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Original Article

Reference Data of Multi Frequencies Bioelectric Impedance Method in Japanese

Nobuyuki Miyatake [1], Akiko Tanaka [1], Miki Eguchi [1], Motohiko Miyachi [2], Izumi Tabata [2], Takeyuki Numata [1]

1) Okayama Southern Institute of Health, Okayama Health Foundation, Okayama 700-0952, Japan
2) National Institute of Health and Nutrition, Shinjuku, Tokyo 162-8636, Tokyo

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.

Nobuyuki Miyatake MD,
Okayama Southern Institute of Health, 408-1 Hirata, Okayama, 700-0952, Japan.
Tel +81-86-246-6250 / Fax +81-86-246-6330 / E-mail center@okakenko.jp (N Miyatake)

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 software[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)

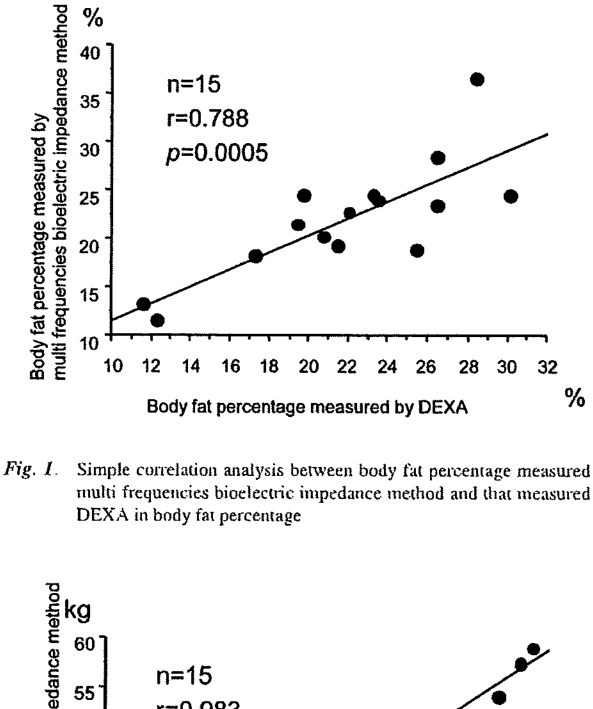

Fig. 1. Simple correlation analysis between body fat percentage measured by multi frequencies bioelectric impedance method and that measured by DEXA in body fat percentage

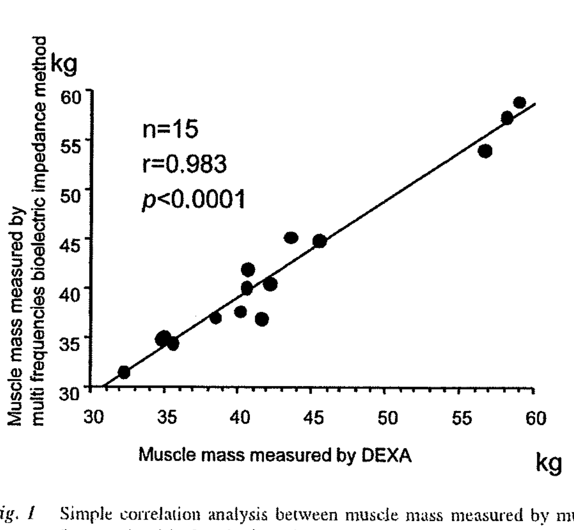

Fig. 1 Simple correlation analysis between muscle mass measured by multi frequencies bioelectric impedance method and that measured by DEXA in muscle mass

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

Nobuyuki Miyatake[a]*, Takeshi Saito[a], Motohiko Miyachi[b], Izumi Tabata[b], and Takeyuki Numata[a]

[a]*Okayama Southern Institute of Health, Okayama Health Foundation, Okayama 700-0952, Japan, and*
[b]*National Institute of Health and Nutrition, Shinjuku-ku, Tokyo 162-8636, Japan*

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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*Corresponding author. Phone:+81-86-246-6250; Fax:+81-86-246-6330
E-mail:center@okakenko.jp (N. Miyatake)

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-

Table 2 Muscle strength as classified by age group

	Men				Women			
	Mean ± SD	Minimum	Maximum	Median	Mean ± SD	Minimum	Maximum	Median
Grip strengh (right) (kg)								
20-29	46.8 ± 7.6	11.7	74.1	46.5	26.8 ± 5.2	10.3	77.6	26.7
30-39	46.6 ± 7.3	22.7	73.3	46.1	27.4 ± 4.9[a]	4.7	46.4	27.3
40-49	46.0 ± 7.5	9.8	71.6	45.4	27.7 ± 5.1[a]	6.1	52.2	27.6
50-59	42.9 ± 7.2[abc]	13.6	65.2	42.8	24.5 ± 4.8[abc]	5.3	38.6	24.5
60-69	38.2 ± 6.5[abcd]	8.7	53.7	38.7	23.0 ± 4.6[abcd]	11.8	39.9	22.8
Total	45.3 ± 7.8	8.7	74.1	45.1	26.4 ± 5.2	4.7	77.6	26.4
Grip strength (left) (kg)								
20-29	44.2 ± 7.4	11.9	68.9	43.5	25.3 ± 4.7	8.4	45.2	25.0
30-39	44.4 ± 7.1	15.4	71.3	44.2	26.1 ± 4.8[a]	8.8	44.0	25.9
40-49	44.0 ± 7.1	20.5	69.3	43.6	26.4 ± 4.8[a]	4.0	48.5	26.5
50-59	41.0 ± 6.6[abc]	14.5	59.4	41.4	23.6 ± 4.6[abc]	3.3	39.4	23.4
60-69	36.7 ± 6.4[abcd]	17.5	55.7	36.8	22.0 ± 4.3[abcd]	11.0	38.9	21.7
Total	43.1 ± 7.4	11.9	71.3	43.0	25.2 ± 4.9	3.3	48.5	25.1
Leg strength (kg)								
20-29	72.3 ± 16.7	32.1	152.0	71.0	43.3 ± 9.9	9.0	93.9	42.6
30-39	71.4 ± 16.9	31.0	161.4	69.4	43.4 ± 9.8	13.5	85.9	42.7
40-49	68.4 ± 15.5[ab]	27.0	124.4	67.3	43.4 ± 9.7	10.5	82.2	43.0
50-59	61.9 ± 14.4[abc]	27.2	109.6	62.4	40.1 ± 9.1[abc]	10.1	79.8	39.9
60-69	54.9 ± 12.5[abcd]	26.3	92.0	54.0	36.6 ± 8.3[abcd]	11.0	65.2	36.1
Total	68.1 ± 16.8	26.3	161.4	67.1	42.3 ± 9.8	9.0	93.9	41.8
Leg strength per body weight								
20-29	1.05 ± 0.22	0.48	1.80	1.04	0.83 ± 0.17	0.21	1.59	0.82
30-39	1.00 ± 0.22[a]	0.50	1.75	0.99	0.81 ± 0.18	0.28	1.55	0.80
40-49	0.96 ± 0.20[ab]	0.41	1.67	0.96	0.77 ± 0.17[ab]	0.23	1.60	0.77
50-59	0.90 ± 0.19[abc]	0.34	1.58	0.89	0.72 ± 0.16[abc]	0.23	1.45	0.71
60-69	0.84 ± 0.19[abcd]	0.42	1.49	0.83	0.68 ± 0.16[abcd]	0.21	1.23	0.67
Total	0.98 ± 0.22	0.34	1.80	0.97	0.78 ± 0.18	0.21	1.60	0.77

