Table 2 (*Continued*)

	Dyslipidemia (+) and high blood pressure (+)	Dyslipidemia (−) and/or high blood pressure (−)
Number of subjects	142	168
Age	46.6 ± 8.8	47.5 ± 9.5
Oxygen uptake at VT (ml/(kg min))	14.6 ± 2.9	15.6 ± 3.6[a]
Work rate at VT (W)	75.8 ± 17.8	80.2 ± 21.7
Heart rate at VT (beat/min)	105.6 ± 12.3	105.9 ± 11.5
	High blood pressure (+) and impaired glucose tolerance (+)	High blood pressure (−) and/or impaired glucose tolerance (−)
Number of subjects	89	221
Age	49.4 ± 8.8	46.2 ± 9.1[a]
Oxygen uptake at VT (ml/(kg min))	14.2 ± 2.7	15.5 ± 3.5[a]
Work rate at VT (W)	75.6 ± 16.1	79.2 ± 21.5
Heart rate at VT (beat/min)	104.6 ± 11.1	106.2 ± 12.1
	Dyslipidemia (+) and high blood pressure (+) and impaired glucose tolerance (+)	Dyslipidemia (−) and/or high blood pressure (−) and/or impaired glucose tolerance (−)
Number of subjects	54	256
Age	47.8 ± 8.7	47.0 ± 9.3
Oxygen uptake at VT (ml/(kg min))	14.3 ± 2.7	15.3 ± 3.4[b]
Work rate at VT (W)	76.6 ± 17.6	78.5 ± 20.6
Heart rate at VT (beat/min)	106.0 ± 11.0	105.7 ± 12.0

VT: ventilatory threshold.
[a] $P < 0.01$ vs. (+).
[b] $P < 0.05$ vs. (+).

three components was significantly lower than that the subjects without one of these components.

To avoid the influence the BMI on VT, we compared the parameters at VT in obese (BMI ≧ 25) metabolic syndrome subjects with those in obese non-metabolic syndrome subjects (Table 3). There were no significant differences of age and BMI between the subjects with and without metabolic syndrome. Oxygen uptake and work rate at VT in obese men with metabolic syndrome were significantly lower than those in obese men without metabolic syndrome.

Table 3
Comparison of parameters at VT between metabolic and non-metabolic subjects in obese (|BM| ≧ 25) men

	Metabolic syndrome (+)	Metabolic syndrome (−)
Number of subjects	130	87
Age	46.7 ± 9.3	46.2 ± 8.1
BMI (kg/m^2)	28.7 ± 3.4	27.9 ± 2.3
Oxygen uptake at VT (ml/(kg min))	14.0 ± 2.5	14.8 ± 2.6[b]
Work rate at VT (W)	76.2 ± 15.5	84.3 ± 21.7[a]
Heart rate at VT (beat/min)	105.1 ± 12.1	104.9 ± 10.8

VT: ventilatory threshold, BMI: body mass index.
[a] $P < 0.01$ vs. metabolic syndrome (+).
[b] $P < 0.05$ vs. metabolic syndrome (+).

We evaluated the relationship between metabolic syndrome and exercise habits. Of 310 men, 116 men (37.4%) were classified as having exercise habits. The prevalence of metabolic syndrome in subjects with exercise habits (42.2%) was significantly lower than that in subjects without exercise habits (54.6%) (Table 4).

Finally, we compared the parameters at VT between subjects with and without exercise habits (Table 5). Age in subjects with exercise habits was significantly higher than that in subjects without exercise habits. However, oxygen uptake and work rate at VT were significantly higher in subjects with exercise habits than those in subjects without exercise habits.

Table 4
Relationship between metabolic syndrome and exercise habits in men

	Metabolic syndrome (+)	Metabolic syndrome (−)
Exercise habits (+)	49	67
Exercise habits (−)	106	88

$P < 0.05$ by χ^2-test.

Table 5
Comparison of parameters at VT between subjects with and without exercise habits in men

	Exercise habits (+)	Exercise habits (−)
Number of subjects	116	194
Age	48.5 ± 8.7	46.3 ± 9.3[b]
Oxygen uptake at VT (ml/(kg min))	15.9 ± 3.9	14.7 ± 2.8[a]
Work rate at VT (W)	81.8 ± 23.5	76.0 ± 17.5[b]
Heart rate at VT (beat/min)	105.6 ± 11.4	105.9 ± 12.1

VT: ventilatory threshold.
[a] $P < 0.01$ vs. exercise habits (+).
[b] $P < 0.05$ vs. exercise habits (+).

4. Discussion

Our study is the first report on the relationship between metabolic syndrome, defined by the new criterion of metabolic syndrome in Japan, and exercise habits and the levels of VT. Metabolic syndrome has important clinical and public health implications because it is a common disorder in Japan [1,2]. Previous studies documented that metabolic syndrome is an important risk factor for diabetes, coronary heart disease and stroke [11–13]. Our study shows new and important information about the relationship between metabolic syndrome, and exercise habits and oxygen uptake at VT in Japanese men.

The prevalence of subjects with exercise habits in Japan was reported to be 29.3% in men and 24.1% in women by the National Nutrition Survey in Japan [10] and our results were not similar and the prevalence of subjects with exercise habits was higher than that in the previous study. Definition of prolonged time in our study was shorter and, in addition, enrolled subjects in our study were undertook annual health check-ups and they might therefore be more careful of their own health than subjects in the National Nutrition Survey.

