

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

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

VT: ventilatory threshold.

<sup>a</sup>  $P < 0.01$  vs. exercise habits (+).

<sup>b</sup>  $P < 0.05$  vs. exercise habits (+).

#### 4. Discussion

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

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

Regular physical activity has been linked to increases in HDL and reductions in resting blood pressure, triglycerides, abdominal fat, fasting glucose levels, and insulin responses to oral glucose challenge [14–16]. In several reports in the cross sectional study, metabolic syndrome was significantly correlated with physical fitness [17–19]. However, the hypothesis that metabolic syndrome may be caused by lower oxygen uptake at VT cannot be proven in our current cross-sectional design. The Kuopio Ischemic Heart Disease Risk Factor Study [20] followed several hundred men who did not have metabolic syndrome at baseline. Four years later, subjects in the upper one-third of  $VO_2$ max at baseline were 75% less likely than unfit men to develop

metabolic syndrome. Katzmarzyk et al. reported that the effects of 20 weeks supervised aerobic training program on the prevalence of the metabolic syndrome in 621 men and women who were enrolled in the Heritage Study. After exercise intervention, 30.5% of the participants with metabolic syndrome at baseline were no longer classified as having metabolic syndrome [21]. Ekelund et al. reported that physical activity energy expenditure predicts progression toward the metabolic syndrome independent of aerobic fitness, obesity, and other confounding factors by observation of 5.6 years [22]. In our study, oxygen uptake at VT in men with metabolic syndrome was significantly lower than that in men without metabolic syndrome, even after adjusting for BMI. Oxygen uptake at VT in subjects with sub criterion of metabolic syndrome was also significantly lower than that in subjects without sub criterion of metabolic syndrome. In addition, the number of subjects with exercise habits was significantly lower in metabolic syndrome and the subjects with exercise habits had higher oxygen uptake at VT. It may be hard to clarify the mechanisms as to why the exercise habits are linked to higher oxygen uptake at VT and beneficial for preventing the metabolic syndrome. Although the mechanism is not well-understood, we previously reported that the education program, in which we instructed overweight Japanese men to increase daily step per day and join a weekly exercise course, resulted in increased oxygen uptake at VT and reduced visceral fat area [5].

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

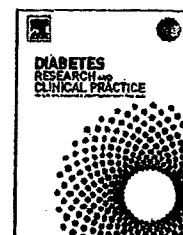
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#### References

- [1] Definition and the diagnostic standard for metabolic syndrome—Committee to Evaluate Diagnostic Standards for Metabolic

- Syndrome, *Nippon Naika Gakkai Zasshi* 94 (2005) 794–809 (in Japanese).
- [2] N. Miyatake, Y. Kawasaki, H. Nishikawa, S. Takenami, T. Numata, Prevalence of metabolic syndrome in Okayama prefecture, Japan, *Intern. Med.* 45 (2006) 107–108.
- [3] K. Wasserman, B.J. Whipp, S.N. Koyl, W.L. Beaver, Anaerobic threshold and respiratory gas exchange during exercise, *J. Appl. Physiol.* 35 (1973) 236–243.
- [4] K.T. Weber, J.S. Janicki, Cardiopulmonary exercise testing for evaluation of chronic cardiac failure, *Am. J. Cardiol.* 55 (1985) 22–31.
- [5] N. Miyatake, J. Wada, K. Takahashi, H. Nishikawa, A. Morishita, H. Suzuki, et al., Changes in serum leptin concentrations in overweight Japanese men after exercise, *Diabetes Obes. Metab.* 6 (2004) 332–337.
- [6] The Examination Committee of Criteria for 'Obesity Disease' in Japan; Japan Society for the Study of Obesity, New criteria for 'obesity disease' in Japan, *Circ. J.* 66 (2002) 987–992.
- [7] N.L. Jones, L. Makrides, C. Hitchcock, T. Chypchar, N. McCartney, Normal standards for an incremental progressive cycle ergometer test, *Am. Rev. Respir. Dis.* 131 (1985) 700–708.
- [8] J.A. Davis, M.H. Frank, B.J. Whipp, K. Wasserman, Anaerobic threshold alterations caused by endurance training in middle-aged men, *J. Appl. Physiol.* 46 (1979) 1039–1046.
- [9] W.L. Beaver, K. Wasserman, B.J. Whipp, A new method for detecting anaerobic threshold by gas exchange, *J. Appl. Physiol.* 60 (1986) 2020–2027.
- [10] The National Nutrition Survey in Japan, Available from <http://www.mhlw.go.jp/houkoku/2005/04/h0421-1b.html> (accessed June 1, 2006) (in Japanese).
- [11] S.M. Haffner, R.A. Valdez, H.P. Hazuda, B.D. Mitchell, P.A. Morales, M.P. Stern, Prospective analysis of the insulin-resistant syndrome (syndrome X), *Diabetes* 41 (1992) 715–722.
- [12] B. Isomaa, P. Almgren, T. Tuomi, B. Forsen, K. Lahti, M. Nissen, et al., Cardiovascular morbidity and mortality associated with the metabolic syndrome, *Diabetes Care* 24 (2001) 683–689.
- [13] H.M. Lakka, D.E. Laaksonen, T.A. Lakka, L.K. Niskanen, E. Kumppusalo, J. Tuomilehto, et al., The metabolic syndrome and total and cardiovascular disease mortality in middle-aged men, *JAMA* 288 (2002) 2709–2716.
- [14] N. Miyatake, K. Takahashi, J. Wada, H. Nishikawa, A. Morishita, H. Suzuki, et al., Daily exercise lowers blood pressure and reduces visceral fat in overweight Japanese men, *Diabetes Res. Clin. Pract.* 62 (2003) 149–157.
- [15] N. Miyatake, H. Nishikawa, A. Morishita, M. Kunitomi, J. Wada, H. Suzuki, et al., Daily walking reduces visceral adipose tissue areas and improves insulin resistance in Japanese obese subjects, *Diabetes Res. Clin. Pract.* 58 (2002) 101–107.
- [16] R.J. Barnard, E.J. Ugianskis, D.A. Martin, S.B. Inkeles, Role of diet and exercise in the management of hyperinsulinemia and associated atherosclerotic risk factors, *Am. J. Cardiol.* 69 (1992) 440–444.
- [17] S. Carroll, C.B. Cooke, R.J. Butterly, Metabolic clustering, physical activity and fitness in non smoking, middle-aged men, *Med. Sci. Sports Exerc.* 32 (2000) 2079–2086.
- [18] I.J. Kullo, D.D. Hensrud, T.G. Allison, Relation of low cardiorespiratory fitness to the metabolic syndrome in middle-aged men, *Am. J. Cardiol.* 90 (2002) 795–797.
- [19] M. Nagano, Y. Kai, B. Zou, T. Hatayama, M. Suwa, H. Sasaki, et al., The contribution of cardiorespiratory fitness and visceral fat to the risk factors in the Japanese patients with impaired glucose tolerance and type 2 diabetes mellitus, *Metabolism* 53 (2004) 644–649.
- [20] D.E. Laaksonen, H.M. Lakka, J.T. Salonen, L.K. Niskanen, R. Rauramaa, T. Lakka, Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome, *Diabetes Care* 25 (2002) 1612–1618.
- [21] P.T. Katzmarzyk, A.S. Lenon, J.H. Wilmore, J.S. Skinner, D.C. Rao, T. Rankinen, et al., Targeting the metabolic syndrome with exercise: evidence from the Heritage Family Study, *Med. Sci. Sports Exerc.* 35 (2003) 1703–1709.
- [22] U. Ekelund, S. Brage, P.W. Franks, S. Hennings, S. Emms, N.J. Wareham, Physical activity energy expenditure predicts progression toward the metabolic syndrome independently of aerobic fitness in middle-aged healthy Caucasians: the Medical Research Council Ely Study, *Diabetes Care* 28 (2005) 1195–1200.