[a] $p<0.05$ vs age 20-29, [b] $p<0.05$ vs age 30-39, [c] $p<0.05$ vs age 40-49, [d] $p<0.05$ vs age 50-59.

Table 3 Prevalence of subjects with exercise habits in Japanese

	Exercise habits (+)		Exercise habits (−)	
Age	Number of subjects	%	Number of subjects	%
Men				
20-29	240	29.4	577	70.6
30-39	254	28.0	652	72.0
40-49	235	36.1	416	63.9
50-59	157	35.3	288	64.7
60-69	98	49.2	101	50.8
Total	984	32.6	2,034	67.4
Women				
20-29	341	16.7	1,705	83.3
30-39	297	17.7	1,381	82.3
40-49	373	25.0	1,122	75.1
50-59	395	34.4	752	65.6
60-69	258	50.1	257	49.9
Total	1,664	24.2	5,217	75.8

jects with and without exercise habits as classified by age group (Table 4). In men, right grip strength under the age of 50, left grip strength in 20's, leg strength under the age of 40 and the ratio of leg strength to body weight under the age of 50 were significantly higher in subjects with exercise habits than in those without. In women, right grip strength under the age of 40, left grip strength in 20's, 30's and 50's, leg strength in 20's, 30's and 50's, and the ratio of leg strength to body weight in 20's, 30's and 50's were significantly higher in subjects with exercise habits than in those without.

Discussion

In this study, we explored muscle strength and its

Table 4 Comparison of muscle strength between Japanese with and without exercise habits as classified by age group

	Men			Women		
Age	Exercise habits (+)	Exercise habits (−)	*p*	Exercise habits (+)	Exercise habits (−)	*p*
Grip strength (right) (kg)						
20-29	47.9 ± 7.9	46.3 ± 7.4	0.0082	27.8 ± 5.2	26.6 ± 5.2	0.0003
30-39	47.5 ± 7.4	46.3 ± 7.2	0.0300	28.1 ± 5.1	27.3 ± 4.9	0.0094
40-49	46.9 ± 7.3	45.4 ± 7.5	0.0156	28.1 ± 5.3	27.5 ± 5.0	0.0590
50-59	43.4 ± 7.2	42.7 ± 7.3	0.4444	24.9 ± 4.9	24.3 ± 4.7	0.0602
60-69	37.8 ± 6.4	38.6 ± 6.6	0.3840	23.0 ± 4.7	23.0 ± 4.5	0.9198
Grip strength (left) (kg)						
20-29	45.2 ± 7.1	43.8 ± 7.4	0.0146	25.9 ± 4.9	25.1 ± 4.6	0.0103
30-39	45.1 ± 7.5	44.1 ± 6.9	0.0520	26.8 ± 5.0	26.0 ± 4.7	0.0065
40-49	44.6 ± 6.8	43.6 ± 7.2	0.0833	26.7 ± 5.2	26.3 ± 4.7	0.1737
50-59	41.5 ± 7.0	40.8 ± 6.3	0.2822	24.0 ± 4.6	23.4 ± 4.5	0.0459
60-69	36.6 ± 6.2	36.8 ± 6.7	0.8076	21.9 ± 4.4	22.1 ± 4.1	0.7156
Leg strength (kg)						
20-29	75.4 ± 16.8	70.9 ± 16.4	0.0004	45.9 ± 10.3	42.8 ± 9.7	<0.0001
30-39	73.5 ± 17.4	70.5 ± 16.6	0.0155	45.0 ± 9.8	43.1 ± 9.8	0.0033
40-49	69.2 ± 15.4	67.9 ± 15.5	0.3057	44.0 ± 9.8	43.2 ± 9.7	0.1479
50-59	63.4 ± 14.4	61.1 ± 14.4	0.1101	40.9 ± 9.8	39.7 ± 8.7	0.0397
60-69	55.0 ± 11.3	54.8 ± 13.6	0.9202	37.0 ± 8.0	36.2 ± 8.6	0.3203
Leg strength per body weight						
20-29	1.09 ± 0.22	1.03 ± 0.22	0.0006	0.87 ± 0.18	0.82 ± 0.17	<0.0001
30-39	1.04 ± 0.24	0.99 ± 0.21	0.0013	0.85 ± 0.19	0.81 ± 0.18	0.0007
40-49	0.99 ± 0.20	0.95 ± 0.20	0.0206	0.79 ± 0.17	0.77 ± 0.17	0.0765
50-59	0.92 ± 0.20	0.89 ± 0.14	0.0658	0.74 ± 0.17	0.71 ± 0.15	0.0031
60-69	0.85 ± 0.20	0.82 ± 0.17	0.2406	0.68 ± 0.16	0.67 ± 0.16	0.3496

Mean ± SD

relation to exercise habits in Japanese. This information gathered should serve as a quite useful database for evaluating muscle strength in Japanese subjects.

The prevalence of subjects with exercise habit in Japan was reported to be 30.2% of men and 28.1% of women by the National Nutrition Survey in Japan. The definition of duration (3 months) in our study was shorter than in the survey definition, and we eliminated subjects who took medications. The subjects enrolled in our study undertook annual health checkups and they might therefore be more careful of their own health than subjects in the National Nutrition Survey. However, our results by analysis of subjects without medications were comparable to those in the survey. The prevalence of exercise habits in subjects with medications is higher than that in subjects without medications in both sexes (data not shown).

