Table 3: Relationship between changes in oxygen uptake at ventilatory threhold and metabolic syndrome

Metabolic syndrome		Oxygen uptake at ventilatory threshold				
		Group I		Group D		p
Baseline	Follow up		%		%	
(-)	(-)	11	31.4	23	65.7	
(-)	(+)	3	8.6	2	5.7	
(+)	(-)	8	22.9	4	11.4	0.0393
(+)	(+)	13	37.1	6	17.1	
Total		35	100.0	35	100.0	

Group I: Delta oxygen uptake at VT ≧ 0 ml/kg/min
Group D: Delta oxygen uptake at VT < 0 ml/kg/min

We further compared parameters at baseline and changes in each parameter at baseline and follow up between Group I and Group D (Table 4). At baseline, significant differences were noted in abdominal circumference, oxygen uptake at VT, work rate at VT, heart rate at VT and diastolic blood pressure. After 1-year follow up, there were also significant differences in delta oxygen uptake at VT (Group I: 1.6±1.2 ml/kg/min vs Group D: -1.5±0.8 ml/kg/min), delta work rate at VT, delta heart rate at VT, delta abdominal circumference, delta HDL cholesterol and delta blood sugar between the two groups. However, delta systolic blood pressure, delta diastolic blood pressure and delta triglyceride in Group I were similar to those in Group D.

Table4: Comparison of clinical parameters at baseline and changes in parameters with 1-year follow up

	Group I	Group D	p
Number of subjects	35	35	
Age	48.2 ± 7.0	45.8 ± 8.4	0.7459
Abdominal circumference (cm)	95.6 ± 7.6	91.1 ± 7.6	0.0037
Oxygen uptake at ventilatory threshold (ml/kg/min)	13.5 ± 1.7	15.6 ± 3.0	0.0005
Work rate at ventilatory threshold (W)	81.4 ± 14.1	88.7 ± 15.1	0.0409
Heart rate at ventilatory threshold (beats/min)	103.8 ± 9.6	104.5 ± 11.1	0.2780
Systolic blood pressure (mmHg)	134.2 ± 15.3	133.8 ± 14.5	0.8867
Diastolic blood pressure (mmHg)	88.6 ± 10.8	79.6 ± 13.1	0.0185
Triglyceride (mg/dl)	185.7 ± 76.6	163.4 ± 129.3	0.7981
HDL cholesterol (mg/dl)	50.3 ± 12.2	53.8 ± 16.1	0.2033
Blood sugar (mg/dl)	110.3 ± 25.0	105.5 ± 21.5	0.5136
Delta oxygen uptake at ventilatory threshold (ml/kg/min)	1.6 ± 1.2	-1.5 ± 0.8	<0.0001
Delta work rate at ventilatory threshold (W)	8.0 ± 10	-9.4 ± 12.4	<0.0001
Delta heart rate at ventilatory threshold (beats/min)	-3.7 ± 7.3	-6.3 ± 8.3	0.0226
Delta abdominal circumference (cm)	-4.1 ± 5.2	-1.5 ± 3.7	0.0304
Delta systolic blood pressure (mmHg)	-7.7 ± 11.2	-11.3 ± 14.5	0.2500
Delta diastolic blood pressure (mmHg)	-7.4 ± 10.9	-8.2 ± 12.8	0.6302
Delta triglyceride (mg/dl)	-37.2 ± 85.7	-33.1 ± 112.5	0.9328
Delta HDL cholesterol (mg/dl)	4.3 ± 5.0	-1.1 ± 8.3	0.0038
Delta blood sugar (mg/dl)	2.8 ± 28.2	-2.8 ± 12.2	0.0447

Mean±SD
Group I: Delta oxygen uptake at VT ≧ 0 ml/kg/min
Group D: Delta oxygen uptake at VT < 0 ml/kg/min

Finally, we evaluated the relationship between delta oxygen uptake at VT and each delta parameter of metabolic syndrome by a simple correlation analysis. Oxygen uptake at VT was weakly correlated with delta abdominal circumference (r=-0.308, p=0.0094) and delta HDL cholesterol (r=0.312, p=0.0085). Although a significant difference in delta blood sugar was noted between Group I and Group D, the correlation between delta oxygen uptake at VT and delta blood sugar was not at a significant level (r=0.172, p=0.1556).

Table5: Simple correlation analysis between changes in (delta) oxygen uptake at ventilatory threshold and clinical parameters

	r	p
Delta abdominal circumference (cm)	-0.308	0.0094
Delta systolic blood pressure (mmHg)	0.086	0.4794
Delta diastolic blood pressure (mmHg)	-0.129	0.2872
Delta triglyceride (mg/dl)	-0.089	0.4634
Delta HDL cholesterol (mg/dl)	0.312	0.0085
Delta blood sugar (mg/dl)	0.172	0.1556

Discussion

We explored, using the Japanese criterion, whether an increase in oxygen uptake at VT can improve metabolic syndrome and its components in Japanese men.

Regular physical activity has been shown to increase HDL and reduce resting blood pressure, triglycerides, abdominal fat, fasting blood sugar, and insulin responses to oral glucose challenge test [12-16]. Some cross sectional studies show that metabolic syndrome is significantly correlated with physical fitness [17-19]. We also previously showed that lower oxygen uptake at VT was characteristic in Japanese men with metabolic syndrome [8]. In addition, lower exercise habits were noted in subjects with metabolic syndrome compared to those without [8]. It seems reasonable to suggest that simply moving from the lower oxygen uptake at VT to a higher oxygen uptake at VT might result in the amelioration of metabolic syndrome in some Japanese men. However, these were cross sectional studies and the hypothesis that metabolic syndrome may be caused by lower oxygen uptake at VT cannot be accurately proven.

In turn, few longitudinal studies have been carried out to prove a link between metabolic syndrome and exercise. Katzmarzyk *et al* reported on the effects of 20 weeks supervised aerobic training program on the prevalence of metabolic syndrome in 621 men and women who were enrolled in the HERITAGE Study. 30.5% of the participants with metabolic syndrome at baseline were classified as not having the syndrome after the intervention [20]. The Kuopio Ischemic Heart Disease Risk Factor Study [21] followed several hundred men without the syndrome at baseline. After four years, subjects in the upper one-third of VO_2max at baseline were 75% less likely than unfit men to develop metabolic syndrome. Ekelund *et al* reported that the energy expenditure of physical activity predicts progression to metabolic syndrome independent of aerobic fitness, obesity, and other confounding factors followed by 5.6 years [22]. By using the criterion developed in Japan, Okura *et al* recently reported that '67 women with metabolic syndrome were treated with a 14-week weight loss program, which included a low-calorie diet and aerobic exercise. The adjusted odds ratios for metabolic syndrome improvement in the two interventions with diet alone and diet plus exercise were 1.0 and 3.68. In addition, $\dot{V}O_2max$ in subjects on the low-calorie diet and aerobic exercise treatment was 22.9±3.2 ml/kg/min at baseline and 27.0±3.8 ml/kg/min after intervention (p<0.001) [23].

In the present study, using the criterion developed in Japan, increasing oxygen uptake at VT was associated with improvement of metabolic syndrome in Japanese men with a 1-year follow up. In addition, clinical impacts of abdominal circumference and HDL-cholesterol improvement were also noted. Compared to Okura *et al*, the observation period was longer and oxygen uptake at VT as a parameter of aerobic exercise was used. Our results suggest the clinical significance of increasing aerobic exercise level.

Potential limitations still remain in this study. First, the 14,345 subjects in our study voluntarily underwent the annual health check-up; they were, therefore, probably more health-conscious than the average person. The selected 70 subjects (0.5%) underwent an annual health check-up every year with a follow-up duration of 1-year and received no medication; they were, therefore, probably even more health-conscious than most of the subjects in the database, and the small sample size makes it difficult to infer causality between increasing oxygen uptake at VT and metabolic syndrome. Second, the parameters of VT were significantly lower and diastolic blood pressure was significantly higher in subjects in Group I than those subjects in Group D at baseline. Third, although delta blood sugar was significantly higher in Group I than in Group D by unpaired t test, delta oxygen uptake at VT was not correlated with delta blood sugar. Blood sugar might be more changeable compared to other parameters.

In conclusion, 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. In addition, exercise habit was closely linked to oxygen uptake at VT [8]. Therefore, we need promote exercise habits for preventing and improving metabolic syndrome. Further prospective investigation studies are needed in Japanese using the new criterion of Japan.