Regular physical activity has been linked to increases in HDL and reductions in resting blood pressure, triglycerides, abdominal fat, fating glucose levels, and insulin responses to oral glucose challenge [14–16]. In several reports in the cross sectional study, metabolic syndrome was significantly correlated with physical fitness [17–19]. However, the hypothesis that metabolic syndrome may be caused by lower oxygen uptake at VT cannot be proven in our current cross-sectional design. The Kuopio Ischemic Heart Disease Risk Factor Study [20] followed several hundred men who did not have metabolic syndrome at baseline. Four years later, subjects in the upper one-third of VO_2max at baseline were 75% less likely than unfit men to develop metabolic syndrome. Katzmarzyk et al. reported that the effects of 20 weeks supervised aerobic training program on the prevalence of the metabolic syndrome in 621 men and women who were enrolled in the Heritage Study. After exercise intervention, 30.5% of the participants with metabolic syndrome at baseline were no longer classified as having metabolic syndrome [21]. Ekelund et al. reported that physical activity energy expenditure predicts progression toward the metabolic syndrome independent of aerobic fitness, obesity, and other confounding factors by observation of 5.6 years [22]. In our study, oxygen uptake at VT in men with metabolic syndrome was significantly lower than that in men without metabolic syndrome, even after adjusting for BMI. Oxygen uptake at VT in subjects with sub criterion of metabolic syndrome was also significantly lower than that in subjects without sub criterion of metabolic syndrome. In addition, the number of subjects with exercise habits was significantly lower in metabolic syndrome and the subjects with exercise habits had higher oxygen uptake at VT. It may be hard to clarify the mechanisms as to why the exercise habits are linked to higher oxygen uptake at VT and beneficial for preventing the metabolic syndrome. Although the mechanism is not well-understood, we previously reported that the education program, in which we instructed overweight Japanese men to increase daily step per day and join a weekly exercise course, resulted in increased oxygen uptake at VT and reduced visceral fat area [5].

Our study has potential limitation. First, our study was a cross-sectional and not a longitudinal training study. Second, we could not accurately prove the mechanism between lower oxygen uptake at VT and metabolic syndrome. However, it seems reasonable to suggest that simply moving from the lower oxygen uptake at VT to higher oxygen uptake at VT might result in the amelioration of the metabolic syndrome in some Japanese men. Therefore, we need promote exercise habits for preventing and improving metabolic syndrome. Further prospective studies are needed in Japanese using the new criterion of Japan.

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Short Communication

Relationship between Changes in Body Weight and Waist Circumference in Japanese

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Abstract

Objectives: We investigated the correlation between changes in body weight and body composition parameters.

Methods: We used the data of 2635 Japanese (40.2±12.2 years) at baseline and at 1-year follow-up from a database of 13522 subjects, which is available at the Okayama Southern Institute of Health in Okayama prefecture, Japan. Body weight, waist circumference at the umbilical level, hip circumference, and body fat percentage were used in the analyses.

Results: Body composition parameters were significantly reduced after 1 year. Changes in body weight significantly correlated with changes in waist circumference, changes in hip circumference, and changes in body fat percentage. A decrease in body weight of 3 kg corresponded to a 3.45 cm decrease in waist circumference in men and a 2.83 cm decrease in that in women.

Conclusion: A decrease in body weight of 3 kg corresponded to an almost 3 cm decrease in waist circumference at the umbilical level in Japanese men and women.

Key words: body weight, waist circumference, hip circumference, body fat percentage

Introduction

Metabolic syndrome has become a public health issue in Japan (1). For example, 30.7% of men and 3.6% of women are diagnosed as having metabolic syndrome (2), and reducing visceral fat is considered to be a critical therapeutic approach (1). In 2006, a 3 kg decrease in body weight and a 3 cm decrease in waist circumference were recommended by the Japan Society for the Study of Obesity (JASSO) (http://wwwsoc.nii.ac.jp/jasso/, accessed on Jan 25, 2007) for the prevention and alleviation of metabolic syndrome. However, the link between changes in body weight and waist circumference still remains to be investigated. Therefore, we evaluated how changes in body weight correlate with changes in body composition parameters, namely, waist circumference, hip circumference, and body fat percentage, using baseline and 1-year follow-up data of a large sample of the Japanese population, which is available at the Okayama Southern Institute of Health in Okayama prefecture, Japan.

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Subjects and Methods

Subjects

We used the retrospective data of 2635 Japanese (40.2±12.2 years) from a database of 13522 subjects (42.5±14.9 years) who underwent an annual health check-up from June 1997 to March 2005 at the Okayama Southern Institute of Health in Okayama prefecture, Japan, for the purpose of improving their lifestyle. The selected 2635 subjects met the following criteria: (1) underwent an annual baseline health check-up from June 1997 to March 2005, (2) underwent an annual health check-up after 1 year, (3) received no medication for diabetes, hypertension, or dyslipidemia, and (4) provided written informed consent (Table 1).

At the annual health check-up, all the subjects were instructed by well-trained medical staff to change their lifestyle according to the results.

Approval for the study was obtained from the Ethical Committee of the Okayama Health Foundation.

Anthropometric and body composition measurements

Anthropometric and body compositions were evaluated on the basis of the following parameters: height, body weight, waist circumference, hip circumference, and body fat percentage (3). The waist circumference was measured at the umbilical level, and the hip was measured at the widest circumference over the trochanter in standing subjects after normal expiration as previously described (1, 3). Body fat percentage was measured using an air displacement plethysmograph called the BOD POD Body Composition System (Life Measurement Instruments, Concord, CA, USA) (4, 5). The coefficient variation (CV: %) for same-day tests was 2.48, that for three separate-day tests was 2.27, and that for independent operators was 4.53. There was a clear correlation between the results from BOD POD and those from dual-energy X-ray absorptiometry (DEXA) ($r=0.910$, $p<0.01$) (4).