## Reducing waist circumference by at least 3 cm is recommended for improving metabolic syndrome in obese Japanese men

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### ABSTRACT

**Objective:** We investigated the link between a reduction in waist circumference and metabolic syndrome.

**Methods:** 105 obese Japanese men were enrolled in this study with a 1-year follow-up. Anthropometric and body composition parameters, i.e. height, body weight, body fat percentage, waist circumference and hip circumference, blood pressure, triglyceride, HDL cholesterol and blood sugar, were evaluated. Metabolic syndrome was diagnosed using criteria developed in Japan.

**Results:** After a 1-year follow-up, the parameters of metabolic syndrome were significantly improved. The prevalence of metabolic syndrome was significantly reduced in subjects with at least 3 cm of waist circumference reduction (Group R). However, in subjects without such reduction (Group C), the prevalence of metabolic syndrome was similar to baseline levels. The prevalence of abdominal obesity, hypertension and dyslipidemia was also significantly reduced in Group R. In addition, there were remarkable differences of delta triglyceride (delta represents positive changes in parameters) and delta HDL cholesterol between Group R and Group C.

**Conclusion:** At least 3 cm of waist circumference reduction may be beneficial for improving metabolic syndrome in obese Japanese men.

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### 1. Introduction

Metabolic syndrome is a common public health challenge in Japan. We previously reported that 30.7% of men and 3.6% of women were diagnosed as having metabolic syndrome [1]. In addition, metabolic syndrome induces coronary heart disease [2], proteinuria [3] and elevation of hepatic enzymes [4]. The work of Reaven [5] is convincing in showing that visceral fat accumulation is a critical pathogenesis of metabolic syndrome.

In 2006, the Japan society for the study of obesity recommended a 3 cm reduction in waist circumference and 3 kg of body weight for preventing and improving metabolic syndrome (<http://www.soc.nii.ac.jp/jasso/index.html>, accessed on Mar 5, 2007). A reduction in waist size is one important approach to prevent and improve metabolic syndrome. However, whether at least a 3 cm reduction is beneficial for improving metabolic syndrome and what effects this will have on metabolic remain to be investigated.

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In this study, we evaluated the link between a reduction of waist circumference and metabolic syndrome in obese Japanese subjects with a 1-year follow-up.

## 2. Subjects and methods

### 2.1. Subjects

We used data of 105 obese Japanese men (body mass index (BMI)  $\geq 25$  kg/m<sup>2</sup>), aged  $45.4 \pm 8.4$  years, retrospectively from a database of 14,345 subjects who met the following criteria: (1) received an annual health check-up at baseline from June 1997 to March 2006, (2) received an annual health check-up every year with a follow-up duration of 1 year, (3) received anthropometric measurements, fasting blood examination and blood pressure measurements as part of the annual health check-up, (4) received no medications for diabetes, hypertension, and/or dyslipidemia, and (5) 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.

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

### 2.2. Anthropometric and body composition measurements

The anthropometric and body compositions were evaluated based on the following parameters: height, body weight, waist circumference, hip circumference and body fat percentage. Body mass index (BMI) was calculated by weight/[height]<sup>2</sup> (kg/m<sup>2</sup>) and obesity was defined by body mass index (BMI)  $\geq 25$  kg/m<sup>2</sup> [6]. The waist circumference was measured at the umbilical level, and the hip was measured at the widest circumferences over the trochanter in standing subjects after normal expiration. Body fat percentage was measured by an air displacement plethysmograph called the BOD POD Body Composition System (Life Measurement Instruments, Concord, CA, USA) [7,8].

### 2.3. Blood pressure measurements at rest

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

### 2.4. Blood sampling and assays

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

### 2.5. 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  $\geq 150$  mg/dl and/or HDL cholesterol  $< 40$  mg/dl, (2) high blood pressure: blood pressure  $\geq 130/85$  mmHg, (3) impaired glucose tolerance: fasting plasma glucose  $\geq 110$  mg/dl [9].

### 2.6. Statistical analysis

All data are expressed as mean  $\pm$  standard deviation (S.D.) values. A statistical analysis was performed using a paired t test, an unpaired t test and  $\chi^2$  test:  $p < 0.05$  was considered to be statistically significant.

## 3. 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, body mass index, body fat percentage, waist circumference and hip circumference were significantly reduced after 1 year. Systolic blood pressure, diastolic blood pressure and triglyceride levels were also significantly reduced and HDL cholesterol significantly increased.