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Increasing Oxygen Uptake at Ventilatory Threshold is Associated with Improving Metabolic Syndrome in Japanese Men

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The link between changes in oxygen uptake at ventilatory threshold (VT) and metabolic syndrome was evaluated in Japanese men with a 1-year follow up. We used data for 70 Japanese men (45.9±7.7 years) with a 1-year follow up. Metabolic syndrome has been defined by a new criterion in Japan. Changes in oxygen uptake at VT on metabolic syndrome were also evaluated. Body weight, abdominal circumference, systolic blood pressure, diastolic blood pressure and triglyceride were significantly reduced and the prevalence of metabolic syndrome was also significantly reduced with a 1-year follow up. The prevalence of metabolic syndrome was reduced in subjects with an increase in oxygen uptake at VT (Group I) compared to subjects without such an increase (Group D). In addition, there were remarkable differences in delta abdominal circumference (delta represents positive changes in parameters) and delta HDL cholesterol between Group I and Group D. An increase in oxygen uptake at VT may be associated with improving metabolic syndrome and its components in Japanese men.

Key words: Metabolic syndrome, Ventilatory threshold, , Oxygen uptake

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Original Article

Leg Strength per Body Weight is Associated with Ventilatory Threshold in Japanese Women

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Abstract

Objective: The link between leg strength per body weight and oxygen uptake at ventilatory threshold (VT) was evaluated in Japanese women with a 1-year follow up.

Subjects and Methods: We used data for 60 Japanese women (46.1 ± 10.6 years) with a 1-year follow up. Changes in leg strength per body weight on oxygen uptake at VT were also evaluated.

Results: Oxygen uptake at VT (per body weight) was significantly correlated with body weight, body mass index (BMI), abdominal circumference, hip circumference, body fat percentage, leg strength and leg strength per body weight ($r=0.520$, $p<0.001$). Body weight, BMI, abdominal circumference and body fat percentage were significantly reduced; work rate and right grip strength were significantly increased with a 1-year follow up. In addition, changes in oxygen uptake at VT (per body weight) were also significantly correlated with leg strength and leg strength per body weight ($r=0.317$, $p=0.0137$).

Conclusion: An increase in leg strength per body weight may be associated with increasing oxygen uptake at VT in Japanese women.

KEY WORDS: leg strength, oxygen uptake, ventilatory threshold

Introduction

Aerobic exercise has been shown to increase HDL and reduce resting blood pressure, triglycerides, abdominal fat, fasting blood sugar, and insulin responses to oral glucose challenge test [1-5]. Some cross sectional studies show that metabolic syndrome is significantly correlated with physical fitness[6-8].

Although maximum oxygen uptake is generally considered an accurate and reliable parameter of aerobic exercise level, it is not fully applicable to the population in clinical practice. Ventilatory threshold (VT) is defined as the upper limit of aerobic exercise and is also thought to serve as an accurate and reliable standard for exercise prescription [9]. Since exercise intensity at VT is not harmful to cardiovascular function, it can be safely applied to patients with myocardial infarction as exercise prescription [10]. It is also well known that low and declining muscle strength is associated with increased mortality, independent of physical activity and muscle mass [11] and well reported that there is significant loss in muscle strength with aging [12,13]. We have solely reported in a cross sectional study that oxygen uptake at VT was significantly correlated with leg strength per body weight in Japanese women [14]. However, whether an increase in leg strength per body weight is beneficial for increasing oxygen uptake at VT, and what effects this will have on oxygen uptake at VT remain to be investigated in a longitudinal analysis.

In this study, we evaluate the link between increases in leg strength per body weight and oxygen uptake at VT in Japanese women with a 1-year follow up.

Subjects and Methods

Subjects

We used data for 60 Japanese women, aged 46.1 ± 10.6 years who met the following criteria: (1) received an annual health check-up every year with a follow up duration of 1-year, (2) received no medications for diabetes, hypertension, and/or dyslipidemia, and (3) provided written informed consent (*Table 1*).

At the first annual health check-up, all subjects were given instructions by well-trained medical staff on how to change their lifestyle i.e. not to eat too much, consider balance when they eat and increase their daily steps.

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

Anthropometric and body composition measurements

Anthropometric and body compositions were evaluated based on the following parameters: height, body weight, abdominal circumference, hip circumference and body fat percentage. Body mass index (BMI) was calculated by weight / [height]^2 (kg/m^2). Abdominal circumference was measured at the umbilical level and hip circumference was measured at the widest circumferences over the trochanter in standing subjects after normal expiration [15]. Body fat percentage was measured by an air displacement plethysmograph called the BOD POD Body Composition System (Life Measurement Instruments, Concord, CA, USA) [16,17]. Lean body mass was calculated as follows: Body weight(kg) − [body weight(kg) × body fat percentage (%)/100].

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Table 1 Clinical characteristics and changes in parameters with 1-year follow up

	Baseline	Follow up	p
Number of Subjects	60		
Age	46.1 ± 10.6		
Height (cm)	155.8 ± 4.4		
Body weight (kg)	62.0 ± 8.0	60.9 ± 8.4	**0.0159**
Body mass index (kg/m2)	25.5 ± 3.2	25.1 ± 3.5	**0.0133**
Abdominal circumference (cm)	78.3 ± 7.4	76.9 ± 8.2	**0.0184**
Hip circumference (cm)	95.4 ± 6.0	94.6 ± 6.5	0.0797
Lean body mass (kg)	39.5 ± 3.9	39.6 ± 3.9	0.9933
Body fat percentage (%)	35.8 ± 4.9	34.8 ± 5.2	**0.0027**
Systolic blood pressre (mmHg)	122.8 ± 14.0	121.9 ± 15.9	0.5259
Diastolic blood pressure (mmHg)	77.2 ± 9.6	75.2 ± 10.6	0.1142
Triglyceride (mg/dl)	98.0 ± 63.1	95.4 ± 60.4	0.6653
HDL cholesterol (mg/dl)	65.1 ± 14.6	64.9 ± 15.3	0.8599
Blood sugar (mg/dl)	94.3 ± 9.1	93.6 ± 8.7	0.4523
Oxygen uptake at ventilatory threshold (ml/body weight (kg)/min)	12.9 ± 2.1	13.0 ± 1.9	0.6742
Oxygen uptake at ventilatory threshold (ml/lean body mass (kg)/min)	20.1 ± 2.9	19.9 ± 2.3	0.5943
Oxygen uptake at ventilatory threshold (ml/min)	792.7 ± 133.1	784.9 ± 120.0	0.6231
Work rate at ventilatory threshold (watt)	50.7 ± 11.5	55.0 ± 14.5	**0.0131**
Heart rate at ventilatory threshold (beat/min)	102.4 ± 11.7	100.4 ± 10.5	0.1095
Right grip strength (kg)	25.9 ± 5.4	27.0 ± 4.3	**0.0237**
Left grip strength (kg)	25.2 ± 5.1	25.6 ± 4.5	0.1908
Leg strength (kg)	44.2 ± 10.5	45.3 ± 10.3	0.2673
Leg strength per body weight	0.72 ± 0.16	0.75 ± 0.15	0.0645
Leg strength per lean body mass	1.12 ± 0.25	1.15 ± 0.23	0.3901
Flexibility (cm)	8.0 ± 8.8	8.8 ± 8.2	0.1641

Mean ± SD

Blood pressure measurements at rest

Resting systolic and diastolic blood pressure was measured indirectly using a mercury sphygmomanometer placed on the right arm of the seated participant after at least 15 minutes of rest.

Blood sampling assays

Overnight fasting serum levels of high density lipoprotein (HDL) cholesterol, triglycerides (L Type Wako Triglyceride·H, Wako Chemical, Osaka) and serum glucose were measured.

Exercise testing

A graded ergometer exercise protocol [18] was performed. Two hours after breakfast, a resting ECG was recorded and blood pressure was measured. Then, all participants were given graded exercise after 3 min of pedaling on an unloaded bicycle ergometer (Excalibur V2.0, Lode BV, Groningen, Netherlands). The profile of incremental workloads was automatically defined by the methods of Jones [18], in which the workloads reach the predicted VO_2 max in 10 min. A pedaling cycle rate of 60 rpm was maintained. Loading was terminated when the appearance of symptoms forced the subject to stop. During the test, ECG was monitored continuously together with the recording of heart rate (HR). Expired gas was collected and rates of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured breath-by-breath using a cardiopulmonary gas exchange system (Oxycon Alpha, Mijnhrdt b.v., Netherlands). VT was determined by the standard of Wasserman et al [9], Davis et al [19], and the V-slope method of Beaver [20] from VO_2, VCO_2 and minute ventilation (VE). At VT, VO_2 (ml/kg/min), work rate (W), and heart rate (beats / min) were measured and recorded.

