and biochemical data, as well as major clinical findings, of all subjects at baseline.

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Methods

Japanese obese subjects were selected from people who had undergone a medical checkup in the Saku Central Hospital. They were aged 40–64 years with a body mass index (BMI: kg/m^2) greater than 28.3 (the upper 5 percentile of all examinees) and had come for medical checkup since 2000. They were asked to participate in an intervention program for weight loss, the Saku Control Obesity Program (SCOP). The details of the subjects and methods of this program are presented the previous report.[10] The participants had an anthropometric and clinical examination (height, weight, body fat percentage, waist circumference, visceral fat area, and biochemical markers of blood and urine) and were assessed for present illness, physical activity level, and dietary habits at the start of this program.

The height (cm) and weight (kg) of the subjects were measured with an automatic scale (Tanita, BF-220, Tokyo, Japan). Percentage body fat was evaluated by the bioelectric impedance method with the same scale. The BMI was calculated as the weight (kg) divided by the squared height (m^2). Visceral and subcutaneous fat areas were assessed by a computed tomography scan at the level of the umbilicus, with the subjects in the supine position, and calculated using commercially available software (Fat Scan; N2 System Corp., Osaka, Japan).

Adipocytokines (i.e., leptin, TNF-α, adiponectin, and free fatty acid), c-peptide, and insulin levels were examined using the laboratory testing services provided by SRL Inc. (Tokyo, Japan). Leptin (ng/mL) was measured by a radioimmunoassay (Human Leptin RIA Kit, LINCO Research, St. Charles, MO, USA) with a sensitivity of 0.5 ng/mL. TNF-α (pg/mL) was measured by an enzyme-linked immunoassay (ELISA; Quantikine TNF-α HS Immunoassay Kit, R&D Systems Inc., Minneapolis, MN, USA) with a sensitivity of 0.12 pg/ml. High-molecular-weight form adiponectin (μg/mL) was determined using ELISA (Fujirebio Inc., Tokyo, Japan) with a detection limit of 0.18 μg/ml. Free fatty acid (mEq/L) was determined using an enzymatic assay (NEFA-SS 'Eiken', Eiken Chemical Co. Ltd., Tokyo, Japan) with a sensitivity of 0.005 mEq/L. C-peptide (ng/mL) was measured by a chemiluminescent enzyme immunoassay (CLEIA) (Lumipulse Presto C-peptide, Fujirebio Inc.) with a minimal detection limit of 0.1 ng/mL. Insulin (μIU/mL) was measured using CLEIA (Lumipulse Presto Insulin, Fujirebio Inc.) with a minimal detection limit of 0.3 μIU/mL. Other biochemical markers were examined in the clinical laboratory of the Saku Central Hospital.

Comparisons of the mean values of anthropometric and biochemical markers between sexes and between the groups stratified by the number of metabolic risk factors were tested using Student's t-test and analysis of variance (ANOVA), respectively. The associations of adipocytokines and insulin resistance markers with anthropometric and other biochemical markers for metabolic syndrome were examined using Pearson's correlation. Statistical significance was set at $p < 0.05$ for all analyses. All statistical analyses were performed using the SPSS® system for personal computers (Release 14.0.1, SPSS Japan, Inc., Tokyo, Japan).

Results

Among the 917 people with BMI > 28.3 kg/m^2, 235 subjects (116 men and 119 women) participated in this program. ***Table 1*** shows the basic characteristics of the subjects grouped by sex at baseline. Men were taller, heavier, and had greater visceral fat area than women, but women had significantly greater waist circumferences than men. In terms of clinical and biochemical markers, men showed significantly higher triglyceride and uric acid levels than women. In contrast, total cholesterol, HDL cholesterol, and LDL cholesterol were higher in women than in men.

Table 1 ***Basic Characteristics of the Subjects***

	Men (n = 116)	Women (n = 119)
Age (years)	52.9 ± 6.6	54.4 ± 6.5
Height (cm)	168.4 ± 5.8	155.4 ± 5.5 *
Weight (kg)	86.4 ± 11.8	75.2 ± 9.5 *
BMI (kg/m^2)	30.4 ± 3.5	31.1 ± 3.1
Waist circumference (cm)	101.5 ± 8.7	103.7 ± 8.3 *
Visceral fat area (cm^2)	159.0 ± 54.1	129.8 ± 47.0 *
Systolic blood pressure (mmHg)	132 ± 15	136 ± 18
Diastolic blood pressure (mmHg)	82 ± 13	83 ± 12
Total cholesterol (mg/dL)	204 ± 28	216 ± 39 *
HDL cholesterol (mg/dL)	50 ± 10	56 ± 12 *
LDL cholesterol (mg/dL)	122 ± 27	131 ± 34 *
Triglyceride (mg/dL)	175 ± 120	148 ± 78 *
Fasting glucose (mg/dL)	112 ± 25	112 ± 26
HbA1c (%)	5.9 ± 1.1	5.9 ± 1.1
Uric acid (mg/dL)	6.6 ± 1.3	5.3 ± 1.0 *
C-reactive protein (mg/dL)	0.17 ± 0.28	0.18 ± 0.17
Free fatty acid (mEq/L)	0.51 ± 0.19	0.57 ± 0.21 *
Leptin (ng/mL)	8.2 ± 5.6	21.3 ± 11.2 *
Tumor necrosis factor-α (pg/mL)	1.6 ± 2.9	1.2 ± 0.4
Adiponectin (μg/mL)	2.8 ± 1.8	5.5 ± 3.1 *
C-peptide (ng/mL)	2.86 ± 1.25	2.54 ± 0.92 *
Insulin (μIU/mL)	12.11 ± 9.97	11.11 ± 5.91

Values are means±SD.
*: Significant difference between men and women ($p<0.05$).

Figure 1 shows the distribution of visceral fat area stratified for BMI and sex. Despite the fact that we selected subjects with BMI > 28.3 at the last medical checkup, 53 subjects (22.6%) had BMIs ≤ 28.3. However, all subjects were classified as obese (BMI > 25). In terms of the waist circumference, all subjects (except four women) met the criteria of the central obesity defined in the Japanese diagnostic criteria of metabolic syndrome (men: ≥ 85 cm, women: ≥ 90 cm). The prevalence of subjects with visceral fat area less than 100 cm^2 was 19.1% (men: 8.6%, women: 29.4%). One-fifth of the women with a BMI ≥ 30 had a visceral fat area less than 100.

Using the Japanese diagnostic criteria, the prevalence of metabolic syndrome in men and women was 62.9% and 51.3%, respectively (***Figure 2***). ***Figure 2*** also presents the prevalence of subjects with high blood pressure, dyslipidemia, and high blood glucose using the cut-off points defined in the Japanese diagnostic criteria of metabolic syndrome. Less than 30% of male and female subjects were diagnosed with diabetes mellitus, based on the Japan Diabetes Society criteria.

Among the adipocytokines, leptin levels exhibited a significantly positive correlation with anthropometric obesity parameters in both men and women (***Table 2***). In women, adiponectin levels were significantly correlated with four components of the metabolic syndrome criteria. In men, however,

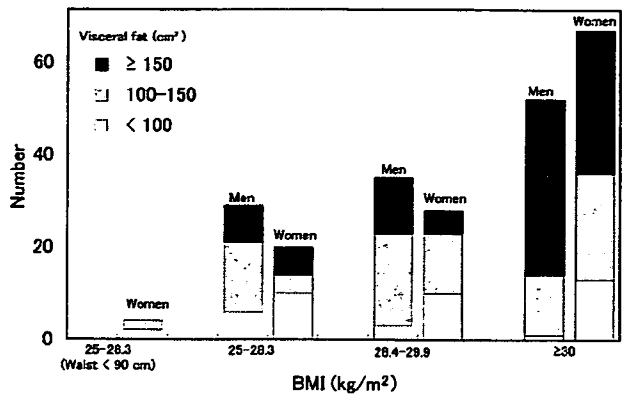

Fig. 1. Distribution of all subjects classified according to BMI and visceral fat area.
All men had a waist circumferences ≥ 85 cm; with the exception of four subjects (left), all women had waist circumference ≥ 90 cm.

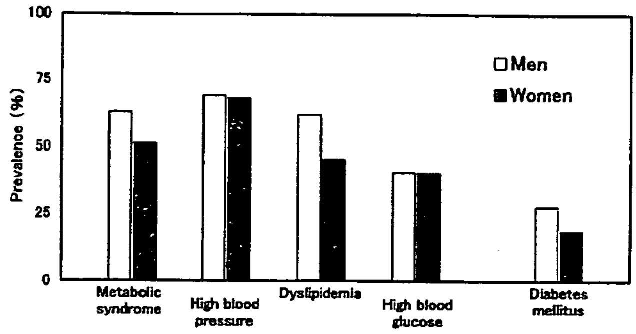

Fig. 2. Prevalence of metabolic syndrome and each metabolic abnormality. The cut-off values defining metabolic abnormalities were established at 130/85 mmHg for high blood pressure; ≥ 150 mg/dL triglyceride and/or < 40 mg/dL HDL cholesterol for dyslipidemia; and 110 mg/dL for high blood glucose; or patients being treated for hypertension, dyslipidemia, and/or diabetes, all according to Japanese diagnostic criteria for metabolic syndrome. A 75-g oral glucose tolerance test was used to calculate the prevalence of diabetes mellitus based on 1999 Japan Diabetes Society criteria.

***Table 2** Pearson's correlations between components of metabolic syndrome and adipocytokines and other plasma biochemical markers in relation to metabolic disorder*

	C-reactive protein	Free fatty acid	Leptin	Tumor necrosis factor-α	Adiponectin	C-peptide	Insulin
				Men (n=116)			
Weight	0.381 *	0.082	0.646 *	-0.064	-0.043	0.193 *	0.165
BMI	0.402 *	0.114	0.740 *	-0.041	-0.060	0.285 *	0.247 *
Waist circumference	0.389 *	0.120	0.763 *	-0.094	-0.022	0.186 *	0.123
Visceral fat area	0.088	0.058	0.511 *	-0.092	-0.020	0.228 *	0.164
Systolic blood pressure	0.126	0.071	0.070	-0.124	-0.096	0.039	0.050
Diastolic blood pressure	0.016	0.163	0.062	-0.166	-0.006	-0.031	-0.053
HDL cholesterol	-0.061	0.142	0.033	-0.044	0.132	-0.117	-0.122
Triglyceride	-0.077	0.334 *	0.026	-0.049	-0.198 *	0.186 *	0.078
Fasting glucose	0.012	0.153	0.120	-0.095	-0.133	0.078	0.115
				Women (n=118)			
Weight	0.104	-0.068	0.488 *	0.000	-0.007	0.492 *	0.474 *
BMI	0.062	0.139	0.549 *	0.079	0.068	0.447 *	0.478 *
Waist circumference	0.151	-0.074	0.468 *	0.062	0.082	0.416 *	0.366 *
Visceral fat area	0.167	0.158	0.286 *	0.293 *	-0.053	0.325 *	0.341 *
Systolic blood pressure	0.052	0.100	0.061	0.075	-0.134	0.046	0.080
Diastolic blood pressure	0.048	0.056	0.109	-0.065	-0.232 *	0.253 *	0.285 *
HDL cholesterol	-0.056	0.015	0.051	-0.153	0.352 *	-0.208 *	-0.133
Triglyceride	0.129	0.051	0.051	0.172	-0.288 *	0.359 *	0.315 *
Fasting glucose	0.176	0.293 *	0.102	0.184 *	-0.225 *	0.088	0.074

*: Significant correlation ($p<0.05$)

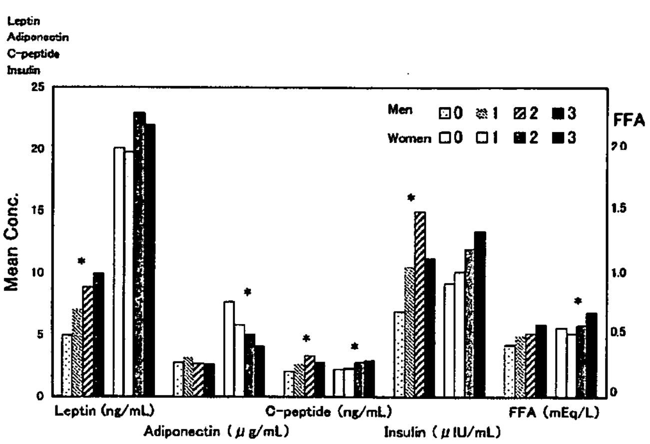

Fig. 3. Association between adipocytokines and the number of the risk factors: high blood pressure (≥ 130/85 mmHg); high triglyceride (≥ 150 mg/dL) and/or low HDL cholesterol (< 40 mg/dL); high blood glucose (≥ 110 mg/dL); or under treatment for hypertension, dyslipidemia, and/or diabetes, according to metabolic syndrome criteria. FFA, free fatty acid.
* Significant difference in the number of the risk factors among groups (analysis of variance [ANOVA], $p < 0.05$).

a significant but smaller correlation was seen only for triglyceride level. C-peptide level in both men and women and insulin level in women was significantly correlated with most parameters of metabolic syndrome.