We investigated the changes in the number of subjects with metabolic syndrome as classified into different levels of

Table 1 - Clinical parameters at baseline and 1-year follow-up in obese Japanese men

	Mean $\pm$ S.D.		p
	Baseline	Follow-up	
Number of subjects	105		
Height (cm)	169.2 $\pm$ 5.7		
Body weight (kg)	180.9 $\pm$ 8.8	173.7 $\pm$ 8.9	<0.0001
Body mass index (kg/m <sup>2</sup> )	28.2 $\pm$ 2.8	27.5 $\pm$ 2.7	<0.0001
Body fat percentage (%)	28.7 $\pm$ 4.8	26.9 $\pm$ 6.7	<0.0001
Waist circumference (cm)	93.3 $\pm$ 7.2	90.5 $\pm$ 8.1	<0.0001
Hip circumference (cm)	99.6 $\pm$ 4.5	98.3 $\pm$ 4.6	<0.0001
Systolic blood pressure (mmHg)	133.5 $\pm$ 15.4	124.3 $\pm$ 12.2	<0.0001
Diastolic blood pressure (mmHg)	83.0 $\pm$ 12.0	77.8 $\pm$ 9.5	<0.0001
Triglyceride (mg/dl)	167.2 $\pm$ 101.7	125.2 $\pm$ 76.3	<0.0001
HDL cholesterol (mg/dl)	51.0 $\pm$ 11.5	53.5 $\pm$ 13.6	0.0091
Blood sugar (mg/dl)	105.8 $\pm$ 21.3	106.1 $\pm$ 29.7	0.8773

Table 2 - Changes in the number of subjects with metabolic syndrome as classified into different levels of waist circumference and body weight reduction

	Number of subjects		Change rate (%)
	Baseline	Follow-up	
<b>Delta waist circumference (cm)</b>			
-1<	12	15	25.0
-2<	8	4	-50.0
-3<	15	5	-66.7
-4<	5	2	-60.0
-5<	5	1	-80.0
-6<	10	3	-70.0
<b>Delta body weight (kg)</b>			
-1<	15	13	-13.3
-2<	8	5	-37.5
-3<	6	2	-66.6
-4<	7	3	-57.1
-5<	4	4	0.0
-6<	7	3	-57.1

waist circumference and body weight reduction (Table 2). Change rate was under the level of -50% in subjects by at least 3 cm of waist circumference reduction. However, clear relation between body weight reduction and metabolic syndrome and the threshold of body weight reduction were not noted.

Forty-two men reduced their waist circumference by at least 3 cm by the time of the 1-year follow-up. We investigated the changes in the prevalence of metabolic syndrome amongst men who had different levels of waist circumference reduction [Group R: Delta (delta represents positive changes in parameters) waist circumference  $\leq -3$  cm, Group C: Delta waist circumference  $> -3$  cm] (Table 3). The prevalence of metabolic syndrome at baseline was 43.8% (Group R: 20 men, Group C: 26 men, total: 46 men). This was significantly reduced in both Group R (6 men, change rate: -70.0%) and total subjects (28 men, change rate: -39.1%) supporting the recommendation of the Japan society for the study of obesity. However, for Group C (22 men, change rate: -15.4%) the prevalence of

Table 3 - Number of subjects with and without metabolic syndrome at baseline and follow-up

	Baseline		Follow-up		Total
	Group R	Group C	Group R	Group C	
Metabolic syndrome (+)	4	16	6	22	28
Metabolic syndrome (-)	16	10	14	7	21
p			0.0002	0.2558	0.0093

p: compared with baseline by  $\chi^2$  test. Group R: Delta waist circumference  $\leq -3$  cm. Group C: Delta waist circumference  $> -3$  cm.

metabolic syndrome was similar to baseline levels and the change rate was significantly lower compared with that in Group R.

We further analyzed changes in each component of metabolic syndrome at baseline and follow-up (Table 4). The prevalence of abdominal obesity diagnosed by waist circumference, hypertension and dyslipidemia was remarkably reduced in Group R and total subjects. Only the prevalence of hypertension was significantly reduced in Group C.

Finally, we compared the delta parameters between Group G and Group C (Table 5). Significant differences were noted in delta triglyceride and delta HDL cholesterol between Group R and Group C. However, delta systolic blood pressure, delta diastolic blood pressure and delta blood sugar in Group R were similar to those in Group C.

#### 4. Discussion

We explored, using Japanese criterion, whether at least 3 cm of waist circumference reduction can improve metabolic syndrome in obese Japanese men.

In some literature, a reduction in waist circumferences is closely linked to an improvement of metabolic risk factors through life style modification [10,11]. Villareal et al. reported

Table 4 - Number of subjects with and without each component of metabolic syndrome at baseline and follow-up

	Baseline		Follow-up		Total
	Group R	Group C	Group R	Group C	
Abdominal obesity (+)	95	26	58	58	116
Abdominal obesity (-)	10	16	5	7	12
p			0.0001	0.7269	0.0324
Hypertension (+)	169	14	39	43	82
Hypertension (-)	36	25	14	6	40
p			0.0003	0.0122	<0.0003
Dyslipidemia (+)	54	8	24	37	61
Dyslipidemia (-)	51	34	39	17	56
p			0.0003	0.0994	0.0020
Impaired glucose tolerance (+)	28	7	14	14	28
Impaired glucose tolerance (-)	77	35	49	18	67
p			0.1984	0.5195	0.2534

p: compared with baseline by  $\chi^2$  test. Group R: Delta waist circumference  $\leq -3$  cm. Group C: Delta waist circumference  $> -3$  cm. Abdominal obesity (+): waist circumference  $\geq 85$  cm.