Measurement of muscle strength

To assess muscle strength, grip and leg strength had been measured. Grip strength was measured using THP-10 (SAKAI, Tokyo, Japan), while leg strength was measured by COMBIT CB-1 (MINATO, Osaka, Japan). Isometric leg strength was measured as follows: the subject sat in a chair, grasping the armrest in order to fix the body position. The dynamometer was then attached to the subject's ankle joint by a strap. Next, the subject extended the leg to 60 degrees [21]. To standardize the influence of the total body weight, we calculated the leg strength (kg) per body weight (kg) [22], the level of which "over 1.0" is recommended for daily activity [21].

Measurements of flexibility

To evaluate the flexibility of all the participants, they were measured as follows: Sit-and-reach measurements were obtained to assess the overall flexibility in the forward flexion, with the measurements recorded as the distance (in centimeters) between the fingertips and toes. The subject's knees were kept straight throughout the test and ankles were maintained at 90 degrees by having the soles of the feet pressed against a board perpendicular to the sitting surface [23].

Statistical analysis

All data are expressed as mean ± standard deviation (SD) values. A statistical analysis was performed using a paired t test: $p<0.05$ was considered to be statistically significant. Pearson's correlation coefficients were calculated and used to test the significance of the linear relationship among continuous variables.

Results

The clinical parameters at the baseline and the 1-year follow up are summarized in *Table 1*. Anthropometric and body composition parameters such as body weight, BMI, abdominal circumference and body fat percentage were significantly reduced after one year. Work rate at VT and right grip strength were significantly increased.

Relationship between oxygen uptake at VT and clinical parameters at baseline was evaluated. Oxygen uptake at VT (per body weight) was negatively correlated with body weight, BMI, abdominal circumference, hip circumference and body fat percentage; and it was positively correlated with leg strength ($r=0.295$, $p=0.0220$), leg strength per body weight ($r=0.520$, $p<0.0001$) and leg strength per lean body mass ($r=0.385$, $p=0.0024$) (*Table 2, Figure 1*). Oxygen uptake at VT (per lean body mass) was also correlated with leg strength, leg strength per body weight and leg strength per lean body mass (*Table 2*). However, there was no significant relationship between oxygen uptake at VT (per body mass and per lean body mass) and other clinical parameters.

Simple correlation analysis between oxygen uptake at VT and age (*Figure 2*), and between leg strength per body weight, leg strength and age (*Figure 3*) were also evaluated. Leg strength per body weight and leg strength were negatively correlated with age. Leg strength per lean body mass was also weakly correlated with age ($r=-0.281$, $p=0.0297$). Oxygen uptake at VT (ml/min) was weakly correlated with age (*Figure 2: B*). However, oxygen uptake at VT (per body weight: ml/kg/min) (*Figure 2: A*) and oxygen uptake at VT (per lean body mass: ml/kg/min) were not correlated with age at a significant level (per body weight: $r=-0.187$, $p=0.1529$, per lean body mass: $r=-0.106$, $p=0.4185$).

Table 2 Simple correlation analysis between oxygen uptake at ventilatory threhold and clinical parameters at baseline

	Per body weight		Per lean body mass	
	r	*p*	r	*p*
Body weight (kg)	−0.344	**0.0072**	−0.058	0.6602
Body mass index (kg/m^2)	−0.361	**0.0046**	−0.043	0.7414
Abdominal circumference (cm)	−0.373	**0.0034**	−0.027	0.8361
Hip circumference (cm)	−0.321	**0.0125**	−0.070	0.5977
Body fat percentage (%)	−0.395	**0.0018**	0.085	0.5191
Systolic blood pressre (mmHg)	0.088	0.5031	0.231	0.0758
Diastolic blood pressure (mmHg)	0.077	0.5598	0.181	0.1675
Triglyceride (mg/dl)	−0.185	0.1571	−0.172	0.1890
HDL cholesterol (mg/dl)	0.198	0.1303	0.114	0.3843
Blood sugar (mg/dl)	−0.136	0.2990	−0.004	0.9759
Right grip strength (kg)	0.229	0.0789	0.246	0.0579
Left grip strength (kg)	0.183	0.1607	0.161	0.2191
Leg strength (kg)	0.295	**0.0220**	0.422	**0.0008**
Leg strength per body weight	0.520	**<0.0001**	0.487	**<0.0001**
Leg strength per lean body mass	0.385	**0.0024**	0.522	**<0.0001**
Flexibility (cm)	−0.035	0.7881	−0.046	0.7247

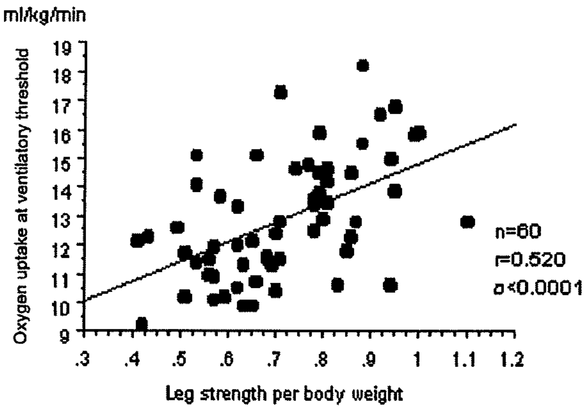

Fig. 1. Simple correlation analysis between oxygen uptake at ventilatory threshold (per body weight) and leg strength per body weight in Japanese women at baseline.

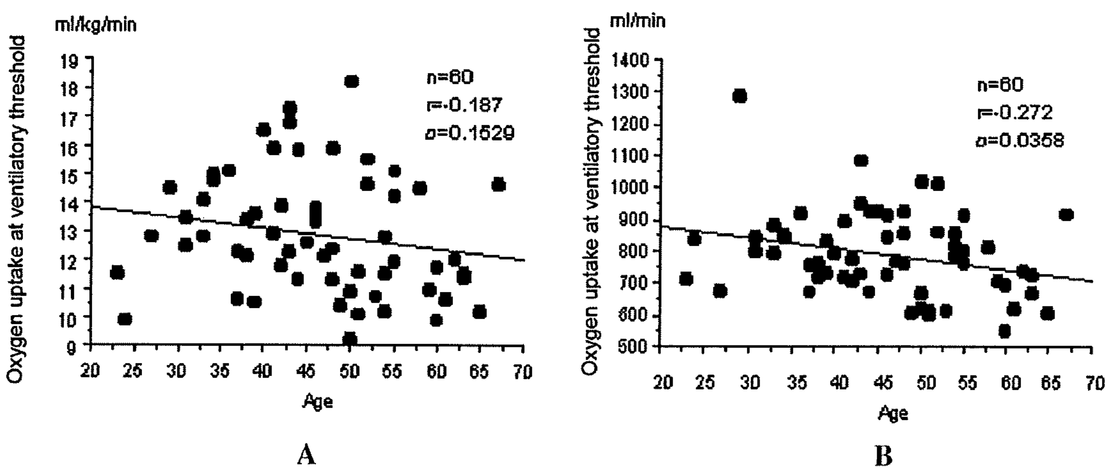

Fig. 2. Simple correlation analysis between oxygen uptake at ventilatory threshold (A: ml/body weight (kg)/min, B: ml/min) and age.

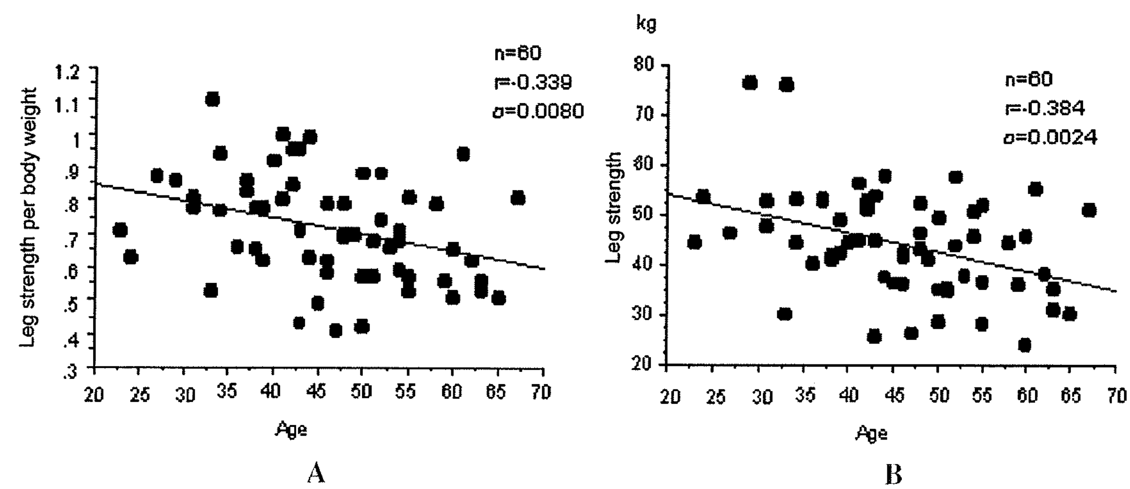

Fig. 3. Simple correlation analysis between leg strength per body weight (A), Leg strength (B) and age.