Table 1 Clinical parameters at baseline (1997–2005) and at 1-year follow-up (1998–2006)

	Baseline	Follow-up	*p*
Total			
Number of subjects	2635		
Age	40.2±12.2		
Body weight (kg)	60.1±12.0	59.7±11.9	<0.0001
Waist circumference (cm)	74.9±10.7	74.5±10.5	<0.0001
Hip circumference (cm)	92.1±6.0	91.8±5.9	<0.0001
Body fat percentage (%)	28.1±7.3	27.4±7.4	<0.0001
Men			
Number of subjects	856		
Age	39.4±12.1		
Body weight (kg)	70.4±11.0	70.1±11.1	0.0015
Waist circumference (cm)	83.1±9.6	82.4±9.5	<0.0001
Hip circumference (cm)	94.3±5.8	94.1±5.7	0.0020
Body fat percentage (%)	23.6±6.6	22.8±6.6	<0.0001
Women			
Number of subjects	1779		
Age	40.6±12.2		
Body weight (kg)	55.1±5.6	54.7±8.6	<0.0001
Waist circumference (cm)	71.0±8.7	70.6±8.7	0.0001
Hip circumference (cm)	91.0±5.7	90.7±5.7	<0.0001
Body fat percentage (%)	30.2±6.6	29.6±6.7	<0.0001

Mean±SD

Statistical analysis

All data are expressed as mean±standard deviation (SD). Statistical analysis was performed using the paired *t* test: $p<0.05$ was considered to be statistically significant. Relationships of the parameters of interest were determined by univariate regression analysis. Pearson's correlation coefficients were calculated and used to test the significance of the linear relationship among continuous variables.

Results

Clinical parameters at baseline (1997–2005) and at 1-year follow-up (1998–2006) are summarized in Table 1. At 1-year follow-up, anthropometric and body composition parameters, namely, body weight, waist circumference, hip circumference, and body fat percentage were significantly reduced.

We investigated the correlation between body weight and body composition parameters at baseline (1997-2005) by simple correlation analysis (Table 2). Body weight significantly correlated with these parameters in both sexes. In addition, changes in body weight also significantly correlated with the changes in waist circumference, hip circumference, and body fat percentage in both sexes (Table 3, Fig. 1). Furthermore, the slopes of the regression line (change in waist circumference vs change in body weight) for men and women were 1.069 and

Table 2 Simple correlation analysis between body weight and body composition parameters at baseline (1997–2005)

	r	*p*
Total		
Waist circumference (cm)	0.894	<0.0001
Hip circumference (cm)	0.864	<0.0001
Body fat percentage (%)	0.176	<0.0001
Men		
Waist circumference (cm)	0.856	<0.0001
Hip circumference (cm)	0.938	<0.0001
Body fat percentage (%)	0.567	<0.0001
Women		
Waist circumference (cm)	0.848	<0.0001
Hip circumference (cm)	0.912	<0.0001
Body fat percentage (%)	0.631	<0.0001

Table 3 Univariate regression and correlaion analyses between changes in (delta) body weight and body composition parameters in 856 men and 1779 women aged 14–77 years from 1997–2005 and 1998–2006

	r	*p*	Regression formula	y	x
Total					
Delta waist circumference (cm)	0.734	<0.0001	y=1.002x−0.062	Delta waist circumference	Delta body weight
Delta hip circumference (cm)	0.739	<0.0001	y=0.667x−0.038	Delta hip circumference	Delta body weight
Delta body fat percentage (%)	0.670	<0.0001	y=0.764x−0.403	Delta body fat percentage	Delta body weight
Men					
Delta waist circumference (cm)	0.794	<0.0001	y=1.069x−0.243	Delta waist circumference	Delta body weight
Delta hip circumference (cm)	0.742	<0.0001	y=0.557x−0.066	Delta hip circumference	Delta body weight
Delta body fat percentage (%)	0.699	<0.0001	y=0.767x−0.425	Delta body fat percentage	Delta body weight
Women					
Delta waist circumference (cm)	0.689	<0.0001	y=0.950x+0.018	Delta waist circumference	Delta body weight
Delta hip circumference (cm)	0.749	<0.0001	y=0.752x−0.012	Delta hip circumference	Delta body weight
Delta body fat percentage (%)	0.649	<0.0001	y=0.761x−0.392	Delta body fat percentage	Delta body weight

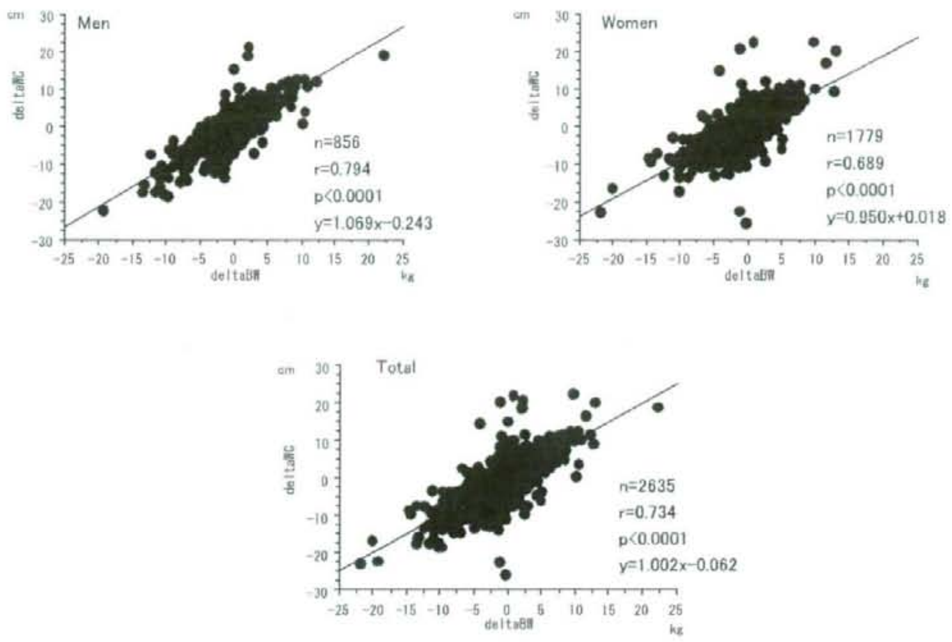

Fig. 1 Univariate regression and correlation analyses of changes in (delta) body weight and waist circumference. BW: body weight, WC: waist circumference.