Table 5 – Comparison of delta clinical parameters between group R and C

	Group R	Group C	P
Number of subjects	42	63	
Delta systolic blood pressure (mmHg)	-11.3 ± 14.7	-7.7 ± 13.2	0.4503
Delta diastolic blood pressure (mmHg)	-7.0 ± 11.6	-4.1 ± 11.6	0.2052
Delta triglyceride (mg/dl)	-76.3 ± 108.9	-19.1 ± 61.1	0.0009
Delta HDL cholesterol (mg/dl)	5.4 ± 11.7	0.6 ± 7.6	0.0127
Delta blood sugar (mg/dl)	-20.3 ± 24.4	0.7 ± 14.3	0.8099

(Mean ± S.D. Group R: Delta waist circumference ≤ -3 cm; Group C: Delta waist circumference > -3 cm)

that in obese older adults after a 6-months trial, 10 cm of waist reduction through diet and exercise was associated with improvements in glucose (-4 mg/dl), systolic blood pressure (-10 mmHg), diastolic blood pressure (-8 mmHg), serum free fatty acids (-99 micromol/l) and the number of subjects with metabolic syndrome (59%) [10]. Kuller et al. also reported that 508 postmenopausal women through exercise and diet change could reduce their waist size by 10 cm. This also improved low-density lipoprotein cholesterol, insulin and glucose levels in an 18-months follow-up [11]. One common factor in both these interventions is a 10 cm waist circumference reduction.

In the present study, with a 1-year follow-up, approximately 3 cm of waist circumference reduction was noted and all the parameters of metabolic risk factors, except blood sugar, improved. The prevalence of metabolic syndrome was significantly reduced in Group R and total subjects, and we can conclude that at least 3 cm of waist reduction was beneficial for improving metabolic syndrome. However, the prevalence of metabolic syndrome did not change in Group C. In addition, although the prevalence of abdominal obesity which was diagnosed by waist circumference measurements, hypertension and dyslipidemia was significantly reduced in Group R, the prevalence of impaired glucose tolerance was similar at the follow-up as it was at the baseline. Finally, the differences of delta parameters were noted only in delta triglyceride and delta HDL cholesterol. In sum, the main clinical impact of dyslipidemia was noted in the obese Japanese men with at least 3 cm of waist circumference reduction. Tonstand et al. [12] also reported that a difference of 3.1 cm of waist circumference was noted between an intervention group with nurse-led lifestyle counseling and a control group. Although there was a difference in triglyceride between the two groups, the difference in blood pressure was not at a significant level. These results suggest that an improvement of metabolic risk factors may be different according to the level of waist circumference reduction.

There are several potential limits in this study. First, although we proved a link between a reduction in waist circumference and metabolic risk factors, and it seems that at least 3 cm of waist circumference reduction was beneficial for improving metabolic syndrome, we could not prove the precise threshold of waist circumference reduction as well as body weight reduction. Second, we could not directly measure visceral fat accumulation using computed tomography. Finally, the small number of subjects is a limitation of this study.

In conclusion, it may be beneficial for obese Japanese men to reduce their waist circumference by at least 3 cm for improving metabolic syndrome.

### Conflict of interest statement

All co-authors have no conflict of interest.

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### REFERENCES

- [1] N. Miyatake, Y. Kawasaki, H. Nishikawa, S. Takenami, T. Numata, Prevalence of metabolic syndrome in Okayama prefecture, Japan, *Intern. Med.* 45 (2006) 107-108.
- [2] P.W. Wilson, W.B. Kannel, H. Silbershatz, R.B. D'Agostino, Clustering of metabolic factors and coronary heart disease, *Arch. Intern. Med.* 159 (1999) 1104-1109.
- [3] N. Miyatake, J. Wada, Y. Kawasaki, S. Matsumoto, H. Makino, T. Numata, Relationship between metabolic syndrome and proteinuria in the Japanese population, *Intern. Med.* 45 (2006) 599-603.
- [4] N. Miyatake, S. Matsumoto, H. Makino, H. T. Numata, Comparison of hepatic enzymes between Japanese men with and without metabolic syndrome, *Acta. Med. Okayama* 61 (2007) 31-34.
- [5] G.M. Reaven, Banting lecture 1988. Role of insulin resistance in human disease, *Diabetes* 37 (1988) 1595-1607.
- [6] Examination Committee of Criteria for 'Obesity Disease' in Japan; Japan Society for the Study of Obesity: new criteria for 'obesity disease' in Japan, *Circ. J.* 66 (2002) 987-992.
- [7] M.A. McGrory, T.D. Gomez, E.M. Bernauer, P.A. Mole, Evaluation of a new air displacement plethysmograph for measuring human body composition, *Med. Sci. Sports Exerc.* 27 (1995) 1686-1691.
- [8] N. Miyatake, K. Nonaka, M. Fujii, A new air displacement plethysmograph for the determination of Japanese body composition, *Diab. Obes. Metab.* 1 (1999) 347-351.
- [9] Definition and the diagnostic standard for metabolic syndrome—Committee to evaluate diagnostic standards for metabolic syndrome, *Nippon Naika Gakkai Zasshi* 94 (2005) 794-809 (in Japanese).
- [10] D.T. Villareal, B.V. Miller 3rd., M. Banks, L. Fontana, D.R. Sinacore, S. Klein, Effect of lifestyle intervention on

- metabolic coronary heart disease risk factors in obese older adults, *Am. J. Clin. Nutr.* 84 (2006) 1317-1323.
- [11] L.H. Kuller, L.S. Kinzel, K.K. Pettee, A.M. Kriska, L.R. Simkin-Silverman, M.B. Conroy, et al., Lifestyle intervention and coronary heart disease risk factor changes over 18 months in post menopausal women: the Women On the Move through Activity and Nutrition (WOMAN study) clinical trial, *J. Womens Health (Larchmt)* 15 (2006) 962-974.
- [12] S. Tonstad, C.S. Alm, E. Sandvik, Effect of nurse counseling on metabolic risk factors in patients with mild hypertension: a randomized controlled trial, *Eur. J. Cardiovasc. Nurs.* 6 (2007) 160-164.

Original Article

## Linkage between Oxygen Uptake at Ventilatory Threshold and Muscle Strength in Subjects with and without Metabolic Syndrome

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We evaluated the linkage between oxygen uptake at the ventilatory threshold (VT) and muscle strength in subjects with and without metabolic syndrome. We used data of 226 Japanese men with metabolic syndrome and 265 Japanese men without the syndrome. Metabolic syndrome has recently been defined by a new criterion in Japan. Oxygen uptake at VT and muscle strength, *i.e.* grip strength and leg strength were measured. Oxygen uptake at VT and muscle strength/body weight were found to be significantly lower in subjects with metabolic syndrome than in those without the syndrome. However, the differences did not reach significant levels after adjusting for leg strength/body weight or oxygen uptake at VT. A combination of aerobic exercise and resistance training might be considered for preventing and improving metabolic syndrome.