Table 3 Simple correlation analysis between changes in oxygen uptake at ventilatory threhold and changes in clinical parameters with 1-year follow up

	Per body weight		Per lean body mass	
	r	*p*	r	*p*
Body weight (kg)	−0.181	0.1670	0.009	0.9456
Body mass index (kg/m²)	−0.165	0.2087	0.024	0.8596
Abdominal circumference (cm)	−0.162	0.2157	−0.014	0.9132
Hip circumference (cm)	−0.156	0.2354	0.046	0.7268
Body fat percentage (%)	−0.216	0.1005	0.056	0.6751
Systolic blood pressre (mmHg)	0.138	0.2922	0.169	0.2006
Diastolic blood pressure (mmHg)	0.091	0.4911	0.130	0.3249
Triglyceride (mg/dl)	−0.079	0.5501	−0.073	0.5840
HDL cholesterol (mg/dl)	0.015	0.9066	−0.038	0.7777
Blood sugar (mg/dl)	0.220	0.0909	0.258	**0.0487**
Right grip strength (kg)	−0.050	0.7087	0.026	0.8440
Left grip strength (kg)	0.027	0.8403	−0.005	0.9706
Leg strength (kg)	0.260	**0.0440**	0.309	**0.0172**
Leg strength per body weight	0.317	**0.0137**	0.305	**0.0188**
Leg strength per lean body mass	0.264	**0.0430**	0.307	**0.0179**
Flexibility (cm)	0.159	0.2260	0.091	0.4952

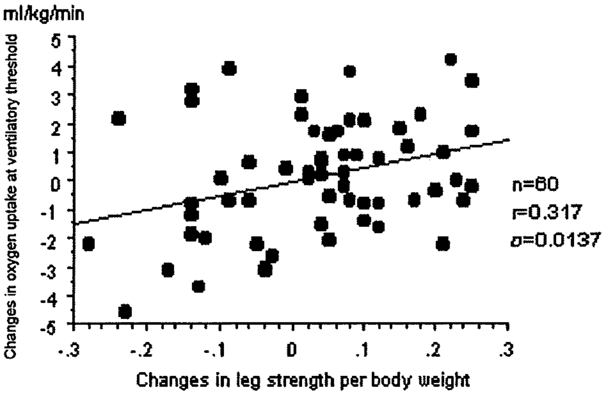

Fig. 4. Simple correlation analysis between changes in oxygen uptake at ventilatory threshold (per body weight) and changes in leg strength per body weight in Japanese women with 1-year follow up.

We further evaluated the relationship between changes in oxygen uptake at VT and changes in clinical parameters. Changes in oxygen uptake at VT (per body weight) were weakly correlated with changes in leg strength (r=0.260, p=0.0440), leg strength per body weight (r=0.317, p=0.0137) and leg strength per lean body mass (r=0.264, p=0.0430) (*Table 3*, *Figure 4*). Changes in oxygen uptake at VT (per lean body mass) were also correlated with leg strength parameters (*Table 3*).

Discussion

The main findings of this study were explored the link between changes in oxygen uptake at VT (per body weight) and changes in leg strength per body weight in Japanese women with a 1-year follow up.

Some cross sectional studies show that aerobic exercise level is significantly correlated with body composition and physical fitness parameters [24-26]. Wong et al reported that high cardiorespiratory fitness group had significantly lower abdominal circumference and less visceral adipose tissue[24]. Thigh skeletal muscle was closely associated with VO2peak and/or VT in both in men and women, and the decrease in VT with age was predominantly due to an age-related decline of skeletal muscle mass[25]. Neder et al also reported that maximal oxygen uptake was related to leg muscle mass and leg strength[26]. We also previously showed oxygen uptake at VT was significantly correlated with abdominal circumference[23] and leg strength per body weight[14] in Japanese. It seems reasonable to suggest that simply improving body composition and increasing leg strength per body weight might result in the amelioration of oxygen uptake at VT in some Japanese. However, these were cross sectional studies and the hypothesis that oxygen uptake at VT is closely linked to leg strength per body weight cannot be accurately proven.

In turn, no longitudinal studies have been carried out to prove a link between oxygen uptake at VT and leg strength per body weight in Japanese. In the present study, in a cross sectional analysis, oxygen uptake at VT was significantly correlated with body composition and leg strength per body weight as previous studies[24-26]. However, in a longitudinal analysis, changes in oxygen uptake at VT were not correlated with changes in body composition parameters such as body weight, BMI, abdominal circumference, hip circumference and body fat percentage. In addition, changes in oxygen uptake at VT (per body weight) were weakly correlated with changes in leg strength per body weight in Japanese women with a 1-year follow up. Our results solely suggest the clinical significance of increasing leg strength per body weight level for increasing oxygen uptake at VT. It is difficult for subjects with lower leg strength per body weight to support the entire body's weight; and also difficult for subjects with lower leg strength per body weight to carry out aerobic exercise i.e. walking and jogging. In addition, changes in oxygen uptake at VT (per lean body mass) were also correlated with changes in leg strength per lean body mass (r=0.307). Although aerobic exercise has been advocated as most suitable for reducing fat mass and increasing aerobic exercise level, it is important for subjects with lower leg strength per body weight to maintain or maximize the muscle strength of their lower limbs as well as to carry out aerobic exercise for reducing fat mass and increasing aerobic exercise level.

Potential limitations remain in our study. First, small sample size in our study makes it difficult to infer causality between oxygen uptake at VT and leg strength per body weight. Second, we could not accurately prove the mechanism of linkage between oxygen uptake at VT and leg strength per body weight. Third, we also could not investigate the relationship between free-living daily physical activity i.e. steps per day and oxygen uptake at VT. It is well known that a reduction in free-living daily physical activity was associated with a decrease in ambulatory ability[27]. Cao et al reported that maximal oxygen uptake was significantly correlated with physical activity determined pedometer-determined step counts[28]. Further prospective studies are needed in Japanese.

In conclusion, an increase in leg strength per body weight may be associated with increasing oxygen uptake at VT and both aerobic exercise and resistance training are necessary for prevention and improvement of age-related change in Japanese women.

Acknowledgement

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フィールド・レポート

岡山県南部健康づくりセンターにおける運動施設利用の実態とその問題点

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岡山県南部健康づくりセンターは，岡山市内から南西部郊外約10kmに位置し，平成9年の事業開始以来，運動，食事，休養を健康づくりの3つの柱として，岡山県民の健康づくりにかかわってきた[1]．特に，肥満，メタボリックシンドロームの予防，改善と高齢者，障害者の健康づくりを事業の中心としている[2,3]．当センターには，岡山県民が健康づくりを運動面から実践できるように，健康度測定（体力測定など）を行なうヘルスチェック室，ジム，プール，スタジオなどがあり，日々多くの県民が利用している．

今回，平成9年以来の当センター利用者の実態を明らかにし，運動施設の利用実態とその問題点を検討した．

1. 対象と方法

当センターで，平成9年6月から平成19年3月までに，メディカルチェック（血液，尿検査），ヘルスチェック（健康度測定）を受診した男性4,651名（43.6±14.3歳），女性9,927名（42.9±14.3歳），計14,578名であった．ヘルスチェックは，当センター会員として安全に効果的に健康づくりに取り組んでもらうために必須となっており，データの解析は，データ欠損者を除きかつデータ利用についての同意が得られた男性4,410名（43.6±14.1歳），女性9,553名（42.5±14.1歳），計13,963名で，前述の期間のうちヘルスチェックを複数回受診の場合は1回目のデータを用いて平成19年4月1日の時点で行なった（表1）．

表1　本調査の対象

	男性	女性
人数	4,410	9,553
年齢（歳）	43.6±14.1	42.5±14.1
身長（cm）	169.0±6.2	156.3±5.6
体重（kg）	70.3±11.7	55.1±9.0
BMI（kg/m²）	24.6±3.7	22.6±3.6
腹囲（cm）	84.3±10.2	72.2±9.7
経過月数（月）	70.5±33.9	72.7±31.6

平均値±標準偏差

筆者：1）みやたけ　のぶゆき（岡山県南部健康づくりセンター医師）
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8）ぬまた　たけゆき（岡山県南部健康づくりセンター医師，センター長）