0.950, respectively (Table 3). Accordingly, we found that a 3 kg decrease in body weight, as recommended by JASSO, corresponded to a 3.45 cm decrease in waist circumference in men and a 2.83 cm decrease in that in women (Fig. 1).

Discussion

The main finding of this study is that a 3 kg decrease in body weight corresponded to an almost 3 cm decrease in waist circumference at the umbilical level after 1 year.

There are few studies on the correlation between change in body weight and change in waist circumference using a large sample of the population. Egger et al. reported that a 1 cm decrease in waist circumference was equivalent to a decrease of about 3/4 kg, but with wide variability, in a study involving 42 retired Caucasian men and 45 indigenous men from Northern Australia who participated in a 1–2 year waist circumference loss program (6). We previously reported that the 1-year weight loss program, in which we instructed 61 overweight Japanese men to increase their number of daily steps per day and join a weekly exercise course, resulted in a 3.3 kg decrease in body weight and a 4.2 cm decrease in waist circumference (7). In this study, we used a large sample of the Japanese population, and body weight significantly correlated with body composition parameters. The average body fat percentage in men (23.6±6.6%) was lower than that in women (30.2±6.6%). Therefore, the correlation coefficient between body weight and body fat percentage in all the subjects was comparatively lower than that in men and women at the baseline. In addition, a 3 kg decrease in body weight corresponded to an almost 3 cm decrease in waist circumference, which agreed with the JASSO recommendation.

Potential limitations still remain in this study. First, although we confirmed the correlation between changes in body weight and changes in waist circumference, we could not provide the threshold of body weight and waist circumference reduction for preventing and alleviating metabolic syndrome. Second, we neither directly measured the visceral fat accumulation using computed tomography nor investigated the correlation between visceral fat accumulation and body composition parameters. Third, the 13522 subjects in our study voluntarily underwent the annual health check-up; they were therefore more health-conscious than the average person. The selected 2635 subjects underwent an annual health check-up every year with a follow-up duration of 1 year and received no medication; they were therefore more health-conscious than most of the subjects in the database. They were also instructed by well-trained medical staff to change their lifestyle, and as a result their anthropometric and body composition parameters were significantly reduced.

Further intervention studies using other populations are necessary to determine the effects of prevention and treatment on metabolic syndrome.

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Experimental Physiology

Resistance training in men is associated with increased arterial stiffness and blood pressure but does not adversely affect endothelial function as measured by arterial reactivity to the cold pressor test

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Resistance training is a popular mode of exercise, but may result in stiffening of the central arteries. Changes in carotid artery diameter were determined using the cold pressor test (CPT), which results in production of nitric oxide via sympathetic activation and is one of the novel methods available for assessing endothelial function in the carotid artery. To investigate the effect of resistance training on endothelial function, we designed a cross-sectional study of carotid arterial vasoreactivity to CPT in men participating in regular resistance training with increased carotid arterial stiffness compared with age-matched control subjects. Twelve resistance-trained middle-aged men (age 38.7 ± 1.7 years) and 17 age-matched control subjects (age 36.8 ± 1.2 years) were studied. The direction and magnitude of changes in carotid artery diameter were measured by B-mode ultrasonography during sympathetic stress induced by submersion of the foot in ice slush for 90 s. Carotid arterial β-stiffness index, and systolic and mean arterial blood pressure were higher (7.7 ± 0.7 *versus* 6.0 ± 0.4 arbitrary units, 116 ± 2 *versus* 131 ± 4 mmHg and 86 ± 2 *versus* 95 ± 2 mmHg, respectively, all $P < 0.05$) in the resistance training group compared with control subjects. There were, however, no significant differences in the amount or percentage change in carotid artery diameter in CPT between the two groups (resistance training group, 0.33 ± 0.07 mm and 5.2 ± 1.1%; control group, 0.37 ± 0.06 mm and 5.8 ± 0.9%, respectively). These findings suggest that while carotid arterial stiffening and higher blood pressure are observed in regular resistance-trained men, these are not associated with abnormalities in carotid arterial vasoreactivity to sympathetic stimulus, which implies intact endothelial function.

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Resistance training is a popular form of exercise, and has become an integral component of exercise recommendations endorsed by a number of national health organizations (American College of Sports Medicine Position Stand, 1998; Pollock *et al.* 2000). Resistance training has favourable effects on the musculoskeletal system, thereby contributing to maintenance of functional capacity and prevention of sarcopenia and osteoporosis. In contrast, resistance training may be associated with reduction of compliance and increases in arterial stiffness in the central elastic artery (carotid artery; Bertovic *et al.* 1999; Miyachi *et al.* 2003, 2004; Cortez-Cooper *et al.* 2005; Kawano *et al.* 2006).