It has been 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]. In frail, institutionalized men and women, muscle strength is a determinant factor for exercise capacity; *e.g.* it is highly related to habitual walking speed. Especially, leg strength is closely related to the speed of walking up stairs, the speed of standing up from a chair, and gait speed. We have previously reported that the ratio of leg strength to body weight in subjects with metabolic syndrome was significantly lower than that in subjects without the syndrome [4] and that increasing the ratio of leg strength to body weight is important in subjects with metabolic syndrome.

In this study, age-related loss of muscle strength was noted as in previous studies using a large sample of subjects not taking any medications. Grip strength was significantly decreased with age in subjects of both sexes over the age of 50. However, the ratio of leg strength to body weight was significantly decreased with age in male subjects over 30 and female subjects over 40. Age-related changes in the ratio of leg strength to body weight were noted in young adults. It seems difficult for subjects with a low ratio of leg strength to body weight to support their entire body's weight; it also seems difficult for such subjects to perform aerobic exercise *e.g.* walking and jogging.

Although muscle strength in subjects with exercise habits was significantly higher than that in subjects without exercise habits after adjusting for age, no significant differences in muscle measurements were noted over the age of 60. According to the National Nutrition Survey in Japan, the prevalence of subjects with exercise habits increases with age, while daily step counts decrease with age (http://www.mhlw.go.jp/houdou/2008/04/dl/h0430-2g.pdf accessed on Jan 20, 2009). Lower exercise intensity and shorter exercise time in elderly adults as well as the small sample size may make it difficult to infer causality between exercise habits and muscle strength in this group. However, lower and declining muscle strength has been associated with increased mortality, independent of physical activity and muscle mass [1]. Tammelin *et al.* reported that men having a heavy physical work score had higher grip strength [10]. Fujita *et al.* also reported that activity of daily living was closely linked to grip strength in community-dwelling elderly after hip fracture [11]. Taken together, it seems reasonable to suggest that simply improving muscle strength by promoting exercise habits might result in decreased mortality in some Japanese.

Further prospective investigation studies to evaluate the relationship between exercise habits and muscle strength are needed in Japanese.

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Original Article

Body Fat Percentage Measured by Dual Energy X-ray Absorptiometry is Associated with Maximal Oxygen Uptake in Japanese

Nobuyuki Miyatake [1], Motohiko Miyachi [2], Izumi Tabata [2], Takeyuki Numata [1]

1) Okayama Southern Institute of Health, Okayama Health Foundation, Okayama 700-0952, Japan
2) National Institute of Health and Nutrition, Shinjuku, Tokyo 162-8636, Tokyo

Abstract

Objective: Both aerobic exercise level and body composition are associated with aging. In addition, lower aerobic exercise level and excess of body fat are risk for atherosclerosis. Therefore, the link between maximal oxygen uptake and anthropometric, body composition parameters was investigated.

Subjects and Methods: We used data for 300 Japanese (150 men: 44.2±14.1 years, 150 women: 44.4±14.1 years) in a cross sectional analysis. Maximal oxygen uptake was measured by breath-by-breath method and body composition was evaluated by dual energy X-ray absorptiometry (DEXA).

Results: Maximal oxygen uptake was significantly decreased with age over the age of 40. Body fat percentage measured by DEXA was significantly correlated with maximal oxygen uptake (men: $r=-0.622$, women: $r=-0.604$). In addition, the significant relationships between body fat percentage and clinical parameters *i.e.* triglyceride, high density lipoprotein (HDL) cholesterol, blood sugar, insulin and homeostasis model assessment (the HOMA index) were also noted.

Conclusion: Lower maximal oxygen uptake may be characteristic in subjects with higher body fat percentage and aerobic exercise should be recommended for preventing lifestyle-related disease.

KEY WORDS: maximal oxygen uptake, dual energy X-ray absorptiometry (DEXA), body fat percentage, abdominal circumference

Introduction

Regular physical activity has been shown to increase high density lipoprotein (HDL) cholesterol 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]. In addition, Sandvik L *et al.* reported that physical fitness was a graded, independent, long-term predictor of mortality from cardiovascular causes in healthy, middle-aged men [9].

Maximal oxygen uptake is generally considered an accurate and reliable parameter. In the Exercise and Physical Activity Reference for Health Promotion 2006, established by the Ministry of Health Labour and Welfare Japan in 2006, maximal oxygen uptake was considered to be the most significant element of physical fitness related to health promotion and the recommended reference value for maximal oxygen uptake to prevent lifestyle-related disease was reported [10]. In general, maximal oxygen uptake is considered to reduce with aging and lower maximal oxygen uptake is characteristic in subjects with lifestyle-related disease *i.e.* metabolic syndrome and also in subjects without exercise habits. Body composition *i.e.* visceral fat accumulation and excess of body fat is closely linked to metabolic syndrome and accelerated the atherosclerosis [11]. Taken together, maximal oxygen uptake may be useful marker of aging and body composition may be also useful marker of atherosclerosis. Therefore, to evaluate the relationship between maximal oxygen uptake and body composition may promise us a quite useful data for anti aging in Japanese general population.

In this study, we measured maximal oxygen uptake and its relation to anthropometric, body composition parameters in Japanese.

Nobuyuki Miyatake MD,
Okayama Southern Institute of Health
408-1, Hirata, Okayama 700-0952, Japan
Tel: +81-86-246-6250 / Fax: +81-86-246-6330 / E-mail: center@okakenko.jp (N. Miyatake)

Subjects and Methods

Subjects

We used data for 150 Japanese men and 150 Japanese women, aged 20-69 years, at Okayama Southern Institute of Health with written informed consent (***Table 1***). No subjects received any medications for diabetes, hypertension, and/or dyslipidemia.

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

Anthropometric Measurements

The anthropometric measurements were performed by using the following parameters such as height, body weight, body mass index (BMI), abdominal circumference and hip circumference. BMI was calculated by weight/[height]^2 (kg/m^2). The abdominal circumference was measured at the umbilical level and the hip circumference was measured at the widest circumferences over the trochanter in standing subjects after normal expiration [1,5].

Body Composition Measurements

Body composition was measured by dual energy X-ray absorptiometry (DEXA) (QDR4500, Hologic Inc., Waltham, MA, USA), which is used as accurate standard [12]. The DEXA measurement consisted of a whole body scan using an array beam [13]. 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 [14].