表２　男女別利用回数，月当たり利用回数の比較

	男性	女性	p	年齢補正後p	年齢，経過月数補正後p
利用回数（回）	49.3±142.2	36.9±115.1	<0.0001	<0.0001	<0.0001
月当たり利用回数（回/月）	1.0±2.6	0.6±1.7	<0.0001	<0.0001	<0.0001

平均値±標準偏差

調査，評価を行なった項目は，年齢，身長，体重，BMI，腹囲，1回目ヘルスチェック受診からの経過月数，当センター運動施設利用回数，運動習慣の有無（1回30分，週2回，3カ月以上継続）であった．

結果は平均値±標準偏差で表し，有意差検定は対応のないt検定，ロジスティック回帰分析を用い，有意水準5%未満を有意とした．

なお，本調査の内容については岡山県健康づくり財団倫理委員会の承認を得た．

2. 結　果

男女別に利用回数，月当たり利用回数を比較すると（表2），平均利用回数は男性49.3回で女性の36.9回に比較して有意に高値で，ロジスティック回帰分析で年齢，年齢と経過月数でそれぞれ補正しても有意であった．なお，男性の最も多い利用回数は1,711回，女性は2,160回であった．平均月当たり利用回数は男性1.0回，女性0.6回で，男性が女性に比較して月当たり利用回数が有意に高値であった．また，ロジスティック回帰分析で年齢，年齢と経過月数でそれぞれ補正しても有意であった．

男女別，年代別に月当たり利用回数を比較した結果を表3に示す．男性では60歳代，女性は50歳代が最も月当たりの利用回数が多かった．男性では20，30歳代に比較して50，60，70歳代が有意に高値を示し，60歳代は40，50歳代に比較しても有意に高値を示した．女性では20歳代に比較して40，50，60歳代が，30，40，60，70歳代に比較して50歳代が有意に高値であった．

男女別，月当たり利用回数別に人数（%）を比較すると，男女とも圧倒的に月当たり利用回数1回未満が多く，男性3,576名（81.1%），女性8,210名（85.9%）であった（表4）．なお，男性で最も多い月当たり利用回数は25.5回，女性22.1回であった．

表３　年代別月当たり利用回数の比較

	人数	月当たり利用回数
男性		
20〜29	891	0.6±1.6
30〜39	1,063	0.7±1.9
40〜49	925	1.0±2.4
50〜59	808	1.2±2.8[ab]
60〜69	570	1.8±4.0[abcd]
70〜79	153	1.5±4.3[ab]
女性		
20〜29	2,363	0.4±1.0
30〜39	2,021	0.5±1.4
40〜49	1,910	0.7±1.9[a]
50〜59	1,894	1.0±2.4[abc]
60〜69	1,148	0.7±1.9[ad]
70〜79	217	0.4±1.1[d]

a：p<0.05 vs 20〜29，b：p<0.05 vs 30〜39，c：p<0.05 vs 40〜49，d：p<0.05 vs 50〜59

1回目ヘルスチェック受診時の運動習慣の有無によるその後の利用回数，月当たり利用回数を比較したものを表5に示す．運動習慣ありと回答したのは男性1,540名（35.0%），女性2,529名（26.5%）であった．男女とも運動習慣ありの群が，なしの群に比較して有意に高値を示し，ロジスティック回帰分析を用いて年齢，年齢と経過月数でそれぞれ補正しても有意であった．

3. 考　察

今回，当センター利用者の運動施設利用実態を調査したところ，男性が女性に比較して月当たり利用回数が多く，男性では60歳代，女性では50歳代の月当たり利用回数が最も多かった．

表４　月当たり利用回数別人数

	男性 人数（%）	女性 人数（%）
0≦ ＜1	3,576 (81.1)	8,210 (85.9)
1≦ ＜2	292 (6.6)	621 (6.5)
2≦ ＜3	151 (3.4)	255 (2.7)
3≦ ＜4	95 (2.2)	134 (1.4)
4≦ ＜5	44 (1.0)	78 (0.8)
5≦ ＜6	59 (1.3)	54 (0.6)
6≦ ＜7	39 (0.9)	31 (0.3)
7≦ ＜8	18 (0.4)	29 (0.3)
8≦ ＜9	18 (0.4)	20 (0.2)
9≦ ＜10	16 (0.4)	21 (0.2)
10≦	102 (2.3)	100 (1.0)

表５　運動習慣別利用回数，月当たり利用回数の比較

	運動習慣あり	運動習慣なし	p	年齢補正後p	年齢，経過月数補正後p
男性					
人数	1,540	2,870			
利用回数（回）	69.8 ± 181.5	38.3 ± 114.2	<0.0001	<0.0001	<0.0001
月当たり利用回数（回/月）	1.3 ± 3.2	0.8 ± 2.2	<0.0001	<0.0001	<0.0001
女性					
人数	2,529	7,024			
利用回数（回）	53.7 ± 156.8	30.9 ± 95.0	<0.0001	<0.0001	<0.0001
月当たり利用回数（回/月）	0.8 ± 2.2	0.6 ± 1.6	<0.0001	0.0002	<0.0001

平均値±標準偏差

平成９年の国民栄養調査によると運動習慣者（1回30分以上の運動を週2回以上実施し，1年以上継続している人）は，男性28.6%，女性24.5%であった[4]．岡山県の平成11年県民健康調査によると，運動習慣者は男性27.1%，女性27.9%であった[5]．今回平成9年6月から平成19年3月までの間に当センターを利用した人を対象とした結果では，運動習慣者は男性35.0%，女性26.5%であった．男性は全国調査，岡山県の調査に比較して運動習慣者の割合は高く，女性ではほぼ同じ結果となった．当センター利用者は，自ら当施設に健康づくりに取り組もうとして来た人で，健康意識の高いことが予想されること，一般地域住民との関連が明らかでないこと，運動習慣の継続期間が全国調査に比較すると3カ月と短いことなどが影響していたと思われた．

運動療法，行動療法などを用いた生活習慣改善の意図的介入の報告では，継続率が比較的高い報告が多い[6~8]．われわれも以前，肥満男性を対象とした週1回90分，1年間，運動施設を利用した運動プログラムの成果を報告したが，継続率は67%であった[9]．これらの報告は，比較的強い介入を行ない，調査期間は長くても1年間である．今回のわれわれの調査対象者は自らの意思で健康づくりに取り組もうと施設利用に来所し，メディカルチェック，ヘルスチェックの結果をもとに運動指導員からアドバイスを受けた人というバイアスのある集団であるが，調査期間は長い人で約10年と長期にわたっていたことは特筆すべき点と思われた．日本における民間運動施設の会員参加率は2005年が3.02%で（http://www.fitnessclub.jp/industry/budget/industry.htm，URLは2009年4月20日現在）運動習慣者の割合に比較するとかなり少ない状況である．また，当施設での調

査からも，利用者の月当たりの利用回数は1回未満が男女とも8割を超えており，継続した施設利用がなされていなかった．特に男女とも20，30歳代の比較的若い年代の方が月当たり利用回数が低かった．これらのことから，施設を利用した運動習慣の獲得および継続の難しさがうかがわれた．一方で，今回の調査から，月当たり利用回数の多かったのは，女性よりも男性，年代別では男性60歳代，女性50歳代と中年期の人，また，最初に運動習慣ありと回答した人であった．運動施設の立地，料金，営業時間，プログラム内容などさまざまな要因はあるものの，今後，運動施設を運動習慣獲得，継続のひとつの場，手段として活用するためには，特に若い人に対する継続のためのアプローチの方法の改善，施設利用初期におけるアプローチ方法の改善などが必要と思われた．

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Original Article

Reference Data of Multi Frequencies Bioelectric Impedance Method in Japanese

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Abstract

Objective: A device of based on the multi frequencies impedance method, named the InBody720, was developed for the purpose of estimating body composition.
Methods: The performance, reliability and validity of this system were evaluated in Japanese subjects.
Results: The coefficient variation (CV: %) in same-day tests was 1.96 (body fat percentage: %), 0.62 (muscle mass: kg), 0.63 (lean body mass: kg) and 1.09 (bone mineral content: kg), in three separate-day tests it was 3.59 (body fat percentage), 1.07 (muscle mass), 1.06 (lean body mass: kg) and 1.22 (bone mineral content: kg). There was a clear correlation between the results from InBody720 and those from dual energy X-ray absorptiometry (DEXA) (body fat percentage: r=0.788, p=0.0005, muscle mass: r=0.983, p<0.0001, lean body mass: r=0.984, p<0.0001, bone mineral content: r=0.759, p=0.0010).
Conclusion: The findings indicate that this device is a highly reliable and valid method for determining body composition. This method has several advantages e.g. it is quick, simple to operate and may accommodate wide population.