Figure 3 illustrates the association of adipocytokines and markers of insulin resistance with the number of risk factors comprising metabolic syndrome criteria. In men, leptin, c-peptide, and insulin levels tended to show a graded increase with increasing numbers of the risk factors. In women, c-peptide and free fatty acid levels tended to increase with increasing numbers of the risk factors, but adiponectin decreased dose-dependently with increasing numbers of these factors.

Discussion

In our obese subjects, the prevalence of metabolic syndrome using the Japanese criteria was 62.9% in men and 51.3% in women. These values are notably lower in both men and women compared to the prevalence calculated using the International Diabetes Federation definition[11] based on waist circumference for Japanese (men: 77.6%, women: 72.3%), whereas only the values for women are lower using the American Heart Association/National Heart, Lung, and Blood Institute definition (men: 51.7%, women: 72.3%).[12] When using the visceral fat area for the criteria of central obesity, the prevalence of metabolic syndrome was lower than that using the waist circumference. Based on these results, the cut-off value of waist circumference, which was equivalent to 100 cm^2 of the visceral fat area, was estimated to be greater than 90 cm. However, the cut-off values of waist circumference in women are lower than those in men for all the criteria of metabolic syndrome in Caucasians and Asians, except for the Japanese criteria. In addition, some studies reported the optimal cut-off point of waist circumference to predict the risk of metabolic syndrome for Japanese women to be less than 85 cm.[13,14] Considering that women tend to accumulate more subcutaneous fat than visceral fat,[15] other predictors that may play a key role in the development of metabolic disorders in obese women must be determined.

The prevalence of metabolic syndrome defined by Japanese criteria in our obese subjects was much higher than the estimated prevalence in the general population according to the National Health and Nutrition Survey.[1] Our subjects had more risk factors than those who had the same waist circumference in the general population.[1] People with serious obesity, such as our subjects, are a high-risk population in which intervention is necessary to prevent the development of metabolic syndrome.

Adipocytes are present within fat tissues and are capable of releasing numerous vasoactive factors leading to cardiovascular morbidity in obese individuals.[16] It is well known that leptin levels are strongly correlated with fat mass and decrease with weight reduction, and we found significant correlations between leptin levels and anthropometric obesity markers. Adiponectin usually decreases with greater insulin resistance and is lower in people with coronary heart disease than those without this disease. In our study, adiponectin was associated with the risk of metabolic syndrome only in women. The reason for this difference between men and women was unclear, although the balance of the risk for insulin resistance and cardiovascular diseases that our subjects had might be different between men and women.

In conclusion, more than half of our subjects with very high BMI met the criteria for metabolic syndrome. Immediate intervention to encourage weight loss and to improve other risk factors of metabolic syndrome is necessary for these seriously obese people.

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References

1) Ministry of Health, Labour and Welfare. National Health and Nutrition Survey, 2004.
2) Reaven GM. Banting lecture 1988: role of insulin resistance in human disease. Diabetes 37:1595-1607, 1988.
3) Kaplan NM. The deadly quartet: upper-body obesity, glucose intolerance, hypertriglyceridemia, and hypertension. Arch Intern Med 149:1514-1520, 1989.
4) DeFronzo RA, Ferrannini E. Insulin resistance: a multifaceted syndrome responsible for NIDDM, obesity, hypertension, dyslipidemia, and atherosclerotic cardiovascular disease. Diabetes Care 14:173-194, 1991.
5) Fujioka S, Matsuzawa Y, Tokunaga K, et al. Contribution of intra-abdominal fat accumulation to the impairment of glucose and lipid metabolism in human obesity. Metabolism 36:54-59, 1987.
6) Bjorntorp P. Abdominal fat distribution and disease: an overview of epidemiological data. Ann Med 24:15-18, 1992.
7) Examination Committee for Criteria of Metabolic Syndrome. Definition and criteria of metabolic syndrome. Nippon Naika Gakkai Zasshi 94:794-809, 2005. (in Japanese)
8) Matsuzawa Y. The metabolic syndrome and adipocytokines. FEBS Lett 580:2917-2921, 2006.
9) Busetto L. Visceral obesity and the metabolic syndrome: effects of weight loss. Nutr Metab Cardiovasc Dis 11:195-204, 2001.
10) Watanabe S, Morita A, Aiba N, et al. Study Design of the Saku Control Obesity Program (SCOP). Anti Aging Med 4:70-73, 2007.
11) Alberti KG, Zimmet P, Shaw J. Metabolic syndrome: a new world-wide definition—a consensus statement from the International Diabetes Federation. Diabet Med 23:469-480, 2006.
12) Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 112:2735-2752, 2005.
13) Hara K, Matsushita Y, Horikoshi M, et al. A proposal for the cutoff point of waist circumference for the diagnosis of metabolic syndrome in the Japanese population. Diabetes Care 29:1123-1124, 2006.
14) Shiwaku K, Anuurad E, Enkhmaa B, et al. Predictive values of anthropometric measurements for multiple metabolic disorders in Asian populations. Diabetes Res Clin Pract 69:52-62, 2005.
15) Miyawaki T, Abe M, Yahata K, et al. Contribution of visceral fat accumulation to the risk factors for atherosclerosis in non-obese Japanese. Intern Med 43:1138-1144, 2004.
16) Guzik TJ, Mangalat D, Korbut R. Adipocytokines: novel link between inflammation and vascular function? J Physiol Pharmacol 57:505-528, 2006.

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Original Article

Nutritional Education and Exercise Treatment Based on Cognitive Behavioral Treatment in the Saku Control Obesity Program (SCOP)

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Abstract

BACKGROUND: Long-term weight loss is difficult to maintain, but recently cognitive behavioral therapy has been shown to be effective for long-term weight loss and maintenance.
METHODS: The 119 participants, who had been assigned to program to lose weight, were interviewed by dieticians regarding their motivation for weight loss and psychological status and self-corrected problems with their eating activities and exercises, following recognition of problems, discussing solutions, and devising personal dietary plans and exercise plan to loose weight at 1.0-2.0 kg per month.
RESULTS: In women, the prevalence of motivation to resolve the situation (n = 44, 84.6%) was significantly higher than that of men (n = 33, 67.3%; $p < 0.05$). In men, awareness of the need to keep healthy by oneself was significantly associated with the motivation to resolve the situation ($p = 0.002$) and the availability of support from others ($p = 0.004$). Thirty problems and 29 dietary goals were set by participants. The percentages of intake of alcohol ($p < 0.05$) and intake of sweets ($p < 0.01$) as the problems and decrease of intake in specified foods ($p < 0.01$) and snacks ($p = 0.05$) as dietary goals were significantly different between men and women. Women with BMI over 31 kg/m^2 set fewer additional steps as exercise goals than those with BMI under 29 kg/m^2 ($p < 0.05$).
CONCLUSIONS: The characters of subjects such as psychological status and the problems and the target recognized by participants were different between gender and the degree of obesity.

KEY WORDS: cognitive behavioral treatment, health education, obesity, baseline data

Introduction

Obesity is increasing in prevalence in Japan, and it represents a major risk not only for metabolic syndromes, such as type 2 diabetes, ischemic heart disease, hypertension, gout, and dyslipidemias, but also some cancers.[1] Loss of 10% of starting weight is thought to be associated with amelioration of risk factors such as hypertension, hypercholesterolemia, and hyperglycemia.[2] Traditional dietary treatment of obesity consists of an energy-reduced diet prescribed by dietitians to achieve weight loss in a short period.[3] Long term evaluations of obesity interventions indicate that weight loss accomplished through changes in diet and physical activity is rarely maintained.[4]

Since Stuart first applied behavior therapy to weight loss in the obese,[5] more than 100 papers have been published in the field. The goal of behavioral treatment is for participants themselves to choose to reduce caloric intake and increase energy expenditures based on alternatives provided by professionals, such as the dietitians.

Recently, cognitive behavioral treatment has been applied to weight loss in the obese. Cognitive behavioral treatment (therapy) is a methodology for systematically modifying eating and activity habits, other behaviors, or negative thoughts that appear to contribute to obesity using a combination of self-monitoring, goal setting, stimulus control, cognitive restructuring, stress management, and social support. The cognitive behavioral treatment can be applied in an individual or group setting to achieve a long-term change in eating and physical activity behaviors. Studies suggest that frequent contact between professionals and patients is necessary to achieve the weight loss. Several studies in a group setting showed that the treatments, typically delivered in 15-26 weekly 30- to 60-min group sessions consisting of fewer than 10 patients, produced a mean post-treatment weight loss of approximately 8.5 kg a 1 year.[4-6,10] However, long-term evaluations of interventions indicated that maintenance of weight loss is difficult.[11-13] The U.S. Institute of Medicine defined success as a weight loss of 5% of body weight maintained for 1 or more years.[13] These results suggested that intensive intervention (weekly group sessions) is successful for weight loss up to 1 year, but long-term adherence to the weight-loss plan cannot be facilitated by these programs. Perri and Corsica evaluated several specific maintenance strategies to achieve better long-term outcomes, including a problem-solving model, relapse prevention training, motivation, and extended behavioral therapy.[14] However, a truly effective intervention treatment for obesity has not yet been established. Renjilian reported the benefits of group treatment as cost-effectiveness and greater weight loss in patients at the end of the program.[15] In the case of intensive intervention, such as weekly sessions for 6 months, individual treatment is more expensive than the group approach.

In this baseline survey, we clarified the characteristics of the psychological status of subjects and the problems and dietary goals that the subjects had realized and set at the first meeting in Saku Control Obesity Program (SCOP), because there were few reports about the problems and targets that the participants made, so far.

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Methods

The study is a randomized controlled trial comparing the effect of 1-year behavioral treatment and exercise versus a control group conducted at the Saku General Hospital Human Dock Center. Details of the aim and design of the study are described in other paper written by Watanabe et al.[16,17]

Participants

235 participants (116 males, 119 females) out of 976 people, who had received the regular medical checkup, were finally recruited through the Saku General Hospital Human Dock Center. Inclusion criteria were age 40–64 years, at body mass index (BMI) over 28.3kg/m^2 within top fifth percentile, stated with desire to lose weight, and no serious medical condition. A total of 119 participants (59 men, 60 women) attended the first group session, and 116 participants (57 men, 59 women) were placed on a waiting list control group for a second session. All participants provided written informed consent, and the ethical committees of the National Institute of Health and Nutrition and the Saku General Hospital approved the study.

Interventions

Dieticians interviewed participants about their motivation for losing weight and to assess psychological status by considering the following: benefits to losing weight, probability of losing weight, level of motivation to resolve the situation, availability of support from others, level of awareness of the need to keep healthy by oneself, obstacles to executing the plans, and the amount of stress felt.

Using a behavioral management treatment, teams of health professionals, including doctors, registered dietitians, and physical activity instructors, conducted a weight-loss intervention that focused on self-management of diet, exercise, and individually set behavior goals. Participants had a brief interview with doctors followed by an individual session for 30–45 min with dieticians and a group session with physical activity instructors; if necessary, participants also received individual instruction in physical activity.

Various strategies were used to modify participants' behaviors, including self-monitoring, problem solving, goal setting, cognitive restructuring, stress management, stimulus control, and social support. Following recognition of the specific dietary problems, participants were expected to self-correct problems with their eating activity and exercise, choose a solution, implement a plan, and evaluate the outcome. During the individual sessions with dieticians every 3 months, participants evaluate their ability to self-monitor weight, physical activity (number of steps per day), accomplishment of the dietary and exercise plan, and daily diet activity. The dietitians provide positive feedback to participants for their progress in weight loss and engaged participants in problem solving to deal with obstacles. Then the dieticians help participant to recognize any dietary problems and to make plans for the following month. Between these face-to-face sessions, participants report their progress for the previous month and their new plans for the following month by mailing records to the dieticians in the months when they have no meeting with dieticians. When the reports are sent from the participants, dieticians and physical activity instructors send back their comments to the participants within 1 week.

The goal of weight loss was set at 1.0–2.0 kg per month, with a final goal of 10 kg lost by the end of the program. Nutritional education focused on individual dietary behaviors as clarified by monitoring participants' dietary records, especially fat intake, amount of grains, cooking methods, snacking, eating out, skipping meals, and alcohol intake. Each month, participants are also required to make their exercise plans with 1,000 more steps per day into the actual steps last month, with aim at the final goal of 10,000 steps per day by the end of the program.

Data Analysis

Data were analyzed using the Statistical Package for Social Sciences® (SPSS/PC, version 12.0, SPSS Inc., Japan). Differences between men and women with regard to psychological status, problem-solving strategies, and goal setting were analyzed using chi-square tests. Analysis of variance was used to examine differences between initial goals for exercise with regard to BMI.