Increased arterial stiffness and reduced arterial compliance may be associated with endothelial dysfunction (Lind *et al.* 1999; Cheung *et al.* 2002; Nakamura *et al.* 2004). Indeed, impaired endothelial function and arterial stiffening are induced with advancing age and in the presence of cardiovascular diseases (Zeiher *et al.* 1989; O'Rourke, 1990; Taddei *et al.* 1995; Tanaka *et al.* 2000; Najjar *et al.* 2005). Therefore,

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Table 1. Subject characteristics

	Control	Resistance trained
Number of subjects	17	12
Age (years)	36.8 ± 1.2	38.7 ± 1.7
Height (cm)	171.0 ± 1.2	171.0 ± 1.8
Body weight (kg)	71.9 ± 1.9	74.9 ± 2.1
Percentage body fat (%)	19.4 ± 1.2	12.3 ± 0.9*
Total cholesterol (mmol l^{-1})	5.0 ± 0.2	4.7 ± 0.2
HDL cholesterol (mmol l^{-1})	1.3 ± 0.1	1.6 ± 0.1*
Plasma glucose (mmol l^{-1})	5.0 ± 0.1	5.1 ± 0.1
Triglycerides (mmol l^{-1})	1.5 ± 0.3	0.9 ± 0.1
Resting heart rate (beats min^{-1})	58 ± 2	56 ± 2
Maximal heart rate (beats min^{-1})	186 ± 3	183 ± 4
$\dot{V}_{O_2max}$ (l min^{-1})	2.7 ± 0.1	2.8 ± 0.1
$\dot{V}_{O_2max}$/body weight (ml kg^{-1} min^{-1})	37.7 ± 1.4	36.9 ± 1.3
Leg extension power (W)	1719 ± 91	2293 ± 155*
Handgrip (kg)	45.6 ± 1.6	51.0 ± 2.0*

Data are means ± S.E.M.; $\dot{V}_{O_2max}$, maximal oxygen consumption. *$P < 0.05$ *versus* control subjects.

impaired endothelial function is thought to be one of the physiological mechanisms underlying the reduction in carotid arterial compliance with resistance training. In this context, we hypothesized that resistance training would cause impairment of endothelial function in the carotid artery.

Local endothelial function in humans can be estimated by flow-mediated dilatation (Corretti *et al.* 2002) and/or vasoreactivity in response to medication with acetylcholine, etc. (Ludmer *et al.* 1986). Since it is difficult to determine endothelial function of the carotid artery in healthy humans using these methods, the cold pressor test (CPT), which results in production of nitric oxide (NO) via sympathetic activation (Nase & Boegehold, 1996; Tousoulis *et al.* 1997) is one of the novel methods (Rubenfire *et al.* 2000; Lavi *et al.* 2006) available for assessing endothelial function in the carotid artery.

To evaluate our hypothesis, we designed a cross-sectional study in which carotid arterial vasoreactivity to receptor-mediated sympathetic cold stimulus in regular resistance-trained men with reduced carotid arterial compliance was compared with age-matched sedentary control subjects.

Methods

Subjects

A total of 29 healthy men, 28–49 years of age, participated in the present study (Table 1). The sedentary subjects were recruited through various forms of advertisement and had not participated in a regular exercise programme for at least the previous 2 years. The resistance-trained men were recruited from various fitness clubs and had been performing vigorous resistance training for > 10 years. All resistance-trained men had been performing moderate- to high-intensity 'full-body' resistance exercise involving large muscle groups. To better isolate the effects of resistance exercise training, those who had been concurrently performing regular aerobic exercise (i.e. 'cross-training') were excluded from the study. All subjects were normotensive (< 140/90 mmHg), non-obese and free of overt chronic diseases as assessed by medical history, physical examination and complete blood chemistry and haematological evaluation. Candidates who smoked in the past 4 years, were taking medications, had ever used anabolic steroids or other performance-enhancing drugs, or who had significant femoral intima–media thickening (< 1.1 mm), plaque formation and/or other characteristics of atherosclerosis [ankle–brachial index (ABI) < 0.9] were excluded. All subjects gave their written, informed consent to participation in this study. All procedures were reviewed and approved by the Human Research Committee of the National Institute of Health and Nutrition.

Measurements

Before testing, subjects abstained from caffeine and fasted for at least 4 h (a 12 h overnight fast was used for determination of metabolic risk factors). All measurements were performed under comfortable laboratory conditions in the morning. Tests of resistance-trained men were conducted 20–24 h after their last exercise training session to avoid the immediate (acute) effects of exercise, but they were still considered to be in their normal (i.e. habitually exercising) physiological state.

Body composition

Body composition was determined using dual-energy X-ray absorptiometry (DEXA; model DPX-IQ, Lunar

Radiation) with subjects in the supine position. Measurement of fat mass using DEXA has been well validated against other standards (Haarbo *et al.* 1991).

Carotid arterial intima–media thickness (IMT)

Carotid artery IMT was measured from the images obtained using a SonoSite 180 PLUS ultrasound system (SonoSite, Bothell, WA, USA) equipped with a high-resolution linear-array broad-band transducer as previously described (Miyachi *et al.* 2004). Ultrasound images were analysed using image analysis software (NIH Image 1.63, Bethesda, MD, USA). At least 10 measurements of IMT were taken at each segment, and the mean values were used for analysis. This technique has excellent day-to-day reproducibility (coefficient of variation, $3 \pm 1\%$) for the carotid IMT.

Carotid arterial compliance

A combination of ultrasound imaging of the pulsatile common carotid artery with simultaneous applanation of tonometrically obtained arterial pressure from the contralateral carotid artery permits non-invasive determination of arterial compliance (Tanaka *et al.* 2000). The carotid artery diameter was measured from images obtained using an ultrasound system (Sonosite, Bothell, WA, USA) equipped with a high-resolution linear-array transducer. A longitudinal image of the cephalic portion of the common carotid artery was acquired 1–2 cm proximal to the carotid bulb. All image analyses were performed by the same investigator who was blinded to the group assignments.