**Key words:** metabolic syndrome, oxygen uptake, ventilatory threshold, muscle strength

**M**etabolic syndrome is a common disorder and has become a public health challenge in Japan [1, 2]. Lifestyle modifications, especially exercise, are important for preventing and improving metabolic syndrome. We have previously reported that a lower level of oxygen uptake at VT (ventilatory threshold) [3], which is the upper limit of aerobic exercise and is thought to serve as an accurate and reliable standard for exercise prescription [3], and lower muscle strength/body weight [4] were characteristic in sub-

jects with metabolic syndrome. However, the relation between oxygen uptake at VT and muscle strength in subjects with and without metabolic syndrome remains to be investigated. In this study, we compared both oxygen uptake at VT and muscle strength in Japanese men with and without metabolic syndrome. In addition, the linkage between oxygen uptake at VT and muscle strength was also examined.

### Subjects and Methods

**Subjects.** We used retrospective data of 226 Japanese men with metabolic syndrome and 265 Japanese men without metabolic syndrome, aged 21-

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77 years from a data base of 14,345 subjects. All subjects met the following criteria: (1) they had received an annual health checkup from June 1997 to May 2006 at Okayama Southern Institute of Health; (2) they had received a fasting blood examination, a cardiopulmonary exercise test and muscle strength measurements as part of their annual health checkups; and (3) they provided informed consent. Ethical approval for the study was obtained from the Ethical Committee of Okayama Health Foundation.

**Oxygen uptake at VT.** A graded ergometer exercise protocol [5] had been carried out at the subjects' checkups. After breakfast (2 h), resting ECG was recorded and blood pressure was measured. All subjects were then given a 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 [5], in which the workloads reach the predicted  $\dot{V}O_{2\max}$  in 10 min. A pedaling cycle 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. Expired gas was collected, and rates of oxygen consumption ( $\dot{V}O_2$ ) and carbon dioxide production ( $\dot{V}CO_2$ ) were measured breath-by-breath using the cardiopulmonary gas exchange system (Oxycon Alpha, Mijnhrdt b.v., Netherlands). The ventilatory threshold (VT) was determined by the standard of Wasserman *et al.* [6], Davis *et al.* [7] and the V-slope method of Beaver [8] from  $\dot{V}O_2$ ,  $\dot{V}CO_2$ , and minute ventilation ( $\dot{V}E$ ).

**Measurements 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 [9]. To standardize the influence of the total body weight, we calculated the muscle strength (kg) per body weight (kg) [10].

**Anthropometric measurements.** Anthropometric parameters *i.e.* height, weight, and waist cir-

cumference were measured. The waist circumference was measured at the umbilical level.

**Definition of metabolic syndrome.** Metabolic syndrome was defined, among men with a waist circumference in excess of 85 cm, as the appearance of 2 or more of the following symptoms: 1) dyslipidemia: triglycerides  $\geq 150$  mg/dl and/or HDL cholesterol  $< 40$  mg/dl, 2) high blood pressure: blood pressure  $\geq 130/85$  mmHg, and 3) impaired glucose tolerance: fasting plasma glucose  $\geq 110$  mg/dl [1].

**Statistical analysis.** Data are expressed as means  $\pm$  standard deviation (SD) values. A comparison of parameters between the 2 groups was made using the unpaired *t*-test and covariance analysis. Simple correlation analysis was performed as well to test for the significance of the linear relationship among continuous variables:  $p < 0.05$  was considered to be statistically significant.

## Results

The measurements of oxygen uptake at VT and muscle strength in subjects with and without metabolic syndrome are indicated in the Table 1. There was no significant difference in age between subjects with and without the syndrome. Body weight and waist circumference in subjects with metabolic syndrome were higher than those in subjects without the syndrome. In subjects with metabolic syndrome, oxygen uptake at VT, grip strength/body weight and leg strength/body weight (WBI: weight bearing index) were significantly lower than those without the syndrome. Leg strength in subjects with metabolic syndrome was significantly higher than that without the syndrome.

To avoid the influence of muscle strength on oxygen uptake at VT, we used WBI as a covariate and compared oxygen uptake at VT using covariance analysis. In subjects with metabolic syndrome, oxygen uptake at VT showed comparable levels to that of subjects without the syndrome. The differences in oxygen uptake at VT between men with and without metabolic syndrome did not show statistical significance after adjusting for other parameters of muscle strength *i.e.* grip strength, leg strength and muscle strength/body weight. In turn, to eliminate the influence of oxygen uptake at VT on muscle strength, we used oxygen uptake at VT as a covariate and compared muscle strength. After adjusting for oxygen uptake at VT, no significant dif-

ference in leg strength and muscle strength/body weight was observed between Japanese men with and without metabolic syndrome.

We investigated the relationship between oxygen uptake at VT and the parameters of muscle strength and muscle strength/body weight. Oxygen uptake at VT was weakly correlated with muscle strength and muscle strength/body weight parameters in metabolic syndrome, non-metabolic syndrome and all subjects (Table 2).

### Discussion

We investigated the linkage between oxygen uptake

at VT and muscle strength in metabolic syndrome.