Results

In this baseline survey, the data collected from 119 participants in first intervention group were analyzed for psychological characteristics and the data from 117 participants except 2 dropout participants were analyzed for problems and dietary and exercise goals.

The prevalence of motivation to resolve the situation in women was significantly higher than that of men ($p < 0.05$; *Table 1*). Compared to women, more men expected support from others ($p < 0.05$), particularly their wives. More women were aware of obstacles to executing their weight-loss plans, although the prevalence of seeing benefits to losing weight, probability of losing weight, awareness of the need to keep healthy by oneself, and stress were not different between men and women.

Table 1 Sample characteristics of psychological status

Variables	levels	Men		Women		
		n	%	n	%	p value *
Benefits to lose weight	High	46	85.2	51	91.1	0.34
	Low	8	14.8	5	8.9	
Probability to lose weight	High	32	61.5	28	53.8	0.43
	Low	20	38.5	24	46.2	
Motivation to resolve the situation	High	33	67.3	44	84.6	0.04
	Low	16	32.7	8	15.4	
Availability of support from others	High	32	66.7	22	45.8	0.04
	Low	16	33.3	26	54.2	
Awareness of necessity to keep healthy by oneself	High	37	84.1	39	76.5	0.35
	Low	7	15.9	12	23.5	
Obstacles to executing plans	Yes	20	45.5	30	66.7	0.06
	No	22	50.0	15	33.3	
Feel stress	Yes	31	77.5	35	71.4	0.52
	No	9	16.7	14	28.6	

* Results of chi-square tests to examine the distribution of psychological status with men and women.

Table 2 Association of awareness of necessity to keep healthy by oneself and other psychological variables

Variables		Men High n	Men High %	Men Low n	Men Low %	Men p value *	Women High n	Women High %	Women Low n	Women Low %	Women p value *
Benefits to lose weight	High	32	72.7	6	13.6	0.96	39	76.5	7	13.7	<0.001
	Low	5	11.4	1	2.3		0	0.0	5	9.8	
Probability to lose weight	High	22	50.0	3	6.8	0.60	24	50.0	2	4.2	<0.01
	Low	15	34.1	4	9.1		12	25.0	10	20.8	
Motivation to resolve the situation	High	27	62.8	1	2.3	<0.01	35	72.9	6	12.5	<0.01
	Low	9	20.9	6	14.0		2	4.2	5	10.4	
Availability of support from others	High	26	60.5	1	2.3	<0.01	18	40.9	2	4.5	0.12
	Low	10	23.3	6	14.0		17	38.6	7	15.9	
Obstacles to executing plans	Yes	18	47.4	2	5.3	0.54	7	17.1	6	14.6	0.03
	No	15	39.5	3	7.9		24	58.5	4	9.8	
Feel stress	Yes	7	20.0	0	0.0	0.23	8	18.6	2	4.7	0.64
	No	23	65.7	5	14.3		24	55.8	9	20.9	

Awareness of necessity to keep healthy by oneself.

* Results of chi-square tests to examine the distribution of psychological status

Table 3 Recognition of problems related to diet

Classification	Contents	Men n	Men %	Women n	Women %
Behaviors for diet					
Behavior as a cause of eating too much	Eat fast	24	40.7	28	47.5
	Eat much at supper	7	11.9	4	6.8
	Eat much	9	15.3	9	15.3
	Can not leave food	2	3.4	7	11.9
	Eat continuously for long time	0	0.0	1	1.7
	Eat meal served in large plate	1	1.7	1	1.7
	Eat until feel full	1	1.7	1	1.7
Time of eating	Eat late supper	4	6.8	4	6.8
	Skip meal	3	5.1	4	6.8
Behavior related eating	Lay down immediately after eating meal	2	3.4	4	6.8
	Eat at any time when the others eat	0	0.0	1	1.7
	Eat something when I feel stress	1	1.7	0	0.0
	Can not refuse when the others offer	0	0.0	1	1.7
	Eat snacks surrounded myself	0	0.0	2	3.4
	Buy too much	0	0.0	1	1.7
	Eat often outside	1	1.7	1	1.7
Snacks	Eat sweet snacks too much	5	8.5	15	25.0
	Eat snacks after supper	6	10.2	5	8.5
Meal contents					
Eat specified foods too much	Eat too few vegetables	14	23.7	10	16.9
	Take much fat or fatty food	18	30.5	16	27.1
	Take much salt or salty food	7	11.9	7	12.1
	Eat grains too much	7	11.9	6	10.3
	Eat noodles too much	5	8.5	0	0.0
	Eat the main dish too much	4	6.8	2	3.4
	Eat meat too much	4	6.8	0	0.0
Alcohol	Drink alcohol too much	13	22.0	3	5.1
Sweets	Drink sweet beverage too much	3	5.1	5	8.5
	Eat fruits too much	1	1.7	3	5.2
	Eat sweets too much	6	10.2	18	30.5
Dietary balance	Eat unbalanced meal	2	3.4	0	0.0

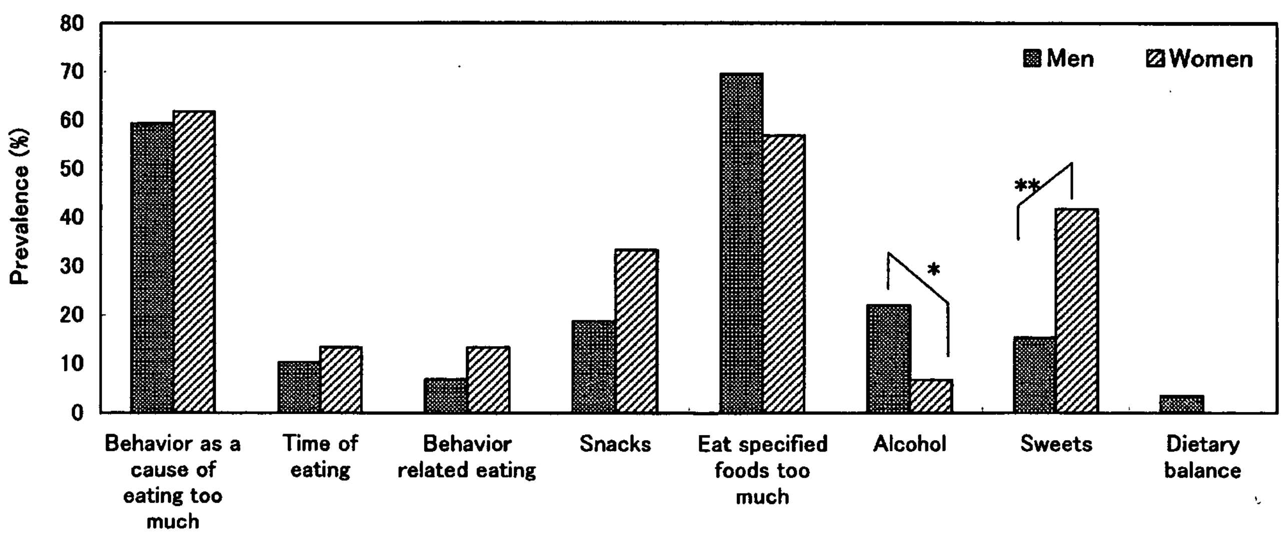

Fig. 1. Prevalence of dietary problems in men and women. The complete list of dietary problems is shown in *Table 3*. $^{*}p < 0.05$, $^{**}p < 0.01$

Table 2 shows the relationships between the awareness of the need to keep healthy by oneself and the other six psychological variables. In men, this awareness was significantly associated with level of motivation to resolve the situation ($p = 0.002$) and the availability of support from others ($p = 0.004$). In women, however, the awareness of the need to keep healthy by oneself was significantly associated with seeing the benefits of weight loss ($p < 0.001$), probability of losing weight ($p = 0.003$), motivation to resolve the situation ($p = 0.001$), and obstacle to executing the plans ($p = 0.027$).

Following the advice of dietitians, participants were asked to define the problems with their dietary habits and behaviors while setting personal goals for the following month. 30 recognized problems were classified into 8 categories and into two final categories of dietary behaviors and meal contents (*Table 3*). More than 40% of men and women recognized eating fast as a problem, and about 15% of men and women recognized eating too much as a problem. Insufficient intake of vegetables and excess intake of fat or fatty foods were recognized by both men and women. *Figure 1* shows the differences between men and women across the categories. With regard to meal contents, 41.7% of women reported eating too many sweets as a problem, whereas only 15.3% of men listed this as a problem ($p < 0.01$). In contrast, 22.0% of men reported drinking too much alcohol as a problem, whereas only 6.7% of women listed this as a problem ($p < 0.05$). The problems of behaviors as a cause of eating too much and eating specified food too mush were major common problems to men and women.

At their first meeting, dieticians and participants discussed which problems could be solved easily and which were the most important to solve. Following these evaluations, participants set and declared their personal dietary goals. Twenty-nine dietary goals were set and fell into the categories of dietary behavior and meal contents and were classified into seven categories (*Table 4*). The most prevalent goal of both men (31%) and women (39%) was chewing well during meal time. More women than men set goals of decreasing their snacking after supper and not eating snacks between meals. Similar percentages of men and women set the goals of eating more vegetables and decreasing their intake of fat or fatty foods. 23.7% of men set the goal of consuming less alcohol, whereas only 3.4% of women set this goal. Compared to men, more women set the goals of decreasing salt intake and replacing high-calorie snacks with low-calorie foods.

Compared to men, more women (30.5% vs. 50.0%) set a goal of decreasing the intake of snacks ($p < 0.05$). In contrast, more men (72.9%) set a goal of decreasing the intake of a specified food compared to women (48.3%; $p < 0.01$; *Figure 2*). There were no differences between the genders with regard to the other five goal categories.

Table 4 The dietary goal-setting at first meeting

Classification	Contents	Men n	Men %	Women n	Women %
Behaviors for diet					
Decrease intake of snacks	Eat less snacks after supper	4	5.8	9	15.0
	Do not eat anything 2 hours before sleep	2	3.4	2	3.4
	Eat fruits on the time decided	2	3.4	3	5.1
	Quit a snack or eat less	9	15.3	19	32.2
	Do not eat nuts	2	3.4	0	0.0
Decrease the amount of meal	Eat with chewing food well	18	30.5	23	39.0
	Leave food when finish meal	0	0.0	5	8.5
	Do not eat once full	1	1.7	2	3.4
	Do not eat continuing for long time	0	0.0	1	1.7
	Serve a meal individually	3	5.1	2	3.4
	Record the energy displayed on foods	2	3.4	0	0.0
Eat regularly	Do not skip meals	3	5.1	2	3.4
Order of certain foods	Eat vegetables first	5	8.5	6	10.0
	Take some drinks or soup first	0	0.0	2	3.4
Meal contents					
Decrease intake of specified foods	Decrease intake of grains	10	16.9	7	11.9
	Decrease intake of main meal	1	1.7	2	3.4
	Decrease intake of meals	5	8.5	4	6.8
	Decrease side dish with alcohol	2	3.4	0	0.0
	Decrease intake of alcohol	14	23.7	2	3.4
	Decrease intake of salt or salty food	1	1.7	6	10.0
	Decrease intake of fat or fatty food	15	25.4	14	23.7
	Decrease amount of supper meals	2	3.4	0	0.0
Increase the amount of specified food	Increase intake of vegetables	16	27.1	14	23.7
Replace with low-calories from high-calories	Replace a main dish with other low-calories	5	8.5	1	1.7
	Replace with other kinds of grains	1	1.7	0	0.0
	Replace snacks with other low-calories	2	3.4	9	15.0
	Replace drinks with other low-calories	4	6.8	4	6.8
	Replace alcohol with other low-calories	0	0.0	1	1.7