Pressure waveforms and amplitudes were obtained from the common carotid artery with a pencil-type probe incorporating a high-fidelity strain-gauge transducer (SPT-301; Millar Instruments, Houston, TX, USA; Kelly *et al.* 1989; Tanaka *et al.* 2000). Since baseline levels of blood pressure are subjected to hold-down force, the pressure signal obtained by tonometry was calibrated by equating the carotid mean arterial and diastolic BP to the brachial artery value (Tanaka *et al.* 2000; Miyachi *et al.* 2004). In addition to arterial compliance (Van Merode *et al.* 1988), we also calculated the β-stiffness index, which provides an index of arterial compliance adjusted for distending pressure (Hirai *et al.* 1989). The arterial compliance and the β-stiffness index were calculated using the following equations:

$$\text{arterial compliance} = \frac{[(D_1 - D_0/D_0)]}{2\,(P_1 - P_0)} \times \pi \times D_0^2$$

and

$$\beta - \text{Stiffness index} = \frac{\ln (P_1/P_0)}{[(D_1 - D_0)/D_0]}$$

where D_1 and D_0 are the maximal and minimal diameters, and P_1 and P_0 are the highest and lowest blood pressures, respectively. The day-to-day coefficients of variation were 2 ± 1, 7 ± 3 and $5 \pm 2\%$ for the carotid artery diameter, pulse pressure and arterial compliance, respectively.

Cold pressor test

The CPT was performed by submersion of the right foot up to the ankle in ice slush for 90 s, a modification of the method published previously (Corretti *et al.* 1995*b*; Rubenfire *et al.* 2000). The foot was chosen to maximize the haemodynamic and sympathetic responses (Seals, 1990). Subjects were instructed to avoid breath-holding, muscle contractions and Valsalva's manoeuvre. Measurements of carotid arterial geometry were obtained before (baseline) and for 10 s during CPT. The day-to-day coefficient of variation for the change in carotid arterial diameter response to CPT was $4 \pm 1\%$.

Maximal oxygen uptake

We measured maximal oxygen consumption ($\dot{V}_{O_2max}$) during incremental cycle ergometer exercise (Miyachi *et al.* 2001). Oxygen consumption (coefficient of variation, $4 \pm 1\%$), heart rate and ratings of perceived exertion were measured throughout the protocol (Miyachi *et al.* 2001).

Metabolic risk factors for coronary heart disease

To screen for the presence of coronary heart disease, concentrations of fasting serum lipids and plasma glucose were determined with enzymatic techniques (Tanaka *et al.* 2000).

Arterial blood pressure at rest

Chronic levels of arterial blood pressure at rest were measured with a semi-automated device (Form PWV/ABI; Colin Medical, Komaki, Japan) over the brachial and dorsalis pedis arteries. Recordings were made in triplicate with subjects in the supine position (Miyachi *et al.* 2005).

Muscle strength

Leg extension power was determined using a dynamometer (Anaero Press 3500; Combi Wellness, Tokyo, Japan) in the sitting position. The subjects were fastened with a seat belt to a chair. In the starting position, the feet were placed on a sliding plate with the knee angle adjusted to 90 deg. Subjects were advised to vigorously extend their legs. Five trials were performed at 15 s intervals and the average of the two highest recorded power outputs (in W) was taken as the definitive measurement (Yoshiga *et al.* 2002).

Table 2. Cardiovascular measures

	Control	Resistance trained
Brachial systolic BP (mmHg)	116 ± 2	131 ± 4*
Brachial mean BP (mmHg)	86 ± 2	95 ± 3*
Brachial diastolic BP (mmHg)	71 ± 2	74 ± 3
Brachial PP (mmHg)	45 ± 1	57 ± 2*
Carotid systolic BP (mmHg)	104 ± 2	123 ± 5*
Carotid PP (mmHg)	33 ± 2	48 ± 4*
Carotid artery diameter (mm)	6.4 ± 0.1	6.2 ± 0.1
Carotid artery IMT (mm)	0.64 ± 0.02	0.65 ± 0.03

Data are means ± S.E.M.; BP, blood pressure; PP, pulse pressure; IMT, intima–media thickness. *$P < 0.05$ *versus* control subjects.

Handgrip strength of the right arm was measured with a hand-held dynamometer, with the subject standing and the arms extended by their sides. The subjects then gripped the dynamometer as strongly as possible for 3 s without pressing the instrument against their body or bending at the elbow, and values (in kg) were recorded as the averages of two trials.

Statistics

Statistical analyses were performed using statistical software (StatView, SAS, Cary, NC, USA). All data are presented as means ± S.E.M. Mean differences between resistance-trained and control men were examined using Student's unpaired *t* test. Analysis of covariance (ANCOVA) was used to test for differences in carotid arterial compliance and β-stiffness index between resistance-trained men and control subjects, with mean arterial blood pressure as a covariate.

Statistical significance was set *a priori* at $P < 0.05$ for all comparisons.

Results

Subject characteristics are presented in Table 1. Body fat was lower in the resistance-trained men compared with the control subjects. Although all metabolic risk factors were well within clinically normal levels in both groups, high-density lipoprotein (HDL) cholesterol levels were higher in resistance-trained men compared with control subjects. Muscle strength, assessed by leg extension power and handgrip strength, was higher in resistance-trained men than in the control subjects. There were no significant differences in other parameters between the two groups.

Table 2 shows cardiovascular measures. With the exception of diastolic blood pressure in the brachial artery, blood pressure parameters of brachial and carotid arteries were higher in resistance-trained men compared with control subjects. Ankle–brachial index was lower in resistance-trained men than control subjects. There were no significant differences in the diameter or IMT in the carotid artery between the two groups.