Blood Sampling and Hormone Assays

After subjects fasted overnight for 10 to 12 hours, we collected blood samples in order to determine serum levels of HDL cholesterol, triglycerides (L Type Wako Triglyceride • H, Wako Chemical, Osaka), insulin and plasma glucose. Serum insulin was measured by immunoradiometric assay (IRMA) using INSULIN RIABEAD II (DAINABOT, Tokyo, Japan). Plasma glucose was measured by using the glucose-oxidant method. The insulin resistance was evaluated using the homeostasis model assessment, the HOMA index [fasting plasma glucose (mg/dl)×fasting serum insulin (μU/ml)/405], according to the method developed by Matthews et al [15].

Blood Pressure Measurements

Blood pressure of each participant was measured after resting at least 15 minutes in the sitting position.

Exercise testing

Maximal oxygen uptake was measured using a maximal graded exercise test with bicycle ergometers (Excalibur V2.0, Lode BV, Groningen, Netherlands). The initial work load was 30-60 watt, and the work rate was increased thereafter by 15 watt/min until the subject could not maintain the required pedaling frequency (60 rpm) [16]. During the latter stages of the test, each subject was verbally encouraged by the test operators to give a maximal effort. In addition, 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). Achievement of maximal oxygen uptake was accepted if two of the following conditions were met: subject's maximal HR was > 95% age-predicted maximal HR (220 – age), and the VO_2 curve showed a leveling off.

Statistical Analysis

Data are expressed as mean ± standard deviation (SD) values. A comparison of parameters was performed by ANOVA and Scheffe's F test: $p<0.05$ was considered to be statistically significant. The Pearson's correlation coefficients were calculated to test for the significance of the linear relationship among continuous variables. Further more stepwise multiple regression analysis was performed to determine what factors correlated with maximal oxygen uptake. Statistical analysis was performed with Statview 5.0 (SAS Institute Inc., Cary, NC).

Table 1 Clinical profiles in subjects

	Men				Women			
	Mean ± SD	Minimum	Median	Maximum	Mean ± SD	Minimum	Median	Maximum
Number of subjects		150				150		
Age	44.2 ± 14.1	21.0	44.0	69.0	44.4 ± 14.1	20.0	46.0	69.0
Height (cm)	170.2 ± 5.6	158.1	170.1	187.3	157.9 ± 5.7	146.0	157.5	175.1
Body weight (kg)	66.5 ± 8.8	48.3	65.2	96.4	52.7 ± 7.5	35.3	51.8	73.4
Body mass index (kg/m^2)	23.0 ± 2.9	17.2	22.8	34.7	21.2 ± 3.0	13.3	20.6	31.3
Body fat percentage (%)	19.7 ± 5.5	8.9	19.5	34.7	26.9 ± 5.9	8.5	26.5	39.5
Body fat (kg)	13.3 ± 4.9	4.8	12.5	32.8	14.5 ± 4.5	3.2	13.5	26.6
Lean body mass (kg)	52.9 ± 5.9	39.0	52.3	75.3	38.9 ± 5.0	28.5	38.0	66.5
Muscle mass (kg)	50.6 ± 5.6	37.5	50.2	72.2	36.8 ± 5.2	11.7	36.1	63.8
Abdominal circumference (cm)	81.3 ± 8.0	63.9	80.4	104.9	76.0 ± 9.0	59.6	73.8	96.9
Hip circumference (cm)	93.5 ± 5.3	79.1	93.2	110.5	90.3 ± 5.4	76.8	90.2	108.5
Systolic blood pressure (mmHg)	130.0 ± 14.6	101.0	127.0	180.0	118.8 ± 15.3	89.0	117.5	162.0
Diastolic blood pressure (mmHg)	80.6 ± 10.8	48.0	80.0	111.0	72.3 ± 10.9	52.0	71.0	97.0
Blood sugar (mg/dl)	93.1 ± 9.9	61.0	92.0	146.0	88.3 ± 8.9	59.0	87.0	133.0
Triglyceride (mg/dl)	99.5 ± 57.6	33.0	83.0	434.0	72.3 ± 41.2	24.0	61.0	298.0
Log triglyceride (mg/dl)	1.94 ± 0.21	1.51	1.92	2.63	1.80 ± 0.20	1.38	1.79	2.47
HDL cholesterol (mg/dl)	57.4 ± 16.4	31.0	54.5	149.0	68.3 ± 14.3	40.0	69.0	103.0
Insulin (mU/ml)	5.1 ± 3.3	0.7	4.2	28.2	4.4 ± 2.0	0.5	4.2	16.1
HOMA index	1.2 ± 0.9	0.2	0.9	7.2	1.0 ± 0.5	0.1	0.9	4.0
Maximal oxygen uptake (ml/kg/min)	37.2 ± 8.7	16.5	35.5	61.9	30.8 ± 6.7	17.6	30.2	49.8
Maximal work rate (watt)	200.5 ± 49.1	91.0	196.0	354.0	141.2 ± 34.2	80.0	136.0	260.0
Maximal heart rate (beat/min)	178.4 ± 23.3	106.0	197.5	230.0	172.8 ± 17.9	117.0	173.0	214.0

Results

Maximal oxygen uptake as classified into age groups was summarized in ***Table 2***. Maximal oxygen uptake was significantly decreased with age over the age of 40 in both sexes.

We evaluated the relationship between maximal oxygen uptake and clinical parameters *i.e.* age, anthropometric and body composition parameters (***Table 3***). Maximal oxygen uptake was significantly correlated with age (men: r=−0.559, women: r=−0.549). Maximal oxygen uptake was negatively correlated with body weight, BMI, body fat percentage, body fat and abdominal circumference and positively correlated with lean body mass and muscle mass in both sexes. In women, weak relationship between maximal oxygen uptake and hip circumference was also noted. Correlation coefficient rate between maximal oxygen uptake and body fat percentage was highest (men: r=−0.622, women: r=−0.604) (***Figure 1***). Single regression lines were expressed as follows [men: y (maximal oxygen uptake: ml/kg/min) = 56.609 − 0.983x (body fat percentage: %), women: y = 49.208 − 0.685x]. We also used stepwise multiple regression analysis to evaluate the effect of anthropometric, body composition parameters on maximal oxygen uptake and we found that body weight, body fat percentage and abdominal circumference was independently related to maximal oxygen uptake at a significant level in both sexes [men: (maximal oxygen uptake)=71.407+0.461(body weight)−0.671(body fat percentage)−0.634(abdominal circumference), r^2=0.512, p<0.001, women: (maximal oxygen uptake)=51.747+0.343(body weight)−0.584(body fat percentage)−0.307(abdominal circumference), r^2=0.444, p<0.0001].