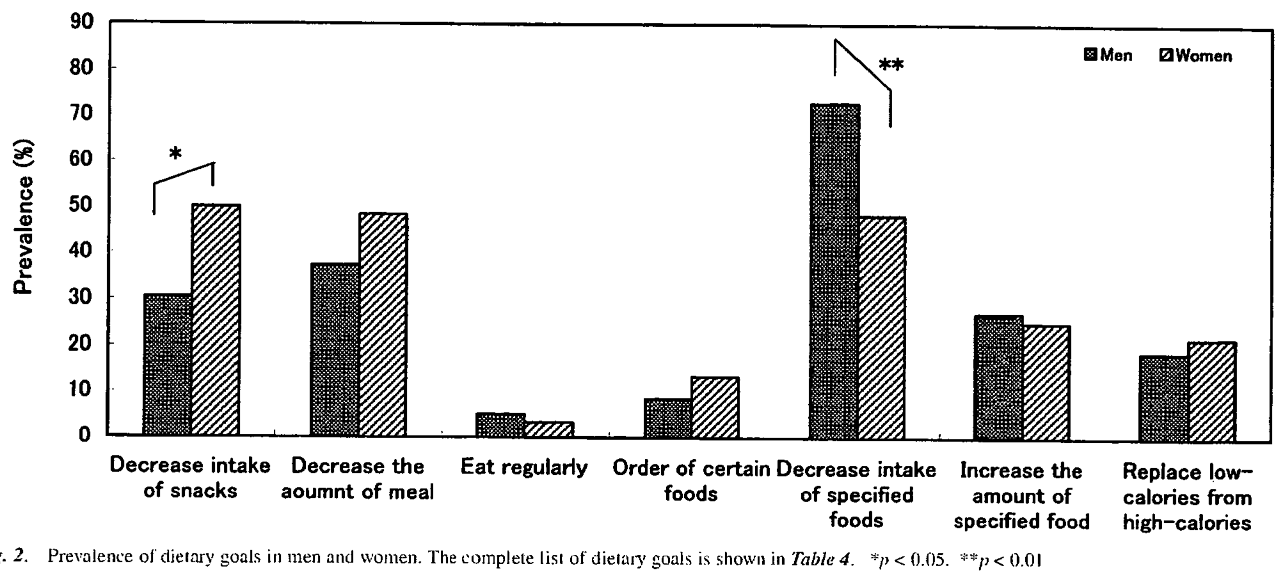

Fig. 2. Prevalence of dietary goals in men and women. The complete list of dietary goals is shown in *Table 4*. $^{*}p < 0.05$. $^{**}p < 0.01$

The final exercise goal was basically set at 10,000 walking steps per day. At the beginning of the program, 21 participants already walked over 10,000 steps per day on average, and their exercise goal was to maintain this level of exercise. The remaining participants walked fewer than 10,000 steps, and their goal was to walk an additional 1,000 steps per day every month, except those participants who had knee or lower back pain. For those participants who were walking fewer than 10,000 steps per day, the average walking steps per day at the beginning of the program were 6314.6 ± 1915.7 (SD) steps in men and 6780.6 ± 1582.4 steps in women, the additional walking steps first goals were 1232.8 ± 789.4 steps in men and 928.1 ± 597.1 steps in women, and the target exercise goals per day were 7581.6 ± 1934.7 steps in men and 7662.8 ± 1470.8 steps in women; there were no significant differences between genders.

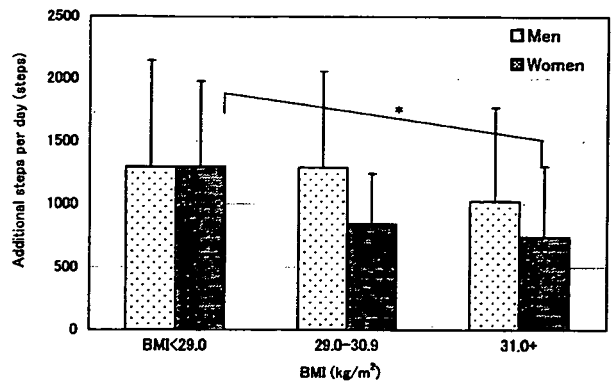

Fig. 3. The additional steps as an exercise goal among body mass index (BMI) tertiles in men and women.
Data represent subgroup mean ± SD. * $p < 0.05$

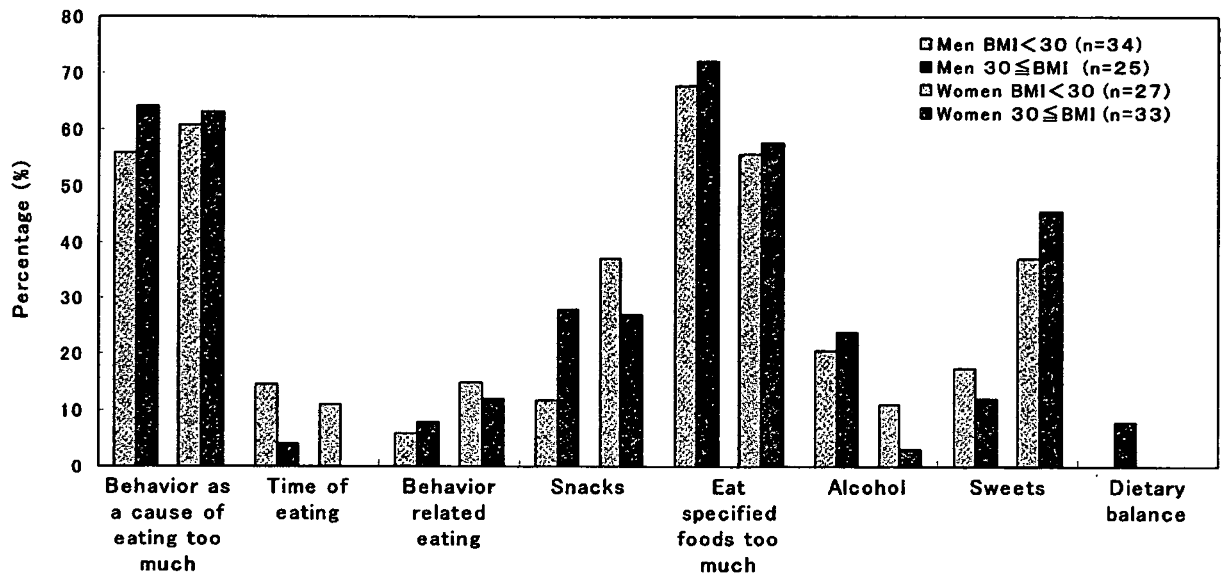

Fig. 4. Prevalence of the diet problems between body mass index (BMI) levels over or under 30 kg/m^2 in men and women.

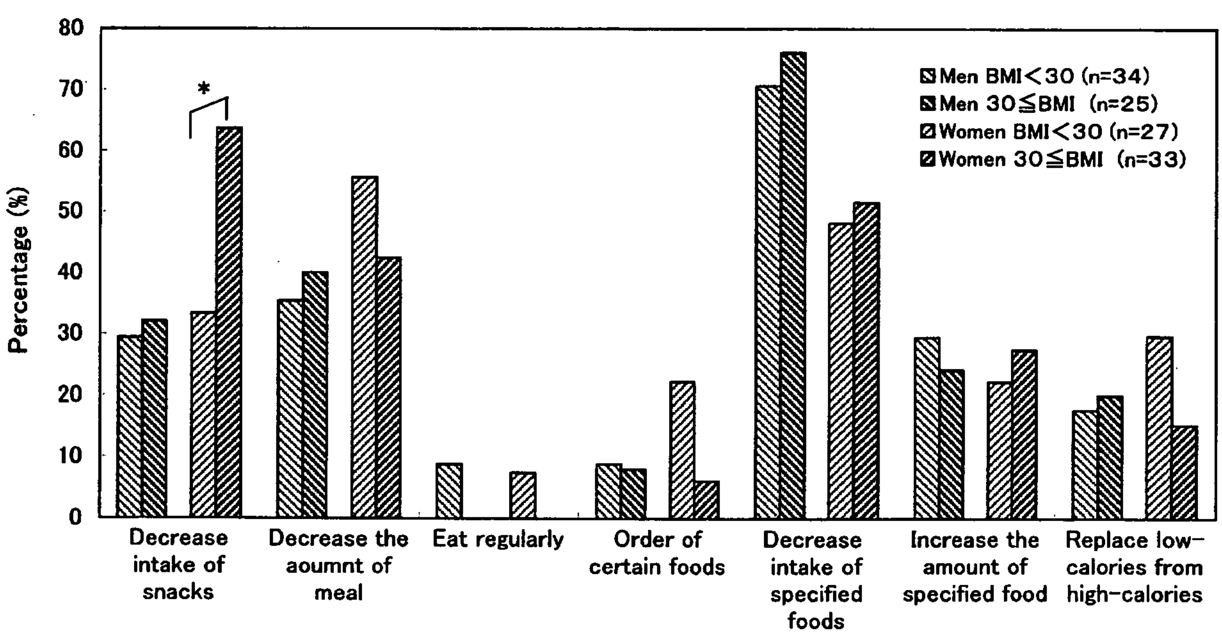

Fig. 5. Prevalence of the diet goals between body mass index (BMI) levels over or under 30 kg/m^2 in men and women. *$p < 0.05$: chi-square tests

Among those participants who set exercise goals, the relationship between BMI and the number of additional steps in the goal was analyzed by BMI tertiles. At baseline, there were no differences among BMI tertiles with regard to level of exercise. Those participants with BMI ≥ 31 set goals of significantly fewer additional steps compared to those with BMI < 29 ($p < 0.05$; ***Figure 3***).

The mean BMI was 30.5 kg/m^2 and the median was 29.8s kg/m^2. We divided two groups over and under 30 kg/m^2 BMI, in order to clarify relationships between BMI and the dietary problems and dietary goals. There were not significant differences of the percentage of dietary problems between the BMI levels over and under 30 kg/m^2 in women and men. (***Figure 4***). Among the dietary goals, the percentage of the decreasing intake of snack was different between the BMI levels over and under 30 kg/m^2 in women ($p < 0.05$; ***Figure 5***).

Discussion

Most studies of traditional obesity treatment, including dietary restriction, nutritional education, and an increase in exercise, have demonstrated limited success. Other methods that have been used as an adjunct to dietary restriction in the treatment of obesity include lifestyle modification, drugs, therapeutic starvation, very low calorie diets, and surgical treatment. Long-term weight loss and maintenance requires management strategies including a combination of nutritional education and physical activity as well as behavioral interventions.[18)]

In the SCOP study, we constructed a strategy for obesity treatment that mainly included cognitive behavioral treatment for nutritional education and physical activity. The dietitians interviewed participants about their levels of social support, stress, motivation, and self-efficacy. More men expected support from others, such as their wives and family than women (***Table 1***). In addition, in men, the awareness of the need to keep healthy by oneself was significantly associated with the motivation to resolve the situation and the availability of support from others (***Table 2***). Studies have shown that social support is an important aid in weight maintenance,[19,20)] although the effect of family involvement on weight control is unclear. Wing et al. reported better weight maintenance when participants, especially women, were treated together with their spouses.[21)] In contrast, Black and Lantz reported weight maintenance to be better when participants were treated alone, particularly men.[22)] In the present study, however, men expected the support from others even though they were aware of the need to keep healthy by themselves in order to succeed in their weight loss.

The motivation to resolve the situation was significantly more prevalent in women than in men ($p < 0.05$; ***Table 1***). In women, the awareness of the need to keep healthy by oneself was also significantly associated with recognition of the benefits and probability of losing weight, the motivation to resolve the situation, and realizing the obstacles to success. Many studies have reported that a higher motivation for weight reduction was related to greater weight loss.[23)] However, the Weight Loss Readiness Test (WLRT), which was developed to access weight loss readiness[24)] and motivation, failed to predict weight loss.[23,25)]

In the SCOP study, the dietary goals were well matched with problems, as participants were first asked to list potential problems and then set goals based on these. More than 40% of men and women recognized eating too fast as a problem and about 15% saw eating too much as an issue (***Table 3***). Likewise, both men and women recognized as problems eating too few vegetables, too much fat or fatty foods, and high salt intake. More women listed eating sweet snacks as a problem, whereas more men saw alcohol intake as an issue (***Figure 1***).

Compared to men, significantly more women set the goal of decreasing the intake of snacks, whereas more men aimed to decrease the intake of specified foods, including drinking alcohol, revealing that the favorite foods and the problem eating behaviors were different between men and women (***Table 4 and Figure 2***). The dietary goal of "Decrease intake of fat or fatty food" was set mainly in the category of "Decrease intake of specified foods" in both men and women. In women, more participants over 30 kg/m^2 BMI focused about decreasing intake of snacks including 5 goals related snacks than that under 30 kg/m^2 BMI, even though the percentage of snacks in the problems was not different between BMI levels. The goals set by participants were in line with sound dietary advice, as studies have shown that weight loss and maintenance is associated with reduced frequency of snacks,[26)] less dietary fat,[26-30)] and increased intake of vegetables and fruits.[26)]

The dieticians usually proposed setting an exercise goal of an additional 1,000 steps per day to the actual steps last month. Although there was no difference among BMI tertiles with regard to the mean number of walking steps at the beginning of the intervention, women in the highest tertile (BMI = 31+) set significantly fewer additional steps as an exercise goal (***Figure 3***), suggesting that women in this tertile hesitate to walk. In women, there was a significant difference in the percentage of decreasing intake of snacks as a dietary goal between BMI levels over and under 30 kg/m^2 (***Figure 5***). This result may show that the participants in SCOP could set the successful dietary goal to lose weight by themselves with the guidance of the dieticians, as reported in previous study.[26)]

Self-monitoring of body weight and food intake were reported as important factors in weight loss as well as weight maintenance.[27,31,32)] In this study, the participants self-monitored and recorded items such as weight, daily food intake, and daily evaluations of their personal dietary and exercise goals and reported to dieticians the results of their efforts at the end of each month.