In some of the literature, cardiorespiratory fitness and muscle strength are closely associated with metabolic syndrome [11-14]. There are few studies focusing on the reciprocal effect of oxygen uptake at VT and muscle strength on metabolic syndrome. Jurca R *et al.* have reported examining the associations for muscle strength with the prevalence of metabolic syndrome using the National Cholesterol Education Program definition [14]. They concluded that muscle strength has an inverse association with metabolic syndrome, but the association was attenuated when further adjusted for cardiorespiratory fitness. In this study, using the new Japanese criteria for metabolic syn-

Table 1 Comparison of parameters between Japanese men with and without metabolic syndrome

	Metabolic syndrome (+)	Metabolic syndrome (-)	<i>p</i>	<i>p</i>	<i>p</i>
Number of subjects	226	265	Unpaired t test	Adjusting for WBI	Adjusting for VT
Age	49.1 ± 10.5	49.3 ± 11.1	0.8428		
Height (cm)	168.6 ± 5.8	168.3 ± 5.7	0.5756		
Body weight (kg)	81.2 ± 12.8	71.9 ± 12.1	< 0.0001		
Waist circumference (cm)	95.6 ± 8.4	85.9 ± 9.2	< 0.0001		
Oxygen uptake at VT (ml/kg/min)	13.2 ± 2.2	14.8 ± 3.4	< 0.0001	0.0611	
Right grip strength (kg)	44.5 ± 8.3	43.5 ± 8.6	0.1792		0.5528
Left grip strength (kg)	42.6 ± 7.9	42.0 ± 8.0	0.4282		0.5790
Leg strength (kg)	68.2 ± 18.1	64.9 ± 17.5	0.0405		0.7202
Right grip strength (kg)/body weight (kg)	0.55 ± 0.10	0.61 ± 0.11	< 0.0001		0.1377
Left grip strength (kg)/body weight (kg)	0.53 ± 0.10	0.59 ± 0.10	< 0.0001		0.1381
WBI	0.84 ± 0.20	0.90 ± 0.20	0.0008		0.9420

VT: Ventilatory threshold

WBI: Weight bearing index [leg strength (kg)/body weight (kg)]

Table 2 Simple correlation analysis between oxygen uptake at VT and muscle strength parameters

	Total		Metabolic syndrome (+)		Metabolic syndrome (-)	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Right grip strength (kg)	0.160	0.0004	0.199	0.0026	0.180	0.0033
Left grip strength (kg)	0.152	0.0007	0.175	0.0082	0.170	0.0055
Leg strength (kg)	0.145	0.0013	0.140	0.0350	0.204	0.0008
Right grip strength (kg)/body weight (kg)	0.365	< 0.0001	0.281	< 0.0001	0.345	< 0.0001
Left grip strength (kg)/body weight (kg)	0.350	< 0.0001	0.248	0.0002	0.330	< 0.0001
WBI	0.336	< 0.0001	0.212	0.0013	0.371	< 0.0001

VT: Ventilatory threshold

WBI: Weight bearing index [leg strength (kg)/body weight (kg)]

drome, leg strength was found to be significantly higher in subjects with than in those without the syndrome. Oxygen uptake at VT and muscle strength/body weight were significantly lower in subjects with metabolic syndrome than in those without it. However, the differences weren't significant when adjusted for WBI or oxygen uptake at VT.

Kawano H *et al.* evaluated the effects of moderate resistance training as well as combined resistance and aerobic training intervention on carotid arterial compliance. They concluded that aerobic training could prevent the stiffening of carotid arteries caused by resistance training [15]. 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 [16]. Metter EJ *et al.* also reported that lower and declining muscle strength was associated with increased mortality, independent of physical activity and muscle mass [17]. These findings suggest that a combination of aerobic exercise and resistance training should be considered for primary prevention of metabolic syndrome. In this study, we found lower levels of oxygen uptake at VT and lower muscle strength/body weight in subjects with metabolic syndrome, as previously reported [3, 4]. However, the differences were not significant after adjusting for muscle strength parameters and oxygen uptake at VT. In addition, oxygen uptake at VT was weakly correlated with muscle strength and muscle strength/body weight parameters. Therefore, oxygen uptake at VT and muscle strength partially depend on each other in subjects with and without the syndrome. Especially in subjects with metabolic syndrome, lower WBI was also noted. A low level of WBI and reduced exercise activity seems to accelerate metabolic syndrome. Although aerobic exercise has traditionally been advocated as the most suitable for reducing fat mass [18, 19], it is difficult for subjects with metabolic syndrome to support the entire body's weight; it is also difficult for subjects with metabolic syndrome to carry out aerobic exercise *i.e.* walking and jogging. A combination of aerobic exercise and resistance training might be considered for preventing and improving metabolic syndrome. It is important for metabolic syndrome patients to maintain or maximize the muscle strength of their lower limbs as well as to carry out aerobic exercise.

Potential limitations remain in our study. First,

the cross-sectional study design as well as the small sample size in our study makes it difficult to infer causality between metabolic syndrome, oxygen uptake at VT and muscle strength. Second, we could not accurately prove the mechanism of linkage between oxygen uptake at VT and muscle strength.

In conclusion, both aerobic exercise and resistance training are necessary for the prevention and treatment of metabolic syndrome.

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## References

1. Definition and the diagnostic standard for metabolic syndrome-Committee to evaluate diagnostic standards for metabolic syndrome. *Nippon Naika Gakkai Zasshi* (2005) 94: 794-809 (in Japanese).
2. Miyatake N, Kawasaki Y, Nishikawa H, Takenami S and Numata T: Prevalence of metabolic syndrome in Okayama prefecture, Japan. *Intern Med* (2006) 45: 107-108.
3. Miyatake N, Saito T, Wada J, Miyachi M, Tabata I, Matsumoto S, Nishikawa H, Makino H and Numata T: Comparison of ventilatory threshold and exercise habits between Japanese men with and without metabolic syndrome. *Diabetes Res Clin Prac* (2007) 77: 314-319.
4. Miyatake N, Wada J, Saito T, Nishikawa H, Matsumoto S, Miyachi M, Makino H and Numata T: Comparison of muscle strength between Japanese men with and without metabolic syndrome. *Acta Med Okayama* (2007) 61: 99-102.
5. Jones NL, Makrides L, Hitchcock C, Chypchar T and McCartney N: Normal standards for an incremental progressive cycle ergometer test. *Am Rev Respir Dis* (1985) 131: 700-708.
6. Wasserman K, Whipp BJ, Koyl SN and Beaver WL: Anaerobic threshold and respiratory gas exchange during exercise. *J Appl Physiol* (1973) 35: 236-243.
7. Davis JA, Frank MH, Whipp BJ and Wasserman K: Anaerobic threshold alterations caused by endurance training in middle-aged men. *J Appl Physiol* (1979) 46: 1039-1046.
8. Beaver WL, Wasserman K and Whipp BJ: A new method for detecting anaerobic threshold by gas exchange. *J Appl Physiol* (1986) 60: 2020-2027.
9. Kigawa A, Yamamoto T, Koyama Y, Kageyama S and Arima K: Evaluation of knee extensor strength for prevention of sports injury. *Japan Ortho Soc Sports Med* (1987) 6: 141-145 (in Japanese).
10. Miyatake N, Takahashi K, Wada J, Nishikawa H, Morishita A, Suzuki H, Kunitomi M, Makino H, Kira S and Fujii M: Changes in serum leptin concentrations in overweight men after exercise. *Diabetes Obes Metab* (2004) 6: 332-337.
11. Laaksonen DE, Lakka HM, Salonen JT, Niskanen LK, Rauramaa R and Lakka T: Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. *Diabetes Care* (2002) 25: 1612-1618.
12. Katzmarzyk PT, Leon AS, Wilmore JH, Skinner JS, Rao DC, Rankinen T and Bouchard C: Targeting the metabolic syndrome with exercise: evidence from the HERITAGE Family Study. *Med*