KEY WORDS: impedance method, coefficient variation, dual energy X-ray absorptiometry,

Introduction

Obesity has become a public health challenge in Japan. It has been shown that a number of obese subjects have a high mortality rate [1] and have associated with atherogenic risk factors, such as hypertension, dyslipidemia, diabetes mellitus and coronary heart disease [2,3]. Recent advances in our understanding of the pathophysiology of obesity indicate that intra-abdominal or visceral adipose tissue accumulation is closely related to insulin resistance and the development of atherosclerosis [4,5]. In addition, the modern lifestyle of a high calorie diet and reduced physical activities are closely related to the increasing number of obese subjects.

It has been also well reported that there is significant loss in muscle strength with aging [6,7]. Aging is associated with alterations in body composition; there is an increase in body fat percentage and a concomitant decline in lean body mass [8]. Aging, therefore, results in substantial alterations in body composition, with a marked reduction in skeletal muscle mass. Loss of muscle strength may be an important cause of the age-related loss in bone strength resulting in osteoporosis and can also influence the ability to perform simple tasks such as sitting on a chair or visiting the toilet [9]. Taken together, precise assessments of body composition are necessary in Japanese.

Bioelectric impedance analysis (BIA) is a newly developed, noninvasive, easy, and reproducible technique to estimate the body fluid volume status [10]. In the initial developmental period of BIA, a single electric frequency system was widely used in assessing the body fat percentage in clinical practice. However, problem of large inter-individual differences because of susceptibility to water distribution was encountered. Recently, an eight-point tactile-electrode impedance-meter (multi frequencies bioelectric impedance method) was developed and made available in Korea (InBody720, Biospace, Seoul, Korea). The aim of this study was firstly to evaluate the reliability and validity of this method for the determination of Japanese body composition, and this reference data will be helpful for future assessment of age-related changes in Japanese body composition and anti-aging medicine.

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Subjects and Methods

Procedures

Body composition measurements were carried out by multi frequencies bioelectric impedance method, using eight tractile electrodes according to the manufacturer's instructions (InBody720, Biospace, Seoul, Korea). The subject stands with her or his soles in contact with the foot electrodes and grabs the hand electrodes. A pair of electrodes was placed on the surface of the thumb, palm and fingers of the hand, and ball of the foot and heel. With these electrodes, microprocessor-controlled switches and impedance analyzer were operated and segmental resistance was measured at six frequencies (1, 5, 50, 250, 500 and 1000 kHz). Thus, a set of 30 segmental resistances was measured for each individual. With these data, body fat percentage and muscle mass were calculated from the sum of each segment, using the equations in the BIA soft ware[11,12].

Experiment 1

Four men and 12 women (age: 30.3 ± 9.1 years, BMI: 21.2 ± 2.2 kg/m^2) were recruited for this study to evaluate the reliability of this method over a single day. Three measurements for each subject took place within 2 hours and the entire process was repeated by the same technician. The reliability of estimating this method was determined by calculating the standard deviation (SD) and coefficient variation (CV: %) for repeated measurements.

Experiment 2

To calculate the occurrence of variation over separate days, 15 subjects (3 men and 12 women, age: 28.7 ± 6.5 years, BMI: 20.9 ± 2.0 kg/m^2) were enrolled in this study. One measurement for each subject took place on 3 separate days and the entire process was repeated by the same technician. Reliability was determined by calculating the SD and CV for repeated measurements.

Experiment 3

To evaluate the validity of this method, 15 subjects (4 men and 11 women, age: 30.5 ± 9.4 years, BMI: 21.2 ± 2.3 kg/m^2) were recruited for this study. Body fat percentage and muscle mass were measured by InBody720 and dual energy X-ray absorptiometry (DEXA) (QDR4500, Hologic Inc., Waltham, MA, USA), which is used as accurate standard[13]. The DEXA measurement consisted of a whole body scan using an array beam[14]. Subjects removed all metal objects and were positioned in the supine position with hands placed prone on either side of the body and with legs held 10 cm apart according to the specifications of the manufacturer. All scans were analyzed according to manufacturer's instructions [15]. Each procedure was performed by the same technician. The Pearson's correlation coefficients were calculated and tested for significance of linear relationship among continuous variables.

Informed consent

All participants were provided with written informed consent and ethical approval for the study was obtained from the Ethical Committee of Okayama Health Foundation.

Results

The results of experiment 1 are shown in *Table 1*. There was no significant difference between three trials in body fat percentage, muscle mass, lean body mass and bone mineral content as measured by multi frequencies bioelectric method. The between trial CV was 1.96 in body fat percentage, 0.62 in muscle mass, 0.63 in lean body mass and 1.09 in bone mineral content. There was high reliability over a single day. We also investigated reliability on 3 separate days (*Table 2*). No significant difference was noted in the three trials for this method; the CV of these three trials was 3.59 in body fat percentage, 1.07 in muscle mass, 1.06 in lean body mass and 1.22 in bone mineral content. Thus, sufficient reliability was ascertained by the repeated procedures.

We evaluated the validity of this method for measuring body fat percentage and muscle mass, and the regression lines were shown in *Figure 1 and 2*. There were significant correlations between the results of this method and DEXA (body fat percentage: r=0.788, p=0.0005, muscle mass: r=0.983, p<0.0001). Lean body mass and bone mineral content measured by the multi frequencies impedance method were also correlated with those measured by DEXA at a significant level (lean body mass: r=0.984, p<0.0001, bone mineral content: r=0.759, p=0.0010)

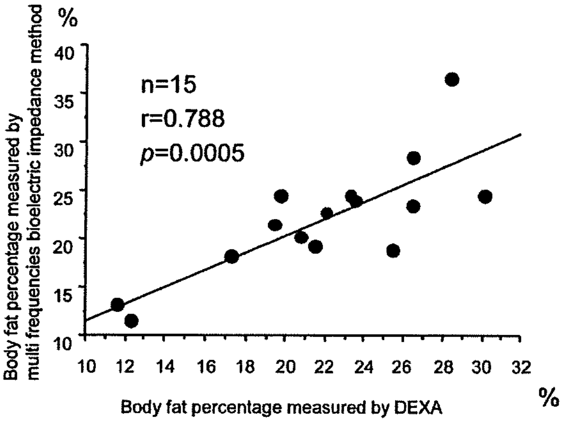

Fig. 1. Simple correlation analysis between body fat percentage measured by multi frequencies bioelectric impedance method and that measured by DEXA in body fat percentage

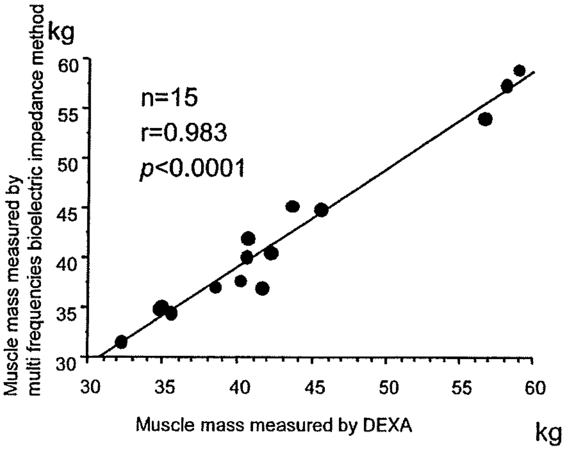

Fig. 1. Simple correlation analysis between muscle mass measured by multi frequencies bioelectric impedance method and that measured by DEXA in muscle mass

Table 1 Coefficient variation (%) of muti frequencies bioelectric impedance method within a single day