Obesity is recognized as a complex disorder involving appetite regulation and energy metabolism, and it is associated with a variety of comorbid conditions. Many studies have shown that traditional obesity treatment has been effective over the short term, but long-term outcomes do not mirror those satisfactory results. Lang and Froelicher concluded that the combination of a low-calorie diet, an increase of physical activity, and behavioral therapy should be incorporated in obesity treatments.[18)] They also found that interventions involving frequent behavioral therapy, such as weekly sessions, seemed to improve the participants' adherence to changes in eating and exercise patterns and produced better outcomes. Elfhag and Rossner reviewed a variety of potential factors and concluded that weight maintenance was associated with an internal motivation to lose weight, social support, better coping strategies, a better ability to handle life stress, self-efficacy, autonomy, assuming responsibility in life, and greater overall psychological strength and stability.[33)]

This survey baseline data revealed that the psychological characters were different in gender and the problems and dietary and exercise targets were also different in gender and BMI.

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References

1) Robinson LE, Graham TE. Metabolic syndrome, a cardiovascular disease risk factor: role of adipocytokines and impact of diet and physical activity. Can. J Appl Physiol 29:808-829, 2004.
2) Pi-Sunyer FX. A review of long-term studies evaluating the efficacy of weight loss in ameliorating disorders associated with obesity. Clin Ther 18:1006-1035, 1996.
3) Wing RR, Hill JO. Successful weight loss maintenance. Annu Rev Nutri 21:323-341, 2001.
4) Anderson JW, Konz EC, Frederich RC, et al. Long-term weight loss maintenance: a meta-analysis of US studies. Am J Clin Nutr 74:579-584, 2001.
5) Stuart RB. Behavioral control of overeating. Behav Res Ther 5:357-365, 1967.
6) Ross R, Janssen I, Tremblay A. Obesity reduction through lifestyle modification. Can J Appl Physiol 25:1-18, 2000.
7) Leemakers E, Perri M, Shinagi C, et al. Effects of exercise-focused versus weight-focused maintenance programs on the management of obesity. Addict Behav 24:219-227, 1999.
8) Tinker L, Perri M, Patterson R, et al. The effects of physical and emotional status on adherence to a low-fat dietary pattern in the Women's Health Initiatives. J Am Diet Assoc 102:789-800, 2002.
9) Wadden T, Vogt R, Foster G, et al. Exercise and the maintenance of weight loss: 1-year follow-up of a controlled clinical trial. J Consult Clin Psychol 66:429-433, 1998.
10) Wadden TA, Vogt RA, Anderson RE, et al. Exercise in the treatment of obesity: effects four interventions on body composition, resting energy expenditure, appetite, and mood. J Consult Clin Psychol 65:269-277, 1997.
11) National Institutes of Health. Clinical guidelines on the identification, evaluation and treatment of overweight and obesity in adults: the evidence report. National Institutes of Health, Bethesda, MD, 1998.
12) Latner J, Wilson G, Stunkard A, et al. Self-help and long-term behavior therapy for obesity. Behav Res Ther 40:805-812, 2002.
13) Institute of Medicine. Weighing the options: criteria for evaluating weight-management programs. Institute of Medicine, Washington, DC, 1995.
14) Perri M, Corsica J. Improving the maintenance of weight lost in behavioral treatment of obesity. In: Wadden TA, Stunkard A, editors. Handbook of obesity. Guilford Press, New York, 357-394, 2002.
15) Renjilian D, Perri M, Nezu A, et al. Individual versus group therapy for obesity: effects of matching participants to their treatment preferences. J Consult Clin Psychol 69:717-721, 2001.
16) Watanabe S, Morita A, Aiba N, et al for SCOP. Study design of the Saku Control Obesity Program (SCOP). Anti-Aging Med 4:70-73, 2007.
17) Morita A, Ohmori Y, Suzuki N, et al for SCOP Group. Anthropometric and clinical findings in obese Japanese: the Saku Control Obesity Program (SCOP). Anti-Aging Med 5:13-16, 2008.
18) Lang A, Froelicher ES. Management of overweight and obesity in adults: behavioral intervention for long-term weight loss and maintenance. Eur J Card Nurs 5:102-114, 2005.
19) Perri MC, Sears SF Jr, Clark JE. Strategies for improving maintenance of weight loss: toward a continuous care model of obesity management. Diabetes Care 16:200-209, 1993.
20) Wolfe WA. A review: maximizing social support—a neglected strategy for improving weight management with African-American women. Ethn Dis 14:212-218, 2004.
21) Wing RR, Marcus MD, Epstein LH, et al. A family-based approach to the treatment of obese type II diabetic patients. Consult Clin Psychol 59:156-162, 1991.
22) Black DR, Lantz CE. Spouse involvement and a possible long-term follow-up trap in weight loss. Behav Res Ther 22:557-562, 1984.
23) Teixeira PJ, Palmeira AL, Branco TL, et al. Who will lose weight? A reexamination of predictors of weight loss in women. Int J Behav Nutr Phys Act 1:12, 2004.
24) Brownell KD. Dieting readiness. Weight Control Dig 1:5-10, 1990.
25) Fontaine KR, Wiersema L. Dieting readiness test fails to predict enrollment in a weight loss program. J Am Diet Assoc 99:664, 1999.
26) Westenhoefer J, von Falk B, Stellfeldt A, et al. Behavioral correlates of successful weight reduction over 3 y: results from the Lean Habits Study. Int J Obes Relat Metab Disord 28:334-335, 2004.
27) Wing RR, Hill OJ. Successful weight loss maintenance. Annu Rev Nutr 21:323-341, 2001.
28) Crawford D, Jeffery RW, French SA. Can anyone successfully control their weight? Findings of a three-year community-based study of men and women. Int J Obes Relat Metab Disord 24:1107-1110, 2000.
29) Leser MS, Yanovski SZ, Yanovski JA. A low-fat intake and greater activity level are associated with lower weight regain 3 years after completing a very-low-calorie diet. J Am Diet Assoc 102:1252-1256, 2002.
30) French SA, Jeffery RW. Current dieting, weight loss history and weight suppression: behavioral correlates of three dimensions of dieting. Addict Behav 22:31-44, 1997.
31) Jeffery RW, Bjornsons-Benson WM, Rosenthal BS, et al. Correlates of weight loss and its maintenance over two years of follow-up among middle-aged men. Prev Med 13:155-168, 1984.
32) McGuire MT, Wing RR, Klem ML, et al. Behavioral strategies of individuals who have maintained long-term weight losses. Obes Res 7:334-341, 1999.
33) Elfhag K, Rossner S. Who succeeds in maintaining weight loss? A conceptual review of factors associated with weight loss maintenance and weight regain. Obesity Rev 6:67-85, 2005.

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Original Article

The Use of a Uniaxial Accelerometer to Assess Physical-activity-related Energy Expenditure in Obese Men and Women: Saku Control Obesity Program (SCOP)

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Abstract

INTRODUCTION: Energy expenditure (EE) associated with physical activity is negatively correlated with prevalence of obesity and related diseases, and exercise plays a major role in prevention and treatment of these diseases. We determined baseline daily step-count and physical activity-related energy expenditure (PAEE) in 230 obese subjects (40–64 years old) participating in the Saku Control Obesity Program. The secondary purpose of this study was to determine the association between abdominal fat and amount of physical activity.

METHODS: Daily step-count and PAEE were measured using a uniaxial accelerometer. The subjects wore the uniaxial accelerometer on their belt from the time they woke up until going to bed for 2 weeks. Adjusted PAEE (METs·h/day) was calculated based on daily PAEE and body weight.

RESULTS AND CONCLUSIONS: Daily step-count, PAEE, and adjusted PAEE were 7,815±3,211 (mean±SD) steps/day, 258±115 kcal/day, and 3.09±1.38 METs·h/day, respectively. There were no significant differences in daily step-count or adjusted PAEE between men and women. Daily step-count and adjusted PAEE were somewhat lower than the reference values for the quantity of physical activity for health promotion (8,000-10,000 steps/day and 3.3 METs·h/day) established by the Ministry of Health, Labour, and Welfare of Japan. BMI, visceral fat area, and abdominal circumference were negatively and weakly correlated with daily step-count and adjusted PAEE (r=-0.13 to -0.19, P<0.05 to 0.01). These results suggest that the amount of physical activity assessed by uniaxial accelerometry is partially associated with not only systemic obesity but also abdominal obesity.

KEY WORDS: accelerometer, energy expenditure, daily step-count, obesity, physical activity

Introduction

The energy expenditure (EE) associated with physical activity is negatively correlated with the prevalence of obesity and related diseases, such as diabetes, hypertension, and cardiovascular disease, and exercise has been shown to play a major role in the prevention and treatment of these diseases.[1-3] When developing treatment strategies for these diseases, including nutritional education, quantitative information related to physical activity is required to provide more effective goals. Thus, to prevent and treat these diseases more effectively, information regarding physical activity is useful, not only for researchers and healthcare workers but also for the general public.

Activity monitoring based on an accelerometry sensor is a useful method for obtaining objective information on physical activity patterns and for estimating the related EE,[4,5] because this type of sensor (Lifecorder; Suzuken Co. Ltd., Nagoya, Japan) can continuously measure the intensity, duration, and frequency of activity. The device has a unique algorithm for assessment of PAEE, especially unstructured activities. In addition, several studies indicated that the EE during running and walking estimated using this device correspond to the EE measured by indirect calorimetry, and the device was also more effective for measuring EE in free-living conditions as compared with a metabolic chamber.[6,7]

Increasing physical activity and decreasing caloric intake are indispensable for the improvement of excess weight and obesity. The Saku Control Obesity Program (SCOP) is a randomized control crossover study that aims to reduce visceral fat in overweight and obese subjects by interventions of physical activity and diet. Our systematic review suggested that an increase in adjusted PAEE at 10 METs·h/week (1.38 METs·h/day) is necessary to reduce visceral fat area in overweight and obese subjects.[8] The increase in adjusted PAEE corresponds to an increase of nearly 3,000 steps/day. Thus, all SCOP subjects receive physical activity modification education so that their daily step-count increase gradually by 3,000 steps/day. As each subject's target for modification of physical activity depends on the baseline level, accurate baseline measurements of physical activity are needed. The first purpose of the present study was to accurately determine the baseline status of physical activity using a uniaxial accelerometer. Furthermore, there have been few studies of the relationship between abdominal obesity and physical activity. Therefore, the second purpose of this study was to determine the association between visceral fat area measured by CT scan and amount of physical activity estimated by accelerometry.

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Methods

Each year about 7,000 examinees came to in Saku Health Doc Center for health checkups. Including all visits, the Saku Health Doc Center database contains approximately 197,000 records. We used the database to select initial examination records, and about 45,000 examinees were identified. For this study, the inclusion criteria were age 40–64 years and a body mass index (BMI:kg/m^2) within the upper quintile (28.3). Exclusion criteria were psychiatric conditions or physical conditions (i.e., significant hepatic or renal dysfunction and significant cardiovascular disease such as heart failure, stroke, and transient ischemic attacks) that would preclude full participation in the study; current treatment for obesity; current treatments known to affect eating or weight (e.g., medications). A total of 917 people whose BMI was more than 28.3 (upper quintile) were identified in the health checkup database, and 235 participants were enrolled in the Saku Control Obesity Program (SCOP). [9]

Five subjects who did not wear the accelerometer for 7 days or more were excluded from the study. Of the remaining 230 subjects, 111 were male and 119 were female. All research procedures of SCOP were performed according to the Helsinki Declaration. All subjects gave their written informed consent to participation in the study, and all procedures were reviewed and approved by the Ethical Review Board of the National Institute of Health and Nutrition.

To determine the baseline values of physical activity, each subject wore a uniaxial accelerometer on his or her belt from the time of waking to going to bed for 2 weeks. Measurements were as follows: daily step-count; PAEE; adjusted PAEE for body weight; and time spent in light, moderate, and vigorous physical activity. As the daily physical activities varied across the measurement period, daily mean values were calculated.

The activity monitor measures acceleration in the vertical direction. According to technical details provided by the manufacturer (Suzuken Co.,Ltd.), it samples the acceleration at 32 Hz and assesses values ranging from 0.06 to 1.94 g (where 1.00 g is equal to the acceleration of free fall). The acceleration signal is filtered by an analog band-pass filter and digitized. The frequency of acceleration signals is used to determine the step frequencies. Studies have shown that during walking the step frequencies measured by the accelerometer are within ±3% of the actual number of steps.[10] A maximum pulse over 4 s is taken as the acceleration value, and the activities are categorized into 11 activity levels based on the pattern of the accelerometer signal. The activity levels are subsequently converted by an algorithm to calculate EE (kcal) based on the following principle: when the sensor detects or more three acceleration pulses for 4 consecutive seconds, the activities are recognized as physical activity and are categorized into one of 9 activity levels (levels 1.0–9.0). The activity levels are calculated and counted every 4 s. The activity levels for ranges from 1.0 to 9.0 in steps of one unit corresponded to 1.465, 2.075, 2.808, 3.601, 4.537, 5.737, 7.324, 9.460, and 10.661 cal/kg/4 s, respectively.[7] There was a strong correlation between the activity levels and the measured EE while walking (r^2=0.93; P<0.001).[7] The daily PAEE (kcal) was calculated by summing the EE corresponding with activity levels every 4 s (cal/kg/4 s) and the product of the body weight (kg) of each subject.