To exclude the effect of aging on both maximal oxygen uptake and body fat percentage, we further evaluated the relationship between maximal oxygen uptake and body fat percentage as classified by age group (***Table 4***). Significant relationships between maximal oxygen uptake and body fat percentage, except 20's in women, were noted.

Table 2 ***Maximal oxygen uptake (ml/kg/min) as classified into age groups***

	Men					Women				
Age	Number of subjects	Mean ± SD	Minimun	Median	Maximum	Number of subjects	Mean ± SD	Minimun	Median	Maximum
20-29	30	44.0 ± 9.0	28.3	45.8	61.9	30	36.1 ± 7.8	17.6	35.2	49.8
30-39	30	40.2 ± 7.2	26.2	41.3	50.3	30	32.5 ± 5.4	22.7	33.1	41.4
40-49	30	36.8 ± 8.2 a	23.7	36.9	54.4	30	31.4 ± 5.3 a	21.8	30.6	45.2
50-59	31	34.1 ± 6.9 ab	16.5	32.9	48.8	30	28.5 ± 5.6 a	18.1	28.0	39.5
60-69	29	30.8 ± 6.1 ab	17.2	31.5	45.2	30	25.6 ± 4.3 abc	18.7	25.1	35.9

a: p<0.05 vs age 20-29 b: p<0.05 vs age 30-39 c: p<0.05 vs age 40-49

Table 3 ***Simple correlation analysis between maximal oxygen uptake and anthropmetric, body composition parameters***

	Men		Women	
	r	p	r	p
Age	−0.559	**<0.0001**	−0.549	**<0.0001**
Body weight (kg)	−0.169	**0.0392**	−0.174	**0.0328**
Body mass index (kg/m²)	−0.287	**0.0004**	−0.360	**<0.0001**
Body fat percentage (%)	−0.622	**<0.0001**	−0.604	**<0.0001**
Body fat (kg)	−0.544	**<0.0001**	−0.519	**<0.0001**
Lean body mass (kg)	0.205	**0.0119**	0.205	**0.0119**
Muscle mass (kg)	0.192	**0.0184**	0.169	**0.0390**
Abdominal circumference (cm)	−0.560	**<0.0001**	−0.488	**<0.0001**
Hip circumference (cm)	−0.152	0.0640	−0.205	**0.0118**

Table 4 ***Simple correlation analysis between maximal oxygen uptake and body fat percentage as classified by age group***

	Men		Women	
	r	p	r	p
20-29	−0.814	**<0.0001**	−0.084	0.6584
30-39	−0.545	**0.0019**	−0.514	**0.0036**
40-49	−0.726	**<0.0001**	−0.808	**<0.0001**
50-59	−0.564	**0.0010**	−0.737	**<0.0001**
60-69	−0.446	**0.0154**	−0.667	**<0.0001**

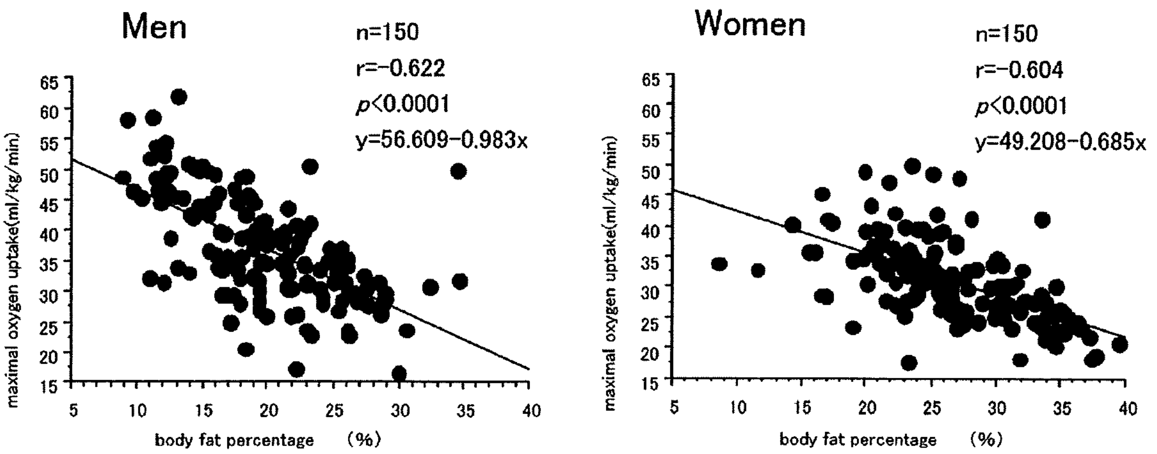

Fig. 1. Simple correlation analysis between maximal oxygen uptake and body fat percentage measured by DEXA in Japanese.

We investigated the link between body fat percentage measured by DEXA and clinical parameters (***Table 5***). Body fat percentage was weakly correlated with triglyceride, log triglyceride, HDL cholesterol, blood sugar, insulin and the HOMA index in both sexes. In women, body fat percentage was also weakly correlated with systolic and diastolic blood pressure.

It is well known that abdominal obesity is closely linked to hypertension, dyslipidemia and glucose intolerance. Therefore, we also investigated the link between abdominal circumference and clinical parameters (***Table 6***). Abdominal circumference was also weakly correlated with triglyceride, log triglyceride, HDL cholesterol, blood sugar, insulin and the HOMA index in both sexes. In women, abdominal circumference was weakly correlated with systolic blood pressure. However, correlation coefficient rates between body fat percentage measured by DEXA and clinical parameters, except blood sugar in men, were higher than those between abdominal circumference and clinical parameters.