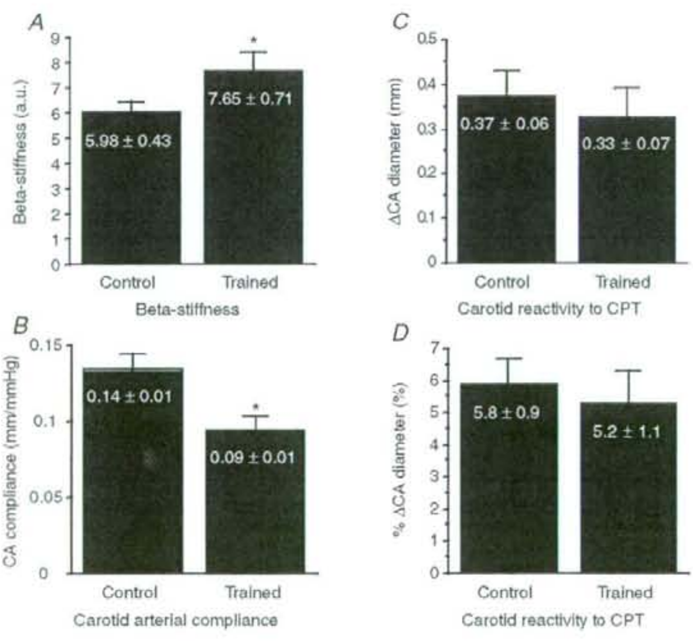

Figure 1. Carotid arterial β-stiffness index (*A*), carotid arterial (CA) compliance (*B*), and amount (*C*) and percentage change (*D*) in carotid artery diameter in response to CPT in resistance-trained men and control subjects

Values are means ± S.E.M. *$P < 0.05$ *versus* control subjects.

Carotid arterial β-stiffness (Fig. 1*A*) was higher and compliance (Fig. 1*B*) was lower in resistance-trained men compared with control subjects. There were no significant differences in the amount (Fig. 1*C*) or percentage change (Fig. 1*D*) of carotid artery diameter in response to CPT between resistance-trained men and control subjects. The differences in carotid arterial compliance and β-stiffness index between resistance-trained men and control subjects disappeared after normalizing carotid arterial compliance and β-stiffness index relative to mean arterial blood pressure (ANCOVA; $P = 0.081$ and $P = 0.101$, respectively).

Discussion

The results of the present study indicated that, although the carotid arterial compliance was lower in resistance-trained men compared with age-matched control subjects, there were no significant differences in the amount or percentage change of carotid arterial diameter in CPT between resistance training and control groups. In contrast to our original hypothesis, these findings suggest that while regular resistance training can increase carotid arterial stiffness, this is not associated with abnormalities of carotid arterial vasoreactivity to sympathetic physiological stress induced by cold.

The endothelial function of conduit arteries is one of the vascular functions, and has been identified as a primary target of injury from mechanical forces and processes that increase cardiovascular risk, such as hypertension (Moyna & Thompson, 2004). Owing to the clinical and functional importance of health of the endothelium, we examined the impact of resistance training on endothelial function. As a primary approach to resolve this issue, we performed a cross-sectional study. To isolate the effects of resistance training as much as possible, resistance-trained men and control subjects were carefully matched for age, height, body weight, aerobic capacity and metabolic risk factors. Although subjects were recruited carefully, as described in the Methods, blood pressure in resistance-trained men was higher than that in the control subjects. As a result, we found a 30% reduction in central arterial compliance in resistance-trained men compared with control subjects. These results are consistent with those of a previous cross-sectional study (Bertovic *et al.* 1999). Differences in carotid arterial compliance and β-stiffness index between resistance-trained men and control subjects were affected after normalizing carotid arterial compliance and β-stiffness index relative to mean arterial blood pressure. Given this association between blood pressure and arterial compliance, higher blood pressure may lead to lower arterial compliance in resistance-trained men than in control subjects due to equation using arterial distensibility and blood pressure. However, we feel that the higher blood pressure in resistance-trained men may be induced by greater arterial stiffening associated with the resistance training. Nevertheless, despite the higher arterial stiffness and blood pressure in resistance-trained men than in control subjects, there was no difference in carotid arterial vasoreactivity to CPT between the two groups.

The response of conduit arteries to systemic cold may be the result of the balance between adrenergic vasoconstriction and vasodilatation, with the latter being mediated by endothelial function (Nabel *et al.* 1988; Zeiher *et al.* 1989; Vita *et al.* 1992; Corretti *et al.* 1995*a*). The normal coronary vasodilator response to CPT can be blocked by competitive inhibition of L-arginine, a substrate for NO synthase (Tousoulis *et al.* 1997), and L-arginine can normalize the vasoconstrictor response to CPT in coronary artery disease (Gellman *et al.* 1996). In addition, both endogenous NO and exogenously administered NO donors suppress sympathetic outflow at the prejunctional level, and NO may exert a tonic influence on the discharge of sympathetic efferents (Zanzinger *et al.* 1994; Nase & Boegehold, 1996). Therefore, the endothelial function, via NO, may play an important role in changing the conduit artery diameter response to sympathetic stimulation by the CPT. We first examined the impact of resistance training with arterial stiffening on endothelial function of the carotid artery using CPT, and found that there were no significant differences in the amount or percentage change in carotid arterial diameter in response to CPT between resistance-trained men and control subjects. Our results were consistent with those of a previous study, which demonstrated that resistance training did not affect endothelial function in the peripheral muscular artery evaluated by flow-mediated dilation (FMD) (Rakobowchuk *et al.* 2005). These findings are consistent with the posit that regular resistance training may protect against the adverse effects of resistance load associated hypertension by preserving arterial endothelial function (Jurva *et al.* 2006).