- Sci Sports Exerc (2003) 35: 1703-1709.
13. Jurca R, Lamonte MJ, Church TS, Earnest CP, Fitzgerald SJ, Barlow CE, Jordan AN, Kampert JB and Blair SN: Associations of muscle strength and fitness with metabolic syndrome in men. *Med Sci Sports Exerc* (2004) 36: 1301-1307.
  14. Jurca R, lamonte MJ, Barlow CE, Kampert JB, Church TS and Blair SN: Association of muscular strength with incidence of metabolic syndrome. *Med Sci Sports Exerc* (2005): 37: 1849-1855.
  15. Kawano H, Tanaka H and Miyachi M: Resistance training and arterial compliance: keeping the benefits while minimizing the stiffening. *J Hypertens* (2006) 24: 1753-1759.
  16. Sandvik L, Erikssen J, Thaulow E, Erikssen G, Mundal R and Rodahl K: Physical fitness as a predictor of mortality among healthy, middle-aged Norwegian men. *N Engl J Med* (1993) 25: 533-537.
  17. Metter EJ, Talbot LA, Schrager M and Conwit R: Skeletal muscle strength as a predictor of all-cause mortality in healthy men. *J Gerontol A Biol Sci Med Sci* (2002) 57: B359-B365.
  18. Ballor DL and Kessey RE: A meta-analysis of the factors affecting exercise induced changes in body mass, fat mass, and fat-free mass in males and females. *Int J Obesity* (1991) 15: 717-728.
  19. Miyatake N, Nishikawa H, Morishita A, Kunitomi M, Wada J, Suzuki H, Takahashi K, Makino H, Kira S and Fujii M: Daily walking reduces visceral adipose tissue areas and improves insulin resistance in Japanese obese subjects. *Diabetes Res Clin Pract* (2002) 58: 101-107.

Short Communication

## Re-evaluation of Waist Circumference in Metabolic Syndrome: A Comparison between Japanese Men and Women

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We re-evaluated the criteria for waist circumference to predict the accumulation of the components of metabolic syndrome. We used data for 3,185 Japanese, aged 20-79 years. Metabolic syndrome has recently been redefined by a new criterion in Japan, in which waist circumference cutoff points, *i.e.* 85 cm for men and 90 cm for women, are employed. Among the 3,185 Japanese considered in the present study, 335 men (26.8%) and 69 women (3.6%) were diagnosed as having metabolic syndrome. A cutoff point as a predictor for 2 or more components of metabolic syndrome was evaluated by sensitivity/specificity and a receiver operating characteristic (ROC) curve. The optimal point was estimated as being approximately 85 cm of waist circumference in men and 75 cm in women. We therefore recommend a cutoff value, 75 cm of waist circumference, for the criterion of metabolic syndrome in women.

**Key words:** metabolic syndrome, waist circumference, sensitivity, specificity, receiver operating characteristic (ROC) curve

Metabolic syndrome is now one of the major targets of the current public health challenge. Since the work of Reaven [1], the syndrome has been well-documented to be associated with an increased risk of cardiovascular disease and is correlated with all-cause mortality [2]. At present, the internationally recognized definitions of metabolic syndrome have been released, namely the criteria of the World Health Organization [3], the National Cholesterol Education Program's Third Adult Treatment Panel Report (ATPIII) [4], and the International Diabetes Federation (IDF) [5]. A new

criterion for metabolic syndrome has recently been defined in Japan [6], and we have previously reported that 30.7% of men and 3.6% of women can be diagnosed as having metabolic syndrome, with the prevalence being 10-fold higher in men than in women based on use of the new criterion [7]. This difference between men and women was due to the prevalence of women with a waist circumference in excess of 90 cm being significantly lower than that of men with a waist circumference exceeding 85 cm. The cutoff point of waist circumference corresponds to 100 cm<sup>2</sup> of the visceral adipose area measured by computed tomography at the umbilical level. The aim of this study was to re-evaluate the waist circumference for detecting metabolic risk accumulation in Okayama prefecture, Japan.

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## Subjects and Methods

We used data for 3,185 Japanese (1,252 men and 1,933 women) aged 20–79 years, who received annual health check-ups at Okayama Southern Institute of Health with informed consent. We measured waist circumference at the umbilical level. Metabolic syndrome was defined among men and women as waist circumferences in excess of 85 cm and 90 cm [6], respectively, in addition to having 2 or more of the following components: 1) Dyslipidemia: triglycerides  $\geq 150$  mg/dl and/or HDL cholesterol  $< 40$  mg/dl; 2) High blood pressure: blood pressure  $\geq 130/85$  mmHg; 3) Impaired fasting glucose: fasting plasma glucose  $\geq 110$  mg/dl [6].