Table 5 Simple correlation analysis between body fat percentage and clinical parameters

	Men		Women	
	r	p	r	p
Systolic blood pressure (mmHg)	0.080	0.3310	0.257	**0.0015**
Diastolic blood pressure (mmHg)	0.039	0.6325	0.165	**0.0442**
Blood sugar (mg/dl)	0.207	**0.0111**	0.289	**0.0003**
Triglyceride (mg/dl)	0.333	**<0.0001**	0.383	**<0.0001**
Log troglyceride (mg/dl)	0.381	**<0.0001**	0.428	**<0.0001**
HDL cholesterol (mg/dl)	−0.311	**0.0001**	−0.264	**0.0011**
Insulin (mU/ml)	0.390	**<0.0001**	0.445	**<0.0001**
HOMA index	0.373	**<0.0001**	0.458	**<0.0001**

Table 6 Simple correlation analysis between abdominal circumference and clinical parameters

	Men		Women	
	r	p	r	p
Systolic blood pressure (mmHg)	0.140	0.0881	0.254	**0.0017**
Diastolic blood pressure (mmHg)	0.075	0.3614	0.089	0.2806
Blood sugar (mg/dl)	0.283	**0.0005**	0.229	**0.0049**
Triglyceride (mg/dl)	0.306	**0.0001**	0.279	**0.0006**
Log troglyceride (mg/dl)	0.335	**<0.0001**	0.320	**<0.0001**
HDL cholesterol (mg/dl)	−0.311	**0.0001**	−0.207	**0.0110**
Insulin (mU/ml)	0.348	**<0.0001**	0.354	**<0.0001**
HOMA index	0.360	**<0.0001**	0.372	**<0.0001**

Discussion

In this study, maximal oxygen uptake was closely linked to body fat percentage measured by DEXA in Japanese.

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 [12]. 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 *i.e.* body fat percentage and muscle mass. However, it is expensive, bulky and is not suitable for field studies.

It has been well reported that there is significant loss in oxygen uptake at ventilatory threshold (VT), which is also considered accurate and reliable parameter of aerobic exercise level [17], with aging [18,19]. Miura reported that oxygen uptake at VT was significantly correlated with age (men: r=−0.626, women: r=−0.578) in 610 Japanese [18]. Sanada *et al* reported that negative correlation was noted between oxygen uptake at VT and age in 1463 Japanese [19]. There are few reports of maximal oxygen uptake, which was directly measured, in healthy Japanese. Ohta *et al* reported that maximal oxygen uptake was significantly decreased with age in 832 apparently healthy subjects [20] and single regression formula were y (ml/kg/min) = 46.6 − 0.36×age (r=0.447) in men and y = 35.3 − 0.23×age (r=0.407) in women. In this study, age-related decreasing of maximal oxygen uptake was noted as previous studies in Japanese without taking any medications. This mean value also promises us one of quite useful database for evaluating maximal oxygen uptake in Japanese subjects.

In some literature, the relationship between maximal oxygen uptake and body composition was reported. Significant relationships between maximal oxygen uptake and body fat percentage were noted in Japanese junior high school boys and girls [21], Danish women [22] and African-American adolescents [23]. Although we could not infer causality between maximal oxygen uptake and body fat percentage, an excess of body fat, which is expressed as body fat percentage (%), may be an excess weight and plays a critical role for determining maximal oxygen uptake. In this study, we found that body fat percentage measured by DEXA was closely linked to maximal oxygen uptake. In addition, the correlation coefficient rates between body fat percentage and clinical parameters of blood examination were higher than those between abdominal circumference and clinical parameters. These suggest that body fat percentage measured by DEXA may be one of good predictor for estimating maximal oxygen uptake in Japanese.

Potential limitations still remain in this study. First, we could not demonstrate the mechanism the link between maximal oxygen uptake and body fat percentage measured by DEXA. Second, we have previously reported that visceral adipose tissue area was negatively correlated with oxygen uptake at VT (r=−0.400) [24] and we could not directly measure visceral fat area by computed tomography (CT) in this study. Although correlation coefficient rate between maximal oxygen uptake and body fat percentage measured by DEXA was higher than that between maximal oxygen uptake and abdominal circumference and that between oxygen uptake at VT and visceral fat area in our previous report, comparison between body fat percentage measured by DEXA and visceral fat area directly measured by CT is urgently required to determine what factors correlated with maximal oxygen uptake. Third, body fat percentage measured by DEXA is less feasible for use in certain clinical applications because of the cost of and technical requirements for its use. Therefore, the relationship between maximal oxygen uptake and body fat percentage measured by other method *i.e.* impedance method also must be evaluated.

In conclusion, we found that body fat percentage measured by DEXA was closely related to maximal oxygen uptake. Lower aerobic exercise level may be characteristic in subjects with higher body fat percentage and aerobic exercise should be recommended. Maximal oxygen uptake may be important marker for preventing and improving lifestyle-related disease in addition to aging and aerobic exercise level.

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INTERNAL MEDICINE

□ ORIGINAL ARTICLE □

Changes in Metabolic Syndrome and Its Components with Lifestyle Modification in Japanese Men

Nobuyuki Miyatake[1], Masafumi Fujii[2], Motohiko Miyachi[3], Izumi Tabata[3], Suzue Takeshi[4], Tomohiro Hirao[4] and Takeyuki Numata[5]

Abstract

Objective Changes in metabolic syndrome and its components with lifestyle modification were evaluated in Japanese men.

Methods We used data for 160 Japanese men (45.6±8.8 years) with a 1-year follow up. Anthropometric, blood examination and blood pressure measurements were evaluated. Metabolic syndrome was defined by using a criterion in Japan. All subjects were given instructions by well-trained medical staff on how to change their lifestyle.

Results With a 1-year follow-up, anthropometric parameters, blood pressure (BP), triglyceride and HDL cholesterol were significantly improved and the prevalence of metabolic syndrome was significantly reduced. The number of subjects with abdominal obesity at baseline and at follow-up was higher (81 men) than that of subjects with other components at baseline and at follow-up. Parameters at baseline were significantly correlated with changes in parameters for one year. With lifestyle modification, the level of 163 mmHg in systolic BP (SBP), 115 mmHg in diastolic BP (DBP), 226 mg/dL in triglyceride and 33 mg/dL in HDL cholesterol at baseline was estimated to improve to the level without medications with a 1-year follow up.

Conclusion Lifestyle modification is useful for improving metabolic syndrome and its components. However, items of metabolic syndrome were improved, even when the abdominal circumference was greater than the normal value for Japanese men.

Key words: lifestyle modification, metabolic syndrome, blood pressure

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Introduction

Metabolic syndrome, characterized by abdominal obesity, has become a public health challenge and common disorder in Japan (1). For example, we have previously described that 30.7% of men and 3.6% of women were diagnosed as having the metabolic syndrome (2). Metabolic syndrome is closely related to elevated hepatic enzymes (3), uric acid (4), reduced exercise capacity (5, 6) and cardiovascular disease (7). Therefore, proper management of metabolic syndrome is urgently required.