If an acceleration pulse due to physical activity (*i.e.*, corresponding to activity levels 1.0–9.0) is not followed immediately by another acceleration pulse, it is not counted as 0.0 but level 0.5 is arbitrarily assigned for 3 min. It is assumed that the subject is standing up (or sitting down) and remaining in that state. These postures involve a higher EE than the resting supine position. Briefly, isolated spurts of acceleration are assumed to be due to acute changes in posture (lying down, sitting, and standing), because walking and moving around are typically rhythmic activities. EE due to very small trunk movements and posture effects (*e.g.*, changing from sitting to standing position, light deskwork) were not included in the PAEE. Thus, the PAEE measured by the accelerometer was systematically underestimated during a 24-h period, and the accelerometer assessed energy expenditure well during both the exercise period and the non-structured activities.[7]

As the PAEE is associated with body weight, PAEE adjusted for body weight (adjusted PAEE) was calculated as follows: adjusted PAEE (METs·h)=PAEE (kcal)/[W (kg) × 1.05].[11] The various activity levels are categorized as light (<3.0 METs), moderate (3.0–6.0 METs), and vigorous (>6.0 METs), and the time spent in each activity category per total time of physical activity (%) was calculated. In addition, the time spent in sedentary activity (sitting at a desk, visiting friends, reading, or watching television) was obtained from subjects' answers to the International Physical Activity Questionnaire (IPAQ).[12]

Anthropometric measurements (height, weight, and abdominal circumference) were determined in the standing position after the subjects removed their clothes, shoes, and socks. Abdominal circumference as a surrogate measurement of abdominal obesity was measured at the level of the umbilicus during expiration. Abdominal fat distribution was determined with subjects in the supine position using CT according to the procedure described previously.[13] Visceral fat areas were measured on one cross-sectional scan obtained at the umbilicus.

All statistical analyses were performed using SPSS® software (version 14.0; SPSS Inc., Chicago, IL, USA). All data are shown as means ± standard deviation. The differences between groups were analyzed by unpaired t-test. Linear regressions and Pearson's correlation coefficients were calculated. In addition, stepwise regression analysis was performed. Statistical significance was set at P<0.05.

Results

The subjects' characteristics are listed in ***Table 1***. Although there were no significant differences in age or BMI between men and women, height, body weight, and abdominal circumference in men were significantly greater than those in women. Using the Japanese diagnostic criteria, the prevalence of metabolic syndrome was 62.9% in men and 51.3% in women. These values

Table 1 Subject characteristics at baseline

Variables	Total (n = 235)	Men (n = 116)	Women (n = 119)
Age (years)	53.9 ± 6.6	53.4 ± 6.6	54.5 ± 6.4
Height (cm)	161.8 ± 8.6	168.4 ± 5.8	155.4 ± 5.5*
Weight (kg)	80.7 ± 12.1	86.4 ± 11.8	75.2 ± 9.5*
BMI (kg/m^2)	30.8 ± 3.4	30.4 ± 3.5	31.1 ± 3.1
Abdominal circumference (cm)	106 ± 9	105 ± 9	107 ± 8
SBP (mmHg)	138 ± 19	136 ± 17	140 ± 20
DBP (mmHg)	85 ± 14	84 ± 14	86 ± 13
FPG (mg/dL)	112 ± 26	112 ± 25	112 ± 27
TG (mg/dL)	158 ± 84	167 ± 89	148 ± 78
HDL cholesterol (mg/dL)	53 ± 11	50 ± 10	56 ± 12*
Visceral fat area (cm^2)	144 ± 53	159 ± 54	130 ± 47*

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; TG, triglyceride; HDL, high density lipoprotein
*: p < 0.05 vs. men

Table 2 Daily physical activity at baseline

Variables	Total (n = 230)	Men (n = 111)	Women (n = 119)
No. steps (steps/day)	7815 ± 3211	7601 ± 3300	8015 ± 3127
PAEE (kcal/day)	258 ± 115	271 ± 127	246 ± 102*
Adjusted PAEE (METs·h/wk)	3.09 ± 1.38	3.02 ± 1.43	3.15 ± 1.35
Time spent in light PA (%)	77.2 ± 12.2	76.1 ± 12.2	78.2 ± 12.2
Time spent in moderate PA (%)	21.5 ± 11.0	23.0 ± 11.9	20.0 ± 9.9*
Time spent in vigorous PA (%)	1.1 ± 1.4	0.9 ± 1.1	1.2 ± 1.5
Time spent in sedentary activity (min/day)	381 ± 230	436 ± 247	324 ± 188*

PAEE, physical-activity-related energy expenditure; METs, metabolic equivalents; PA, physical activity
*: p < 0.05 vs. men

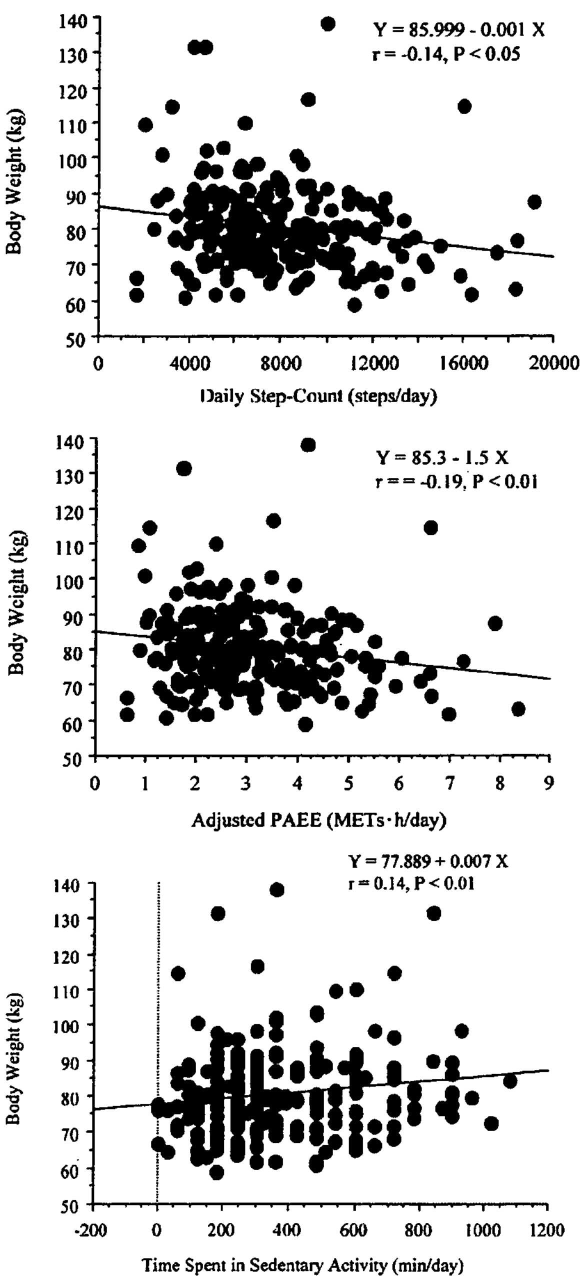

Fig. 1. Relationships between body weight and daily step-count (upper), adjusted physical activity-related energy expenditure (middle), and time spent in sedentary activity (bottom).

are notably lower in both men and women compared to the prevalence calculated using the International Diabetes Federation definition[14)] based on waist circumference for Japanese (men: 77.6%, women: 72.3%), whereas only the values for women are lower using the American Heart Association/National Heart, Lung, and Blood Institute definition (men: 51.7%, women: 72.3%).[15)]

The physical activity properties at baseline (*i.e.*, daily step-count, PAEE, adjusted PAEE, and time spent in light, moderate, and vigorous physical activity) are shown in ***Table 2***. The daily PAEE was significantly larger in men as compared with women. The time spent in moderate physical activity was longer in men than in women. In contrast, the time spent in sedentary activity in women was significantly shorter than that in men. There were no significant differences in other physical activity parameters between men and women. Although the association between occupation and PAEE was examined, there were no significant differences among the occupational categories (data not shown).

In all subjects, the daily step-count was closely related to the daily PAEE (r=0.92, $P<0.001$) and adjusted PAEE (r=0.99, $P<0.001$). The daily step-count was positively associated with the time spent in moderate physical activity (r=0.35, $P<0.001$), but negatively associated with time spent in light physical activity (r=−0.30, $P<0.001$). BMI was negatively correlated with the daily step-count (r=−0.13, $P<0.05$) and adjusted PAEE (r=−0.14, $P<0.05$). Moreover, body weight was negatively correlated to the daily step-count (r=−0.19, $P<0.01$, ***Figure 1, top***) and adjusted PAEE (r=−0.18, $P<0.01$, ***Figure 1, middle***). Visceral fat area was negatively and significantly correlated to the daily step-count (r=−0.14, $P<0.05$, ***Figure 2, top***) and adjusted PAEE (r=−0.15, $P<0.05$, ***Figure 2, bottom***). Abdominal

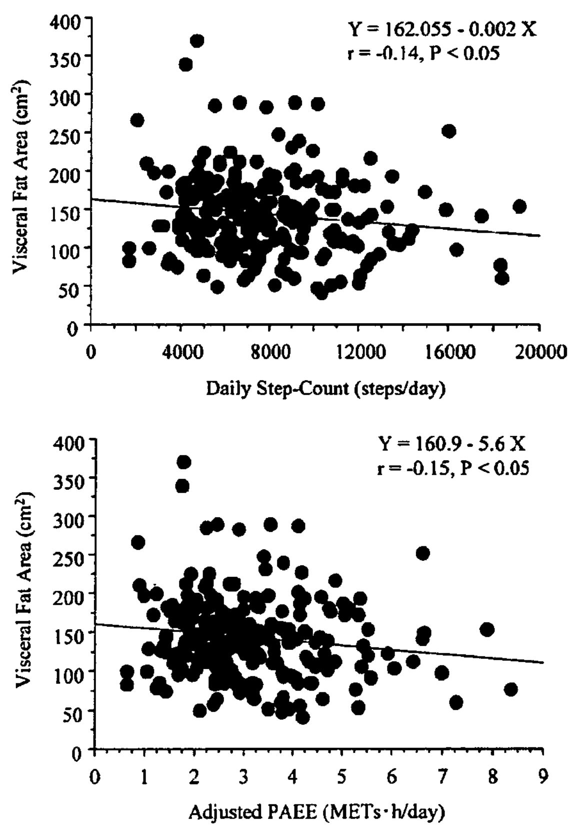

Fig. 2. Relationships between visceral fat area and daily step-count (upper), adjusted physical activity-related energy expenditure (middle), and time spent in sedentary activity (bottom).

circumference as a surrogate measurement of abdominal obesity was negatively and significantly related to the daily step-count ($r=-0.14$, $P<0.05$) and adjusted PAEE ($r=-0.16$, $P<0.05$). However, body weight had positive and significant correlations with daily PAEE ($r=0.15$, $P<0.05$) and the time spent in sedentary activity ($r=0.14$, $P<0.05$, ***Figure 1, bottom***). If all activities were weight-bearing, the PAEE would only be expected to be directly related to body weight.

Stepwise regression analysis showed that the daily step-count could be adopted as an independent variable for BMI and body weight, and adjusted PAEE could be adopted as an independent variable for visceral fat area and abdominal circumference.

Discussion

The main findings of this descriptive study were as follows. First, the mean daily step-count was 7,815 steps in all SCOP subjects, with no difference between men (7,601 steps) and women (8,015 steps). Second, the adjusted PAEE for body weight was 3.09 METs·h/day in all subjects, and there was no sex-related difference. The adjusted PAEE was somewhat smaller than the reference values for the quantity of physical activity for primary prevention of lifestyle-related diseases (3.3 METs·h/day) established by the Ministry of Health, Labour, and Welfare of Japan.[16] Third, the amount of physical activity (daily step-count and adjusted PAEE) was significantly and negatively related to body size (body weight and BMI) and abdominal fat (visceral fat area and abdominal circumference) in the pooled subjects, although the correlation coefficients were weak ($r=-0.1$ to -0.2).

Average daily step-count in Japanese men is generally greater than that in Japanese women as assessed by a national health and nutrition survey.[17] In the present study, the daily step-count in female subjects was about 1,400 steps/day greater than that in male participants. The unexpectedly higher daily step-count in the female subjects may be related to their slower walking speed and shorter stride than the male subjects. In fact, the time spent in moderate physical activity (brisk walking) by women was significantly shorter than that by men, and the time spent in light physical activity (slow walking) tended to be longer in women as compared with men.