The results of the present study indicated that carotid arterial compliance in resistance-trained men was lower than that in control subjects, and blood pressure was significantly higher in resistance-trained men compared with control men. In contrast, HDL cholesterol level was higher in resistance-trained men than in control subjects, and there were no differences in other lipid profiles or IMT between the two groups. Considering the relationships between reduction in arterial compliance and impaired endothelial function, hypertrophied IMT or abnormal lipid profile with advancing age and/or the presence of cardiovascular disease (Zeiher *et al.* 1989; O'Rourke, 1990; Taddei *et al.* 1995; Tanaka *et al.* 2000; Najjar *et al.* 2005), the decrease in carotid arterial compliance induced by resistance training may be different from vascular alterations seen in ageing or in the presence of cardiovascular disease. Arterial compliance is affected by endothelial function as well as by sympathetic vascular tone, arterial calcification, elastin-to-collagen ratio and IMT, and correlates with clinical parameters, such as aerobic capacity, age, blood pressure, body fat, waist circumference and lipids (Nichols & O'Rourke, 1998; Tanaka *et al.* 2000). The degree to which these other factors affect the relationship between training-associated decrease in arterial compliance independent of endothelial function will require further studies in a larger cohort.

Rubenfire *et al.* (2000) reported that the direction and magnitude of the change in carotid artery diameter in response to CPT are altered based on the presence of risk factors and coronary disease independent of IMT. The carotid artery vasoreactivity to CPT may have a valuable role in coronary risk assessment and in predicting response to therapy. The present study revealed that there were no significant differences in carotid arterial vasoreactivity to CPT and IMT between resistance-trained men and control subjects, suggesting that regular resistance training may not affect at least two of the cardiovascular disease risk factors. In addition, HDL cholesterol, leg extension power and handgrip strength were higher in resistance-trained men than in control subjects. Given these functional and physiological benefits of resistance training, we should emphasize that the practice of resistance training should not be discouraged.

Limitations

Endothelial function assessed by FMD should optimally be adjusted by shear stress, shear rate or blood flow velocity (Pyke & Tschakovsky, 2005; Rakobowchuk *et al.* 2005). However, it is technically difficult to determine the blood velocity or shear stress during the relatively short period (90 s) of CPT used in our study. Further, in contrast to the occlusion release technique for assessing brachial endothelial function, the carotid artery vasoreactivity to CPT is a complex interaction between clinical, adrenergic nerve and hormonal responses and endothelial function.

Conclusion

The results of the present study showed that regular resistance training is associated with reduction of central arterial compliance as measured using a combination of ultrasound images and applanation tonometry. However, there were no differences in carotid arterial vasoreactivity to CPT between resistance-trained men and sedentary control subjects. These findings suggest that while carotid arterial stiffening and higher blood pressure are observed in regular resistance-trained men, they are not associated with impaired vasoreactivity to sympathetic stimulus, which implies intact endothelial function. Nevertheless, the results of the present cross-sectional study must be confirmed in future prospective exercise intervention studies.

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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

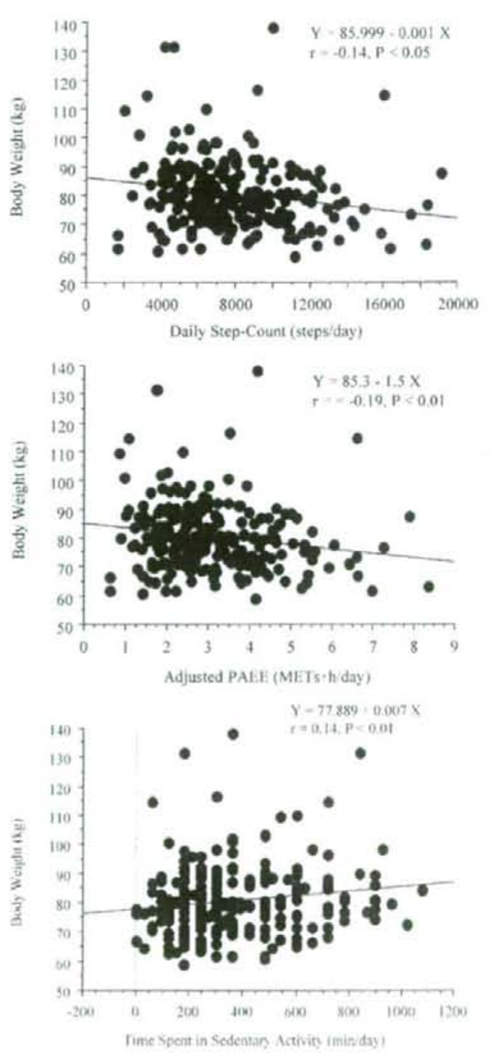

Fig. 1 Relationships between body weight and daily step-count (upper), adjusted physical activity-related energy expenditure (middle), and time spent in sedentary activity (bottom).

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

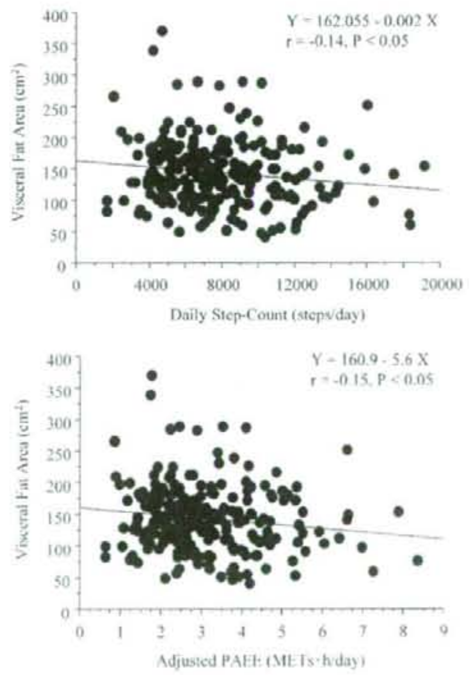

Fig. 2 Relationships between visceral fat area and daily step-count (upper), adjusted physical activity-related energy expenditure (middle), and time spent in sedentary activity (bottom).

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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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

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