The recommendation for medication for hypertension is based on the following from the Japanese Society of Hypertension (http://www.jpnsh.org/, accessed on June 15, 2009.): blood pressure (BP)≧140/90 mmHg, dyslipidemia is defined as triglyceride≧150 mg/dL, LDL cholesterol≧140 mg/dL, HDL cholesterol<40 mg/dL from the Japan Atherosclerosis Society (http://jas.umin.ac.jp/, accessed on July 15, 2009) and diabetes mellitus≧126 mg/dL in fasting plasma glucose from the Japan Diabetes Society (http://www.jds.or.jp/, accessed on July 15, 2009). In addition, lifestyle modification has been considered as useful and an essential method for preventing and improving these disorders. However, whether a lifestyle modification is beneficial for improving metabolic syndrome and its components, and what

[1]Department of Hygiene, Faculty of Medicine, Kagawa University, Kagawa, [2]Department of Health Care Medicine, Kawasaki University Medical School, Kurashiki, [3]National Institute of Health and Nutrition, Tokyo, [4]Department of Public Health, Faculty of Medicine, Kagawa University, Kagawa and [5]Okayama Southern Institute of Health, Okayama Health Foundation, Okayama
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Correspondence to Dr. Nobuyuki Miyatake, miyarin@med.kagawa-u.ac.jp

Table 1. **Clinical Profiles and Changes in Parameters with Lifestyle Modification with a 1-year Follow Up in Japanese Men**

	Baseline	Follow up	p
Number of subjects	160		
Age	45.6 ± 8.8		
Height (cm)	168.7 ± 5.5		
Body weight (kg)	74.9 ± 11.1	73.5 ± 10.2	<0.0001
Body mass index (kg/m^2)	26.3 ± 3.7	25.8 ± 3.3	<0.0001
Abdominal circumference (cm)	88.2 ± 9.9	86.5 ± 9.1	<0.0001
Hip circumference (cm)	96.7 ± 5.7	95.9 ± 5.2	<0.0001
SBP (mmHg)	130.8 ± 14.8	123.4 ± 12.4	<0.0001
DBP (mmHg)	82.5 ± 10.9	77.5 ± 9.3	<0.0001
Triglyceride (mg/dL)	145.2 ± 94.0	119.8 ± 76.5	0.0005
HDL cholesterol (mg/dL)	50.1 ± 14.4	56.1 ± 15.1	0.0109
Blood sugar (mg/dL)	102.0 ± 19.2	102.4 ± 25.6	0.7478

Mean ± SD
SBP: Systolic blood pressure
DBP: Diastolic blood pressure

effects such a modification has on metabolic syndrome and its components remain to be investigated in a longitudinal analysis. In this study, we evaluated the effect of lifestyle modification on metabolic syndrome and its components in Japanese men with a 1-year follow up.

Subjects and Methods

Subjects. We used data for 160 Japanese men, aged 45.6±8.8 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).

In 2008, the Ministry of Health, Labor, and Welfare of Japan started to undertake a specific health check-up and special health guidance for preventing lifestyle-related diseases (http://www.mhlw.go.jp/bunya/shakaihosho/iryouseido01/info02a.html, accessed on Oct 11, 2009). At the first annual health check-up, all subjects were given instructions by well-trained medical staff on how to change their lifestyle as the special health guidance. Nutritional instruction was provided with a well-trained nutritionist, who planned the diet for each subject based on their data and provided simple instructions (i.e. not to eat too much and to consider balance when they eat). Exercise instruction was also provided by a well-trained physical therapist, who encouraged each subject to increase their daily amount of steps walked. At the second health check-up, medical staff subjectively evaluated changes in their lifestyle and the subjects with an evaluation of over the level of recommendation for medications were encouraged to receive medications.

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 and hip circumference. 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 circumference over the trochanter in standing subjects after normal expiration (8).

BP measurements at rest. Resting systolic and diastolic BP (SBP and DBP) were measured indirectly using a mercury sphygmomanometer placed on the right arm of the seated participant after at least 15 minutes of rest.

Blood sampling and 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.

Definition of metabolic syndrome. Men with a waist circumference in excess of 85 cm were defined as having metabolic syndrome if they also had two or more of the following components: 1) Dyslipidemia: triglycerides≧150 mg/dL and/or HDL cholesterol<40 mg/dL, 2) High blood pressure: blood pressure≧130/85 mmHg, 3) Impaired glucose tolerance: fasting plasma glucose≧110 mg/dL (1).

Statistical analysis. All data are expressed as mean ± standard deviation (SD) values. A statistical analysis was performed using a paired t test and χ^2 test: $p<0.05$ was considered to be statistically significant. Simple correlation analysis was used to test the significance of the linear relationship among continuous variables.

Results

Clinical profiles and changes in parameters with lifestyle modification are summarized in Table 1. Body weight, BMI, abdominal circumference and hip circumference were significantly reduced after one year. SBP, DBP and triglyceride were also significantly reduced and HDL cholesterol was significantly increased with lifestyle modification. However, blood glucose at baseline was similar to that at follow up, and abdominal circumference was over the level of 85 cm at follow up.

We also evaluated the changes in prevalence of metabolic syndrome and its components (Table 2). Prevalence of metabolic syndrome and its components i.e. abdominal obesity, hypertension, dyslipidemia and impaired glucose tolerance was significantly reduced with a 1-year follow up. The number of subjects with abdominal obesity [81 men (50.6%)] at

Table 2. **Changes in Metabolic Syndrome and Its Components with Lifestyle Modification after One Year**

		Follow up		p
		Abdominal circumference (−)	Abdominal circumference (+)	
	Abdominal circumference (−)	54	7	<0.0001
	Abdominal circumference (+)	18	81	
		Hypertension (−)	Hypertension (+)	
	Hypertension (−)	53	11	<0.0001
	Hypertension (+)	48	48	
		Dyslipidemia (−)	Dyslipidemia (+)	
Baseline	Dyslipidemia (−)	88	9	<0.0001
	Dyslipidemia (+)	32	31	
		Impaired glucose tolerance (−)	Impaired glucose tolerance (+)	
	Impaired glucose tolerance (−)	129	3	<0.0001
	Impaired glucose tolerance (+)	8	20	
		Metabolic syndrome (−)	Metabolic syndrome (+)	
	Metabolic syndrome (−)	110	5	<0.0001
	Metabolic syndrome (+)	25	20	