In 2006 the Ministry of Health, Labour, and Welfare reexamined the recommended quantity of exercise for primary prevention of lifestyle-related diseases (originally proposed in 1989) and set reference values for the quantity of physical activity and exercise for Japanese people between the ages of 20 and 69 years. Specifically, for individuals who intend to promote health mainly through physical activity, walking 8,000 to 10,000 steps/day (23 METs·h/week) was set as the target daily amount of physical activity.[16] In the present study, the daily step-count and adjusted PAEE for body weight were 7,815 steps/day and 3.09 METs·h/day, respectively, which were somewhat lower than the reference values described above.

Several previous studies from the USA and UK indicated that daily step-counts in overweight and obese adults are lower than those in normal-weight peers.[18,19] The present study showed that adjusted PAEE and daily step-count were significantly and negatively correlated with visceral fat and abdominal circumference in the pooled overweight and obesity subjects. This is the first evidence that the amount of physical activity is partly associated with not only systemic obesity but also abdominal obesity. Furthermore, in accordance with the results of stepwise regression analysis, although daily step-count was an independent predictor of weight and BMI, adjusted PAEE was an independent predictor of abdominal obesity, *i.e.*, visceral fat area and abdominal circumference. As adjusted PAEE is determined by the duration and intensity of physical activity, accumulation of abdominal fat may be associated with not only the duration but also the intensity of physical activity. We should emphasize that the relationships between amount of physical activity and obesity variables were weak ($r=-0.1$ to -0.2). This implies that factors other than physical inactivity (*e.g.*, overeating) may strongly contribute to obesity in the SCOP subjects. To clarify the cause of obesity in SCOP subjects, the results from the uniaxial accelerometer should be compared with the responses to dietary history questionnaires.

Increasing physical activity and reducing caloric intake are indispensable for the improvement of excess weight and obesity. SCOP is a randomized control crossover study aiming to reduce visceral fat of overweight and obese subjects by interventions of physical activity and diet. Our systematic review suggested that an increase in adjusted PAEE at 10 METs·h/week (1.38 METs·h/day) is necessary to reduce visceral fat of overweight and obese subjects. The increase in daily step-count corresponds to an increase of almost 3,000 steps/day as compared with the baseline. Therefore, all SCOP subjects receive physical activity modification education so that their daily step-count increases gradually by 3,000 steps/day, and it is necessary to set the mean value of action targets for 11,000 steps/day and 4.5 METs·h/day.

The validity and reliability of the uniaxial accelerometer have been established.[6,7,10] One methodological limitation, however, is that a uniaxial accelerometer cannot measure very light physical activity (<1.8 METs).[7] Daily life includes a great deal of very light physical activity, and very light PAEE occupies more than the half of total PAEE. Therefore, we should emphasize that the PAEE obtained in the present study was not total PAEE but PAEE at 2METs intensity or more. Moreover, the cross-sectional study design is another limitation of the present study. The results of the present cross-sectional study must be confirmed prospectively with exercise intervention studies in future.

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References

1) Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. Science 283:212-214, 1999.
2) Ravussin E, Bogardus C. Energy balance and weight regulation: genetics versus environment. Br J Nutr 83:S17-S20, 2000.
3) Weinsier RL, Hunter GR, Heini AF, et al. The etiology of obesity: relative contribution of metabolic factors, diet, and physical activity. Am J Med 105:145-150. 1998.
4) Ebine N, Shimada M, Tanaka H. Comparative study of total energy expenditure in Japanese men using doubly labeled water method against activity record, heart rate monitoring, and accelerometer methods. Jpn J Phys Fitness Sports Med 51:151-164, 2002. (in Japanese with English abstract)
5) Schutz Y. Ravussin E, Diethelm R, et al. Spontaneous physical activity measured by radar in obese and control subject studied in a respiration chamber. Int J Obes 6:23-28, 1982.
6) Suzuki I, Kawakami N, Shimizu H. Accuracy of calorie counter method to assess daily energy expenditure and physical activities in athletes and nonathletes. J Sports Med Phys Fitness 37:131-136, 1997.
7) Kumahara H, Schutz Y. Ayabe M, et al. The use of uniaxial accelerometry for the assessment of physical-activity-related energy expenditure: a validation study against whole-body indirect calorimetry. Br J Nutr 91:235-243, 2004.
8) Ohkawara K, Tanaka S, Miyachi M, et al. A dose–response relation between aerobic exercise and visceral fat reduction: systematic review of clinical trials. Int J Obes (Lond) 31:1786-1797, 2007.
9) Watanabe S. Morita A, Aiba N, et al. Study Design of the Saku Control Obesity Program (SCOP). Anti-Aging Med 4:70-74, 2007.
10) Schneider PL, Crouter SE, Lukajic O, et al. Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. Med Sci Sports Exerc 35:779-784, 2003.
11) American College of Sports Medicine, ACSM's Guideline for Exercise Testing and Prescription, 7th ed. Lippincott Williams & Willkins, Phyiladelphia, 272-314, 2006.
12) Craig CL, Marshall AL, Sjostrom M, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 35:381-395, 2003.
13) Yoshizumi T, Nakamura T, Yamane M, et al. Abdominal fat: standardized technique for measurement at CT. Radiology 211:283-286, 1999.
14) Alberti KG, Zimmet P, Shaw J. Metabolic syndrome: a new world-wide definition—a consensus statement from the International Diabetes Federation. Diabet Med 23:469-480, 2006.
15) Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 112:2735-2752, 2005.
16) The Ministry of Health, Labour and Welfare, Japan. Exercise and Physical Activity Reference Quantity for Health Promotion 2006 (EPARQ2006) -Physical Activity, Exercise, and Physical Fitness-. Available at http://www.mhlw.go.jp/bunya/kenkou/undou02/pdf/data.pdf, 2006. (in Japanese)
17) The Ministry of Health, Labour and Welfare, Japan. National Health and Nutrition Survey 2006. Available at http://www.mhlw.go.jp/houdou/2006/05/h0508-1a.html, 2006. (in Japanese)
18) Clemes SA, Griffiths PL, Hamilton SL. Four-week pedometer-determined activity patterns in normal weight and overweight UK adults. Int J Obes (Lond) 31:261-266, 2007.
19) Chan CB, Spangler E, Valcour J, et al. Cross-sectional relationship of pedometer-determined ambulatory activity to indicators of health. Obes Res 11:1563-1570, 2003.

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ORIGINAL ARTICLE

Muscle mass and bone mineral indices: does the normalized bone mineral content differ with age?

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Objective: To investigate the relationships between regional skeletal muscle mass (SM mass) and bone mineral indices and to examine whether bone mineral content (BMC) normalized to SM mass shows a similar decrease with age in young through old age.
Subjects/Methods: One hundred and thirty-eight young and postmenopausal women aged 20–76 years participated in this study and were divided into three groups: 61 young women, 49 middle-aged postmenopausal women and 28 older postmenopausal women. Muscle thickness (MTH) was determined by ultrasound, and regional SM mass (arm, trunk and leg) was estimated based on nine sites of MTH. Whole-body and regional lean soft tissue mass (LSTM), bone mineral density (BMD) and BMC (whole body, arms, legs and lumbar spine) were measured using dual-energy X-ray absorptiometry.
Results: Ultrasound spectroscopy indicated that SM mass is significantly correlated with site-matched regional bone mineral indices and these relationships correspond to LSTM. The BMC and BMD in older women were significantly lower than those in middle-aged women. When BMC was normalized to site-matched regional SM mass, BMC normalized to SM mass in arm and trunk region were significantly different with age; however, whole-body and leg BMC normalized to SM mass showed no significant difference between middle-aged and older postmenopausal women.
Conclusions: The age-related differences in BMC were found to be independent of the ageing of SM mass in the arm and trunk region. However, differences in BMC measures of the leg and whole body were found to correspond to age-related decline of SM mass in postmenopausal women.
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Keywords: age; bone mineral content; bone mineral density; muscle function; skeletal muscle mass; ultrasound

Introduction

Fractures in the elderly are associated with the loss of bone mineral density (BMD) and an increased risk of falls (Pfeifer *et al.*, 2004). Femoral neck and lumbar fractures are especially common problems in the elderly and can have a devastating impact on their ability to remain independent. Many investigators have shown that muscle strength (Gleeson *et al.*, 1990; Peterson *et al.*, 1991; Blain *et al.*, 2001; Sinaki *et al.*, 2002) and muscle mass (Pluijm *et al.*, 2001; Szulc *et al.*, 2005; Walsh *et al.*, 2006) are associated with site-matched bone mineral indices, that is, BMD or bone mineral content (BMC). The greater rates of age-related loss of skeletal muscle mass (SM mass) occur in the legs and lower trunk regions, while only moderate losses occur in the upper trunk and arm regions (Reimers *et al.*, 1998; Kanehisa *et al.*, 2004). These regions correspond to the segments where fractures occur frequently. However, it is not sufficiently clear whether the age-related decrease of regional SM mass (for example, arm, leg and trunk region) affects the age-related decline of bone mineral indices in postmenopausal women.

According to Schiessl *et al.* (1998), more bone mass is accrued per lean body mass after puberty in girls than in boys. It has been speculated that this bone mass is not mechanically needed and serves as a surplus for reproduction. Schonau (2004) has repeated this finding in more depth

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in a series of papers based upon the forearm, but other authors (Ferretti *et al.*, 2000; Rittweger *et al.*, 2000) were unable to detect the surplus bone in the lower body. The accelerated bone loss observed around menopause is predominantly due to oestrogen deficiency (Kassem *et al.*, 1996). The phase of rapid bone loss normally lasts 4–8 years, and after this period, age-related bone loss is considered to occur in women.

Although the dual-energy X-ray absorptiometry (DXA) method can be used to accurately estimate SM mass (appendicular muscle mass), it is also capable of distinguishing between SM mass and the trunk muscles. Ultrasound muscle thickness (MTH) has been widely employed for accurate measurement of SM size *in vivo* (Kawakami *et al.*, 1993; Abe *et al.*, 1997; Reimers *et al.*, 1998), and previous studies have shown it to be highly reliable and valid in measuring MTH (Kawakami *et al.*, 1993; Reimers *et al.*, 1998). These characteristics make ultrasound a useful alternative to other more expensive imaging methods for assessing changes in SM mass. Moreover, ultrasound-derived prediction equations can accurately estimate the regional SM mass involving the measurement of arm, leg and trunk muscles (Sanada *et al.*, 2006).

The present cross-sectional study investigates the relationships between regional SM mass and bone mineral indices, and examines whether regional BMC normalized to SM mass shows a similar decrease with age in young subjects through old age.

Methods

Subjects

One hundred and thirty-eight young and postmenopausal women aged 20–76 years participated in this study and were divided into three groups: 61 young women (YW: 23.7 ± 0.5, 20–39 years), 49 middle-aged postmenopausal women (MW: 58.3 ± 0.6, 40–64 years) and 28 older postmenopausal women (OW: 70.3 ± 0.7, 65–76 years). The NASA/JSC physical activity scale, a questionnaire method, was used to survey the subject's physical activity (Ross and Jacson, 1990). This scale was developed to provide an assessment score of 0–7 on a person's level of regular physical activity. There are a series of eight statements about routine physical activity.

None of the subjects smoked and they were not taking any medications, such as β-blockers, steroids or hormone replacement therapy. The subjects involved in this study were both sedentary and active women. Active young women participated in continuous aerobic exercise for at least one session per week for 1 h per session. Active postmenopausal women participated in a swimming programme for at least two sessions per week for 1 h per session. However, they were not highly trained athletes.

The purpose, procedures and risks of the study were explained to each participant prior to inclusion, and all subjects gave their written informed consent before participating in the study approved by the Human Research Committee of the National Institute of Health and Nutrition. The study was performed in accordance with the guidelines of the Declaration of Helsinki.

Whole-body DXA

Lean soft tissue mass (LSTM), fat mass, BMC and BMD were determined for the whole body using DXA (Hologic QDR-4500A scanner; Hologic, Waltham, MA, USA). Subjects were positioned for whole-body scans according to the manufacturer's protocol. Participants lay in the supine position on the DXA table with the limbs close to their bodies. The bone densitometer delivers a very low dose of radiation (1.5 mR for the whole body) using quantitative digital radiography. Daily DXA calibration of phantoms showed a coefficient of variation of 0.35% for BMD over the past 156 measurement points. The whole-body BMC and LSTM were divided into several regions, that is, arms, legs, trunk and head. The body compositions were analysed using manual DXA analysis software (version 11.2:3). The arm region was defined as the region extending from the head of the humerus to the distal tip of the fingers. The reference point between the head of the humerus and the scapula was positioned at the glenoid fossa. The leg region was defined as the region extending from the inferior border of the ischial tuberosity to the distal tip of the toes. The whole body was defined as the region extending from the shoulders to the distal tip of the toes. To minimize inter-observer variation, all scans and analyses were carried out by the same investigator, and the day-to-day coefficient of variations of his observations were 0.72% for BMD, 2.95% for LSTM and 6.98% for fat mass in the whole body.