Subjects	Sex	Age	Body fat percentage(%) 1	2	3	Mean	SD	CV	Muscle mass(kg) 1	2	3	Mean	SD	CV
1	Men	55	21.4	21.5	21.5	21.5	0.1	0.27	57.3	57.3	57.2	57.3	0.1	0.10
2	Men	40	23.5	22.6	23.0	23.0	0.5	1.96	44.8	45.4	45.1	45.1	0.3	0.67
3	Women	45	19.2	19.1	19.3	19.2	0.1	0.52	41.9	41.9	41.8	41.9	0.1	0.14
4	Women	33	18.2	18.3	18.4	18.3	0.1	0.55	40.0	40.2	39.8	40.0	0.2	0.50
5	Men	31	13.2	13.2	12.8	13.1	0.2	1.77	54.0	54.0	54.2	54.1	0.1	0.21
6	Women	30	28.4	28.4	28.9	28.6	0.3	1.01	34.4	34.3	34.1	34.3	0.2	0.45
7	Women	28	22.5	22.6	22.9	22.7	0.2	0.92	36.0	35.9	35.7	35.9	0.2	0.43
8	Women	28	24.4	24.6	23.9	24.3	0.4	1.48	31.6	31.6	31.9	31.7	0.2	0.55
9	Women	27	24.3	22.9	22.6	23.3	0.9	3.90	37.6	38.3	38.1	38.0	0.4	0.95
10	Women	27	36.5	35.8	35.2	35.8	0.7	1.82	36.8	37.2	37.5	37.2	0.4	0.94
11	Women	25	23.9	23.6	23.3	23.6	0.3	1.27	40.4	40.6	40.8	40.6	0.2	0.49
12	Women	24	24.3	24.8	24.8	24.6	0.3	1.17	35.0	34.8	34.7	34.8	0.2	0.44
13	Women	24	22.6	21.2	23.0	22.3	0.9	4.24	34.8	35.3	34.7	34.9	0.3	0.92
14	Women	23	20.1	19.2	20.3	19.9	0.6	2.95	37.1	37.6	36.3	37.0	0.7	1.77
15	Men	23	11.5	11.7	10.7	11.3	0.5	4.68	58.9	58.7	58.8	58.8	0.1	0.17
16	Women	22	18.7	19.5	18.5	18.9	0.5	2.80	45.1	44.2	44.1	44.5	0.6	1.24
Mean		30.3	22.0	21.8	21.8	21.9	0.4	1.96	41.6	41.7	41.6	41.6	0.2	0.62
			Lean body mass(kg)						**Bone mineral content(kg)**					
1	Men	55	60.7	60.6	60.6	60.6	0.1	0.10	3.39	3.38	3.37	3.38	0.01	0.30
2	Men	40	47.5	48.1	47.8	47.8	0.3	0.63	2.73	2.71	2.75	2.73	0.02	0.73
3	Women	45	44.4	44.5	44.4	44.4	0.1	0.13	2.59	2.59	2.58	2.59	0.01	0.22
4	Women	33	42.4	42.6	42.1	42.4	0.3	0.59	2.36	2.40	2.34	2.37	0.03	1.29
5	Men	31	57.1	57.1	57.4	57.2	0.2	0.30	3.10	3.11	3.12	3.11	0.01	0.32
6	Women	30	36.5	36.4	36.2	36.4	0.2	0.42	2.15	2.15	2.14	2.15	0.01	0.27
7	Women	28	38.2	38.1	37.9	38.1	0.2	0.40	2.26	2.20	2.22	2.23	0.03	1.37
8	Women	28	33.6	33.6	33.9	33.7	0.2	0.51	2.00	1.98	2.02	2.00	0.02	1.00
9	Women	27	40.0	40.7	40.5	40.4	0.4	0.89	2.38	2.41	2.38	2.39	0.02	0.72
10	Women	27	39.1	39.5	39.8	39.5	0.4	0.89	2.31	2.31	2.34	2.32	0.02	0.75
11	Women	25	43.0	43.3	43.4	43.2	0.2	0.48	2.62	2.62	2.64	2.63	0.01	0.44
12	Women	24	37.2	36.9	36.9	37.0	0.2	0.47	2.16	2.15	2.15	2.15	0.01	0.27
13	Women	24	37.0	37.5	36.9	37.1	0.3	0.87	2.24	2.23	2.11	2.19	0.07	3.30
14	Women	23	39.3	39.9	38.5	39.2	0.7	1.79	2.23	2.28	2.17	2.23	0.06	2.47
15	Men	23	62.5	62.2	62.2	62.3	0.2	0.28	3.53	3.49	3.42	3.48	0.06	1.60
16	Women	22	48.0	47.0	46.8	47.3	0.6	1.36	2.85	2.78	2.72	2.78	0.07	2.34
Mean		30.3	44.2	44.3	44.1	44.2	0.3	0.63	2.56	2.55	2.53	2.55	0.03	1.09

SD: standard deviation
CV: coefficient variation

Table 2 Coefficient variation (%) of muti frequencies bioelectric impedance method over 3 separate days

Subjects	Sex	Age	Body fat percentage(%) 1	2	3	Mean	SD	CV	Muscle mass(kg) 1	2	3	Mean	SD	CV
1	Men	40	23.5	22.2	22.9	22.9	0.7	2.85	44.8	45.2	45.1	45.0	0.2	0.46
2	Women	45	19.2	20.0	18.5	19.2	0.8	3.90	41.9	41.0	42.3	41.7	0.7	1.60
3	Women	33	18.2	18.3	18.4	18.3	0.1	0.55	40.0	40.1	40.2	40.1	0.1	0.25
4	Men	31	13.2	15.7	14.8	14.6	1.3	8.69	54.0	54.9	54.6	54.5	0.5	0.84
5	Women	30	28.4	27.8	30.7	29.0	1.5	5.28	34.4	34.8	33.2	34.1	0.8	2.44
6	Women	28	22.5	22.3	22.9	22.6	0.3	1.35	36.0	36.3	36.2	36.2	0.2	0.42
7	Women	28	24.4	23.5	23.6	23.8	0.5	2.07	31.6	32.7	32.4	32.2	0.6	1.76
8	Women	27	24.3	22.0	22.6	23.0	1.2	5.19	37.6	38.2	38.2	38.0	0.3	0.91
9	Women	27	36.5	34.1	34.2	34.9	1.4	3.89	36.8	37.9	37.5	37.4	0.6	1.49
10	Women	25	23.9	24.9	24.5	24.4	0.5	2.06	40.4	40.3	40.5	40.4	0.1	0.25
11	Women	24	24.3	24.4	25.6	24.8	0.7	2.92	35.0	35.7	34.9	35.2	0.4	1.24
12	Women	24	22.6	20.9	22.1	21.9	0.9	4.00	34.8	35.4	35.0	35.1	0.3	0.87
13	Women	23	20.1	21.3	20.0	20.5	0.7	3.53	37.1	36.7	37.5	37.1	0.4	1.08
14	Men	23	11.5	11.4	10.6	11.2	0.5	4.42	58.9	59.1	59.1	59.0	0.1	0.20
15	Women	22	18.7	19.2	19.9	19.3	0.6	3.13	45.1	43.9	43.2	44.1	1.0	2.18
Mean		28.7	22.1	21.9	22.1	22.0	0.8	3.59	40.6	40.8	40.7	40.7	0.4	1.07
			Lean body mass(kg)						**Bone mineral content(kg)**					
1	Men	40	47.5	47.9	47.8	47.7	0.2	0.44	2.73	2.73	2.72	2.73	0.01	0.21
2	Women	45	44.4	43.5	44.9	44.3	0.7	1.60	2.59	2.53	2.60	2.57	0.04	1.47
3	Women	33	42.4	42.5	42.6	42.5	0.1	0.24	2.36	2.37	2.40	2.38	0.02	0.88
4	Men	31	57.1	58.2	57.8	57.7	0.6	0.96	3.10	3.24	3.20	3.18	0.07	2.27
5	Women	30	36.5	36.9	35.3	36.2	0.8	2.30	2.15	2.15	2.10	2.13	0.03	1.35
6	Women	28	38.2	38.5	38.5	38.4	0.2	0.45	2.26	2.26	2.27	2.26	0.01	0.26
7	Women	28	33.6	34.7	34.5	34.3	0.6	1.71	2.00	2.07	2.08	2.05	0.04	2.13
8	Women	27	40.0	40.6	40.6	40.4	0.3	0.86	2.38	2.39	2.41	2.39	0.02	0.64
9	Women	27	39.1	40.3	39.8	39.7	0.6	1.52	2.31	2.37	2.31	2.33	0.03	1.49
10	Women	25	43.0	42.9	43.1	43.0	0.1	0.23	2.62	2.56	2.59	2.59	0.03	1.16
11	Women	24	37.2	37.9	37.0	37.4	0.5	1.26	2.16	2.20	2.16	2.17	0.02	1.06
12	Women	24	37.0	37.7	37.2	37.3	0.4	0.97	2.24	2.24	2.28	2.25	0.02	1.02
13	Women	23	39.3	38.9	39.7	39.3	0.4	1.02	2.23	2.23	2.24	2.23	0.01	0.26
14	Men	23	62.5	62.6	62.6	62.6	0.1	0.09	3.53	3.51	3.44	3.49	0.05	1.35
15	Women	22	48.0	46.7	45.9	46.9	1.1	2.26	2.85	2.78	2.70	2.78	0.08	2.70
Mean		28.7	43.1	43.3	43.2	43.2	0.4	1.06	2.50	2.51	2.50	2.50	0.03	1.22

SD: standard deviation
CV: coefficient variation

Discussion

In this study, we assessed the reliability of multi frequencies bioelectric impedance method and conclude that this method showed high reliability. Furthermore, body fat percentage and muscle mass measured by DEXA were reproducible by this method and high validity was noted.