Table 3. **Simple Correlation Analysis between Parameters at Baseline and Changes in Parameters with Lifestyle Modification with a 1-year Follow Up**

	r	p	Single regression line	Recommendation for medication	Baseline level without medications calculated by formula
SBP (mmHg)	−0.596	<0.0001	y=−0.492x+56.951	y+x=140	163
DBP (mmHg)	−0.626	<0.0001	y=−0.618x+45.959	y+x=90	115
Triglyceride (mg/dL)	−0.654	<0.0001	y=−0.626x+54.488	y+x=150	226
HDL cholesterol (mg/dL)	−0.270	0.0005	y=−0.187x+12.101	y+x=39	33
Blood sugar (mg/dL)	0.052	0.5118			

y: changes in parameters
x: parameters at baseline

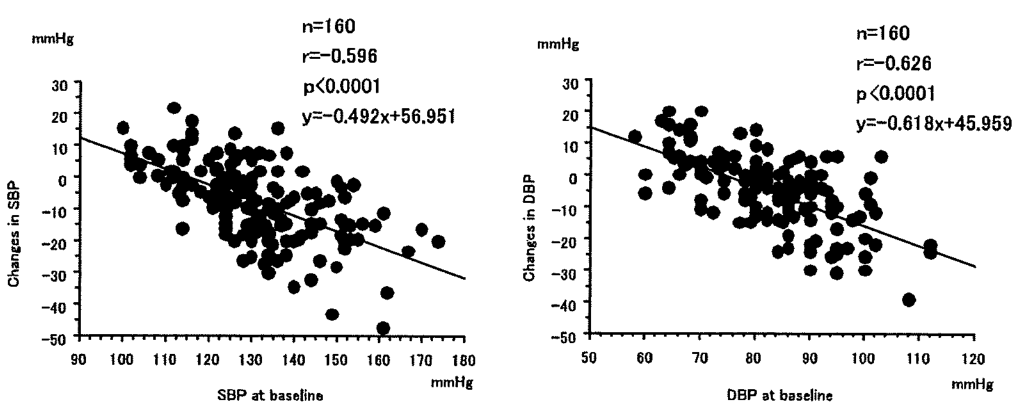

Figure 1. **Simple correlation analysis between BP at baseline and changes in BP with a 1-year follow-up in Japanese men.**

baseline and at follow up was higher than that of subjects with other components [hypertension: 48 men (30.0%), dyslipidemia: 31 men (19.4%), impaired glucose tolerance: 20 men (12.5%)]at baseline and at follow up. Therefore, abdominal obesity was persisted but metabolic parameters were improved.

We further investigated the link between parameters at baseline and changes in parameters (Table 3, Fig. 1). SBP, DBP, Triglyceride and HDL cholesterol at baseline were significantly correlated with changes in each parameter. The recommendation for medications was 140 mmHg in SBP, 90 mmHg in DBP, 150 mg/dL in triglyceride, 39 mg/dL in HDL cholesterol and 126 mg/dL in fasting plasma glucose. Therefore, the baseline level without medications was calculated by single regression line. The level of 163 mmHg in SBP, 115 mmHg in DBP, 226 mg/dL in triglyceride and 33 mg/dL in HDL cholesterol at baseline was estimated to improve to the level without medications with a 1-year follow up.

Discussion

In this study, the prevalence of metabolic syndrome and its components was significantly reduced with lifestyle modification with a 1-year follow up. In addition, the metabolic parameters were improved without normalized abdominal circumference.

There are some reports that show the link between lifestyle modification and metabolic syndrome and its components in a longitudinal analysis. 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 (9). 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 (10). The Kuopio Ischemic Heart Disease Risk Factor Study (11) 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. Muzio et al reported that metabolic syndrome was effectively treated by long-term diet (~500 calorie/day deficit) and lifestyle therapy alone in 37% of obese, nondiabetic patients (12). 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, $\dot{V}O_2$max 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 ($p<0.001$) (13). In this study, although the difference of blood sugar between at baseline and at follow up was not noted, we found that the prevalence of metabolic syndrome and its components including impaired glucose tolerance was significantly reduced with lifestyle modification after one year. Abdominal obesity, which is one of the targets for management of metabolic syndrome, was not improved to the normal range. However, the metabolic parameters were improved without normalized abdominal circumference. The diagnosis of metabolic syndrome is a caution for the general people to be careful in the healthy life, and these are not criteria for diagnosis of a definite disease to be treated with drug administration or with specific medication (14, 15). Taken together, these changes in metabolic components with lifestyle modification would be expected to reduce the risk of cardiovascular diseases or glucose metabolism.

The Japan Society of Hypertension recommends that lifestyle modification is essential for improving hypertension and medications should be considered after one or three months' lifestyle modification in subjects with low or moderate risk. Medications are immediately recommended in subjects with high risk (http://www.jpnsh.org/, accessed on June 15, 2009).

The Japan Atherosclerosis Society and the Japan Diabetes Society also recommended that lifestyle modification is essential in the first place. We explored that the clinical parameters i.e. BP, triglyceride and HDL cholesterol at baseline were closely correlated with changes in these parameters in subjects without medications with a 1-year follow up. In addition, by using single regression line and the recommendation for medications, the baseline level of parameters without medications was calculated. The level of 163 mmHg in SBP, 115 mmHg in DBP, 226 mg/dL in triglyceride and 33 mg/dL in HDL cholesterol at baseline was estimated to improve to the level without medications after one year. Through the concept of metabolic syndrome, the significance of encouraging a reduction of abdominal obesity by lifestyle modification as the first step for the management of individuals with abdominal obesity has become strengthened (14). Although these results may be affected by higher values and limited in the difference of parameters, the estimated level in this study may be one of reference data for improving metabolic syndrome with lifestyle modification in preference to medications in some Japanese men. Further intervention studies are necessary to test the effect of lifestyle modification on metabolic syndrome.

Potential limitations still remain in this study. First, the selected 160 subjects underwent an annual health check-up every year with a follow-up duration of 1-year and received no medication; they were, therefore, probably more health-conscious than most of the average person. Second, the small sample size makes it difficult to infer causality between lifestyle modification and metabolic syndrome. Third, blood sugar did not significantly reduce and blood sugar at baseline was not also associated with changes in blood sugar with a 1-year follow up. These results suggest that an improvement of metabolic risk factors may be different according to the level of lifestyle modification.

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