Blood samples

Before all measurements, fasting (> 12 h) blood samples were collected by venipuncture in EDTA-containing tubes, refrigerated immediately and centrifuged at 1500 r.p.m. for 30 min at 4 °C within 2 h. Serum samples from each participant were stored frozen at −20 °C. Estradiol was assessed by radioimmunoassay (Amersham Biosciences, Piscataway, NJ, USA). In postmenopausal women, menopausal status was confirmed by concentrations of estradiol less than 20 $pg\,ml^{-1}$. In this study, estradiol concentrations were 11.4 ± 0.3 $pg\,ml^{-1}$ (range of 10.0–17.0 $pg\,ml^{-1}$) in MW and 11.8 ± 0.4 $pg\,ml^{-1}$ (range of 10.0–16.0 $pg\,ml^{-1}$; Table 1) in OW. Serum intact osteocalcin was measured with a sandwich enzyme immunoassay that uses polyclonal antibodies against 20 N-terminal residues (amino acids 1–20) and against seven C-terminal residues (amino acids 43–49; MBC, Tokyo, Japan). The inter- and intra-assay coefficient of variations for the estradiol and osteocalcin were < 10%.

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Table 1 Physical characteristics of subjects

	Young (n = 61)	Middle (n = 49)	Old (n = 28)
Age (years)	23.7 ± 0.5	58.3 ± 0.6[a]	70.3 ± 0.7[a,b]
Age at menopause (years)		50.0 ± 0.6	50.1 ± 0.9
Years since menopause		8.3 ± 0.7	20.2 ± 1.1[b]
Serum estradiol (pg ml^{-1})	86.4 ± 8.2	11.4 ± 0.3[a]	11.8 ± 0.4[a]
Osteocalcin (pg ml^{-1})	5.47 ± 0.3	9.7 ± 0.4[a]	9.9 ± 0.6[a]
Body mass (kg)	51.8 ± 0.7	55.4 ± 1.0[a]	52.6 ± 1.0[b]
BMI (kg m^{-2})	20.2 ± 0.2	23.3 ± 0.4[a]	22.6 ± 0.5[a]
Percent body fat (%)	24.6 ± 0.6	31.2 ± 0.9[a]	30.3 ± 0.7[a]
VO_2peak (ml kg^{-1} min^{-1})	33.8 ± 0.7	29.3 ± 0.7[a]	24.6 ± 0.8[a,b]
Handgrip strength (kg)	28.9 ± 0.7	27.2 ± 0.6	23.4 ± 0.7[a,b]
Leg extension power (W kg^{-1})	17.3 ± 0.6	13.8 ± 0.5[a]	12.5 ± 0.7[a]
Physical activity scale	4.2 ± 0.2	4.7 ± 0.2	4.2 ± 0.3

Abbreviations: BMI, body mass index; VO_2peak, peak oxygen uptake.
Data are presented as means ± s.e.m.
[a]Significantly different from young, $P<0.05$.
[b]Significantly different from middle-aged, $P<0.05$.

Ultrasound MTH and measurements

Muscle thickness determined by B-mode ultrasound was assessed at nine sites on the anterior and posterior surfaces of the body as described previously by Abe *et al.* (1994). The sites were lateral forearm, anterior and posterior upper arm, abdomen, subscapula, anterior and posterior thigh, and anterior and posterior lower leg. Ultrasonographic evaluation of MTH was performed using a real-time linear electronic scanner with a 5 MHz scanning head (SSD-500; Aloka, Tokyo, Japan). The scanning head with water-soluble transmission gel was placed perpendicular to the tissue interface at the marked sites and provided acoustic contact without depression of the skin surface. MTHs were measured directly from the screen with electronic callipers, and determined as a distance from the adipose tissue–muscle interface to the muscle–bone interface. Whole-body and regional SM mass were estimated using the equations of Sanada *et al.* (2006). MTHs were converted to mass units in kilograms by ultrasound-derived prediction equations using site-matched MTH × height, which were then used to calculate arm, trunk, thigh and lower leg SM mass. The reliability of image reconstruction and distance measurements were confirmed by comparing the ultrasonic and manual measurements of tissue thickness in human cadavers, and the coefficient of variation for the MTH measurements was 1% (Kawakami *et al.*, 1993).

Measurement of fitness values

Q1 The peak oxygen uptake (VO_2peak) was measured by an incremental cycle exercise test using a cycle ergometer (Monark, Varberg, Sweden). The subjects were encouraged during the ergometer test to exercise at the level of maximum intensity. Subjects breathed through a low-resistance two-way valve, and the expired air was collected in Douglas bags. Expired O_2 and CO_2 gas concentrations were measured by mass spectrometry (WSMR-1400; Westron, Chiba, Japan), and gas volume was determined using a dry gas metre (NDS-2A-T; Shinagawa Dev., Tokyo, Japan). The system of mass spectrometer was calibrated during every measurement by the standard reference gas. The highest value of VO_2 during the exercise test was designated as VO_2peak.

Leg extension power was measured with an isokinetic leg power system (Anaero Press 3500; Combi wellness, Tokyo, Japan) in the sitting position. Handgrip strength of the right upper limb was measured with a hand-held dynamometer, with the subject standing and arms extended by their side.

Statistical analysis

All measurements and calculated values are expressed as the mean ± s.e.m. We compared the mean values of general criteria, bone mineral indices, body composition values and fitness values among the three age groups using one-way analysis of variance with body mass index (BMI) adjusted for the covariate. In cases with a significant F-value, a *post-hoc* test using the Newman–Keuls method was used to identify significant differences among the mean values. Pearson's product correlations were calculated between LSTM, SM mass or fitness values and bone mineral indices. The α level for testing significance was set at $P<0.05$. All statistical analyses were performed using Stat View v5.0 for Windows (SYS Institute).

Results

The physical characteristics of the subjects are presented in Table 1. The BMI and body fat percentage in MW and OW were significantly higher than those in YW ($P<0.05$). There were no significant differences in the NASA/JSC physical activity scale among the groups. Serum estradiol in MW and OW were significantly lower than those in YW ($P<0.05$). Serum osteocalcin in MW and OW were significantly higher than those in YW ($P<0.05$). Handgrip strength in OW was significantly lower than that in YW and MW ($P<0.05$). Leg extension power in MW and OW were significantly lower than those in YW ($P<0.05$). VO_2peak (normalized to body mass) in MW and OW were significantly lower than those in YW ($P<0.05$).

Age-related decline of body composition and bone mineral indices

Leg SM mass and LSTM in MW and OW were significantly lower than those in YW ($P<0.05$, Table 2). Leg SM mass in OW was significantly lower than that in MW ($P<0.05$), but there was no such difference in leg LSTM. Table 3 shows the mean BMC, BMD and bone mineral indices normalized to SM mass. The BMC and BMD in MW and OW were significantly lower than those in YW ($P<0.05$), while BMC (whole body, arms, trunk and legs) and BMD (whole body,

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arms and legs) in OW were significantly lower than in those MW ($P<0.05$). The BMC normalized to SM mass in MW and OW was significantly lower than that in YW ($P<0.05$). The arm BMC normalized to arm SM mass and the trunk BMC normalized to trunk SM mass in OW were significantly lower than those in MW. However, whole-body and leg BMC normalized to leg SM mass were not significantly different between MW and OW. Furthermore, the interaction (age × BMI) of the age-related differences of BMD, BMC and normalized BMC was not significant.

There was significantly negative correlation between age and BMC normalized to SM mass in all women ($P<0.001$, Table 4). However, when the subjects were divided into three age groups, there was no significant correlation between age and BMC normalized to SM mass in middle-aged and older women.

Table 2 Skeletal muscle mass estimated by ultrasound and LSTM and fat mass measured by DXA

Variables	*Body segments*	*Young (n = 61)*	*Middle (n = 49)*	*Old (n = 28)*
SM mass (kg)	Whole body	14.3 ± 0.3	13.7 ± 0.3	12.0 ± 0.4[a,b]
	Arm	1.4 ± 0.0	1.4 ± 0.0	1.3 ± 0.0[a,b]
	Trunk	6.0 ± 0.0	5.8 ± 0.1	5.5 ± 0.1[a,b]
	Leg	7.3 ± 0.1	6.9 ± 0.1[a]	6.1 ± 0.2[a,b]
LSTM (kg)	Whole body	34.3 ± 0.5	34.1 ± 0.5	32.4 ± 0.6[a,b]
	Arm	3.2 ± 0.1	3.2 ± 0.1	3.1 ± 0.1
	Trunk	18.4 ± 0.2	18.8 ± 0.3	17.8 ± 0.3[b]
	Leg	12.8 ± 0.2	12.1 ± 0.2[a]	11.6 ± 0.3[a]
Fat mass (kg)	Whole body	12.8 ± 0.4	17.4 ± 0.7[a]	16.0 ± 0.6[a,b]
	Arm	1.5 ± 0.1	2.0 ± 0.1[a]	1.8 ± 0.1[a]
	Trunk	4.8 ± 0.2	9.0 ± 0.4[a]	8.1 ± 0.4[a,b]
	Leg	6.2 ± 0.2	6.3 ± 0.2	5.8 ± 0.2

Abbreviations: DXA, dual-energy X-ray absorptiometry; LSTM, lean soft tissue mass; SM mass, skeletal muscle mass.
Data are presented as means ± s.e.m.
[a]Significantly different from young, $P<0.05$.
[b]Significantly different from middle-aged, $P<0.05$.

Relationships between SM mass, muscle functions and bone mineral indices

Lean soft tissue mass was significantly correlated with site-matched BMC (arm, trunk, leg and whole body; $r=0.57$, 0.73, 0.53 and 0.47, respectively; $P<0.05$, Figure 1) and BMD (arm, L-spine, leg and whole body; $r=0.38$, 0.40, 0.60 and 0.42, respectively; $P<0.05$, Figure 2). These associations corresponded to the relationships between SM mass measured by ultrasound and the site-matched BMC (arm, trunk, leg and whole body; $r=0.53$, 0.49, 0.66 and 0.55, respectively; $P<0.05$, Figure 1) and BMD (arm, L-spine, leg and whole body; $r=0.38$, 0.44, 0.55 and 0.52, respectively; $P<0.05$, Figure 2) in all women. The BMD in YW, MW and OW is also significantly correlated with the site-matched SM mass; $r=0.29$–0.54, 0.36–0.44 and 0.46–0.60, respectively ($P<0.05$). The correlation coefficients in OW were comparatively higher than those in YW or MW. In older women, absolute VO_2peak ($l\,min^{-1}$) was not significantly correlated with whole-body BMD (Table 5). Moreover, the absolute leg extension power (W) and leg extension power normalized to body mass ($W\,kg^{-1}$) were significantly correlated with leg BMD, but not leg extension power normalized to leg SM mass ($W\,kg^{-1}$).

Discussion

This study investigated the relationships between regional SM mass and bone mineral indices, and sought to determine

Table 3 Age-related differences of bone mineral density, bone mineral and bone mineral content normalized to SM mass

Variables	*Body segments*	*Young (n = 61)*	*Middle (n = 49)*	*Old (n = 28)*
BMD ($g\,cm^{-2}$)	Whole body	1.12 ± 0.01 (12%)	0.99 ± 0.01[a] (8%)	0.91 ± 0.01[a,b]
	Arm	0.71 ± 0.01 (11%)	0.63 ± 0.01[a] (6%)	0.59 ± 0.01[a,b]
	L-spine	1.07 ± 0.02 (14%)	0.92 ± 0.02[a] (7%)	0.86 ± 0.03[a]
	Leg	1.12 ± 0.01 (10%)	1.01 ± 0.01[a] (7%)	0.94 ± 0.02[a,b]
BMC (g)	Whole body	1796 ± 47 (25%)	1350 ± 42[a] (13%)	1175 ± 39[a,b]
	Arm	238 ± 4 (16%)	199 ± 5[a] (13%)	174 ± 5[a,b]
	Trunk	551 ± 12 (18%)	451 ± 12[a] (14%)	388 ± 11[a,b]
	Leg	741 ± 14 (19%)	600 ± 15[a] (9%)	544 ± 16[a,b]
BMC normalized to SM mass ($g\,kg^{-1}$)	Whole body	127 ± 3 (22%)	99 ± 2[a] (−1%)	100 ± 4[a]
	Arm	175 ± 2 (18%)	144 ± 3[a] (7%)	134 ± 3[a,b]
	Trunk	93 ± 2 (16%)	78 ± 2[a](9%)	71 ± 2[a,b]
	Leg	102 ± 2 (15%)	87 ± 2[a] (−5%)	91 ± 2[a]

Abbreviations: BMC, bone mineral content; BMD, bone mineral density; SM mass, skeletal muscle mass.
The percentages were calculated from the value from young versus middle-aged and middle-aged versus old. Data are presented as means ± s.e.m.
[a]Significantly different from young, $P<0.05$.
[b]Significantly different from middle-aged, $P<0.05$.

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