A number of methods have been used to attempt to measure fat mass volume, e.g. hydrostatic weighing [16] the impedance methods [10], and DEXA [13]. A commonly used standard method for the determination of body density is hydrostatic weighing [16]. Hydrostatic weighing utilizes Archimedes' principle to determine body volume by measuring the subject's weight in water compared with that in air. In this technique, the subjects are required to submerge themselves completely under water with maximal exhalation. Hydrostatic weighing is time-consuming and laborious, and it is impossible to repeat the measurements for the obese, elderly and physically handicapped populations.

DEXA is a technique applied to body composition assessment and was originally used for the measurement of total body bone mineral or the lumber spine bone mineral content [13]. It is thought to be a suitable method for in-vivo measurements. A low radiation dosage enables us to repeat the trials and was useful for monitoring the changes in body composition. However, it is expensive, bulky and is not suitable for field studies.

Although the impedance method is safe, non-invasive and rapid, and provides a sufficiently accurate estimate of human body composition in clinical investigation, it is influenced by biological functions such as the pulsatile blood flow and the total amount of water in the bodies of healthy and diseased individuals [17].

Therefore, it has thought to be less reliable and valid than other methods. Jensky-Squires et al reported that body fat percentage measured by multi frequencies bioelectric impedance method was significantly correlated with that measured by hydrostatic weighing (boy: $r=0.79$, $p<0.01$, girl: $r=0.69$, $p<0.01$) and repeatability was supported by small CV (<3.0%) [18]. In this study, the multi frequencies bioelectric impedance method was found to be a highly valid and reliable instrument for measuring human body composition. Body composition can be determined quickly, usually within 1 min. This method may be widely applicable to various populations because this system requires minimum instructions during testing. Okamoto et al also reported that usefulness of multi frequencies bioelectric impedance method in subjects with chronic hemodialysis [19]. This advantage for clinical applications is further strengthened by minimal training needed to operate this method, since it is accessible by minimal tasks i.e. operator simply push the switch button.

However, Jensky-Squires et al reported that independent t tests indicated that the InBody320 mean body fat percentage in girls was significantly different from hydrostatic weighing [18]. Volgyi et al also reported that, compared to DEXA, this method provided on average 2-6% lower values of body fat percentage in Finnish subjects with normal BMI [20]. In this study, there were no significant differences between InBody720 and DEXA in body fat percentage and muscle mass. Yonei et al measured the body composition by using bioelectric impedance method at a frequency of 50kHz (Phsyion-XP or MD, Phsyion Co., Ltd., Kyoto, Japan) in 10355 healthy Japanese [21]. Body fat amount showed an upward curve which plateau in the age range of 40 to 79 years in both sexes. Total muscle mass decreased from 30's in men and 50's in women. Although our sample size was small, we used multi frequencies bioelectric impedance method at six frequencies (1, 5, 50, 250, 500 and 1000 kHz) in this study. In addition, this method was highly reliable and valid method and the results obtained by this system were well correlated with the results measured by DEXA. This reference data will be helpful for future assessment of age-related change in Japanese body composition in clinical practice. Therefore, further clinical studies are needed for determining the usefulness of multi frequencies bioelectric impedance method in large sample of Japanese.

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Original Article

Evaluation of Muscle Strength and Its Relation to Exercise Habits in Japanese

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The aim of this study was to explore muscle strength and its relation to exercise habits in Japanese. We used data from 3,018 men and 6,881 women aged 20-69 years and not using medications in a cross-sectional study. Exercise habits and muscle strength, *i.e.* grip strength and leg strength, were measured. Age-related changes in muscle strength were noted. Exercise habits were found in 984 men (32.6%) and 1,664 women (24.2%). For subjects of both sexes over 50 years, grip strength was significantly decreased with age. However, the ratio of leg strength to body weight significantly decreased with age as early as 30 years in men and 40 years in women. Grip strength, leg strength and the ratio of leg strength to body weight in subjects with exercise habits were significantly higher than those without exercise habits after adjusting for age in both sexes. This standard mean value may provide a useful database for evaluating muscle strength in Japanese adult subjects.

Key words: exercise habits, grip strength, leg strength

Exercise is a critical measure in the prevention of lifestyle-related diseases and improvement of their symptoms. The prevalence of subjects with exercise habits in Japan was reported to be 30.2% in men and 28.1% in women by the National Nutrition Survey in Japan (http://www.mhlw.go.jp/houdou/2008/04/dl/h0430-2g.pdf accessed on July 22, 2008); this report recommended an increase to 39% in men and 35% in women with exercise habits by 2010.

It is also well known that low and declining muscle strength is associated with increased mortality, independent of physical activity and muscle mass [1]. In 2006 in Japan, levels of maximal oxygen uptake and muscle strength were recommended as exercise and physical activity reference quantity for health promotion 2006 (EPARQ2006) by the Ministry of Health, Labor and Welfare (http://www.mhlw.go.jp/shingi/2006/07/dl/s0719-3b.pdf. accessed on July 1, 2007). Although resistance training has been advocated as the most suitable exercise for increasing muscle strength [2, 3], the link between exercise habits and muscle strength in a large sample of Japanese has not yet been investigated.

We evaluated muscle strength in Japanese subjects and compared results in those with and without exercise habits.

Subjects and Methods

Subjects. We used data of 3,018 men (38.8 ± 11.9 years) and 6,881 women (39.3 ± 12.6 years), aged

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20-69 years, in a cross-sectional study. Subjects met the following criteria (Table 1): 1) they underwent an annual health check-up from June 1999 to March 2007 at Okayama Southern Institute of Health, 2) they had muscle strength and exercise habits evaluated as part of their annual health check-up, and 3) they were not taking any medications. In addition, all subjects provided written informed consent for the use of their data in the study.

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

Table 1 Number of subjects as classified by age group

Age	Men	Women
20-29	817	2,046
30-39	906	1,678
40-49	651	1,495
50-59	445	1,147
60-69	199	515
Total	3,018	6,881

Muscle strength. To assess muscle strength, grip and leg strength were measured [4]. Grip strength was measured using THP-10 (SAKAI, Tokyo, Japan), while leg strength was measured by COMBIT CB-1 (MINATO, Osaka, Japan). Isometric leg strength was measured as follows: the subject sat in a chair, grasping the armrest in order to fix the body position. A dynamometer was then attached to the subject's one ankle joint by a strap. The subject extended his or her leg to 60 degrees as described in previous reports [4, 5] which have also demonstrated good accuracy for this measurement [5]. All muscle strength measurements were recorded in 2 trials, and the better one was employed for analysis. In addition, to standardize the influence of body weight, we calculated the ratio of leg strength to body weight; a ratio of 1.0 in leg strength per body weight has been a standard in past studies [5].

Exercise habits. The data on exercise habits were obtained at interviews conducted by well-trained staff using the structured method of the National Nutrition Survey in Japan. The subjects were asked if they currently exercise (over 30 min per session, 2 times per week for a duration of 3 months). When the answer was "yes", they were classified as subjects with exercise habits. When the answer was "no", they were classified as subjects without exercise habits.

Statistical analysis. Data are expressed as means ± standard deviation (SD) values. A comparison of parameters between the 2 groups was made using the unpaired *t*-test and covariance analysis; comparisons among more than three groups were performed by ANOVA and Scheffe's F test. $P < 0.05$ was considered to indicate statistical significance.

Results

Muscle strength as classified by age group is summarized in Table 2. In men, right and left grip strengths were significantly decreased with age in subjects over 50 years. Leg strength was significantly decreased with age in subjects over 40 and the ratio of leg strength to body weight was significantly decreased with age in subjects over 30. In women, right grip strength, left grip strength and leg strength were significantly decreased with age in subjects over 50. The ratio of leg strength to body weight was significantly decreased with age in women subjects over 40.

The prevalence of subjects with exercise habits is summarized in Table 3. A total of 984 men (32.6%) and 1,664 women (24.2%) reported having exercise habits. The prevalence of subjects with exercise habits gradually increased with age, and the prevalence of exercise habits was highest for subjects in their 60's in both sexes (men, 49.2%; women, 50.1%).

We compared muscle strength in Japanese subjects with and without exercise habits. Right grip strength and left grip strength in subjects with exercise habits were similar to those in subjects without exercise habits in both sexes. Leg strength in both sexes and the ratio of leg strength to body weight in men were significantly higher for subjects with exercise habits than for those without exercise habit. However, the age of subjects with exercise habits was significantly higher than that of subjects without exercise habits. Therefore, we used age as a covariate and compared the muscle strength between Japanese with and without exercise habits using covariance analysis. All parameters of muscle strength were significantly higher in subjects with exercise habits than in those without such habits, after adjusting for age in both sexes.

We also compared muscle strength between sub-