## Results

The mean age of the study subjects was  $46.7 \pm 12.3$  years for men and  $48.5 \pm 12.6$  years for women. Among the 3,185 Japanese subjects, 618 men (49.4%) had a waist circumference in excess of 85 cm and 126 women (6.5%) had a waist circumfer-

ence exceeding 90 cm. In addition, the prevalence of metabolic syndrome was found to gradually increased with age, and 335 men (26.8%) were diagnosed with having metabolic syndrome in men. The prevalence of metabolic syndrome also gradually increased with age in women, especially over the age of 50, though only 69 women (3.6%) were diagnosed with metabolic syndrome.

We investigated the sensitivity and specificity of waist circumference in predicting the association with 2 or more metabolic risk factors, *i.e.* dyslipidemia, high blood pressure, and impaired fasting glucose. In men, the sensitivity and specificity of the waist circumference criterion, *i.e.* 85 cm, were 66.3% and 62.1%, respectively. However, in women, the sensitivity and specificity of waist circumference criterion, 90 cm, were found to be 16.0% and 96.2%. A cutoff point as a predictor for 2 or more components of metabolic syndrome was evaluated by sensitivity/specificity curves as well as a receiver operating characteristic (ROC) curve. The optimal point yielding the maximal sensitivity plus specificity for predicting 2 or more risk factors was estimated to be

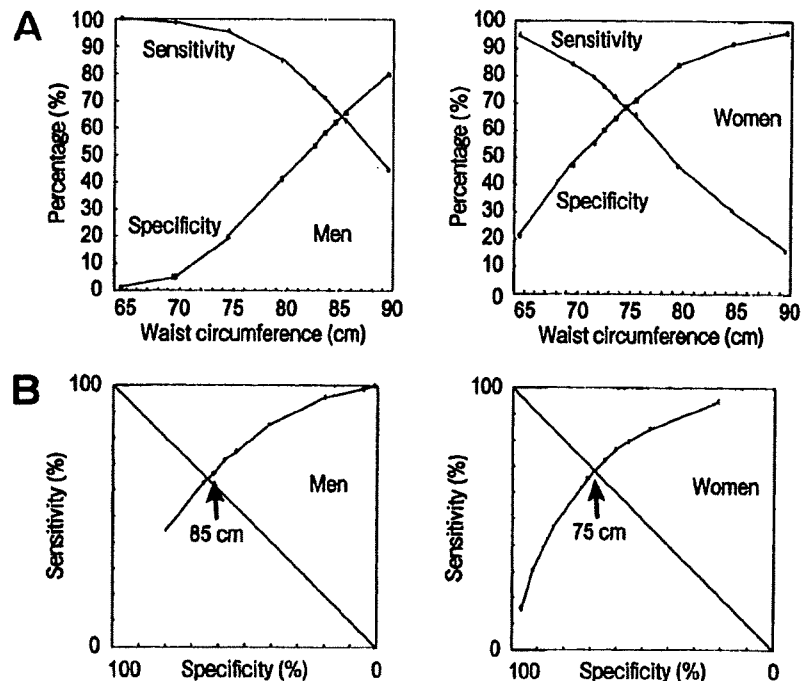


Fig. 1 A, Sensitivity/specificity curve of waist circumference for detecting metabolic risk factor accumulation; B, Receiver operating characteristic (ROC) curve of waist circumference for detecting metabolic risk factor accumulation.

approximately 85 cm (sensitivity: 66.3%, specificity: 62.1%) of waist circumference in men and 75 cm (sensitivity: 68.2%, specificity: 68.7%) in women (Fig. 1). Consequently, 764 women (39.5%) had a waist circumference exceeding 75 cm and 294 women (15.2%) were diagnosed as having metabolic syndrome by using 75 cm as the waist circumference criterion.

### Discussion

The primary finding of this study was that a waist circumference of 75 cm in women is appropriate for predicting the clustering of the components of metabolic syndrome. In men, the criterion of waist circumference deduced from our study was exactly matched to that of the new criterion in Japan. In women, however, the cutoff of waist circumference in our study was lower than that of the new criterion in Japan. Hara K and Kadowaki T *et al.* have also reported that waist circumference of 85 cm in men and 78 cm in women are cutoff points yielding the maximal sensitivity plus specificity for predicting the presence of multiple risk factors [8]. Miyazaki T and Nakao K *et al.* have reported that, by using the computed tomography, visceral fat accumulation of 65 cm<sup>2</sup> is optimal for evaluating multiple risk factors, and the corresponding cutoff value for waist circumference is 77 cm in women [9]. Although we did not measure visceral fat accumulation by computed tomography, the prevalence ratio of metabolic syndrome (men/women) based on use of a waist circumference of 75 cm in women was similar to that of cardiovascular diseases in Japan (Ministry of Health, Labor and Welfare, Japan. Available from [www.dtk.mhlw.go.jp/toukei/kouhyo/data-kou18/data12/junkan-h12-2.pdf](http://www.dtk.mhlw.go.jp/toukei/kouhyo/data-kou18/data12/junkan-h12-2.pdf) accessed Apr 15, 2006, in Japanese).

Potential limitations remain in our study. The cross-sectional study design of our study makes it difficult to infer causality between waist circumference and metabolic risk factors. The enrolled subjects in our study voluntarily received the annual health check-ups; they were therefore more health-conscious than average, which may have caused some bias in the current study. In addition, McNeil AM *et al.* assessed the association between metabolic syn-

drome using the ATP III definition and cardiovascular disease with an 11-year follow-up period, and they reported that waist circumference is not a significant predictor for cardiovascular disease [10]. Therefore, our findings are not fully applicable to clinical and public health practice settings. In conclusion, although follow-up studies are required to prove the feasibility of the definition of metabolic syndrome to predict the development of cardiovascular disease, we would recommend a cutoff value of 75 cm of waist circumference as a criterion for metabolic syndrome in women.

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### References

1. Reaven GM: Banting Lecture 1988. Role of insulin resistance in human disease. *Diabetes* (1988) 37: 1595-1607.
2. Wilson PW, Kannel WB, Silbershatz H and D'Agostino RB: Clustering of metabolic factors and coronary heart disease. *Arch Intern Med* (1999) 159: 1104-1109.
3. WHO: diagnosis and classification of diabetes and its complications. Part I: Diagnosis and classification of diabetes mellitus. World Health Organization, Geneva (1999).
4. Expert panel on detection, evaluation, and treatment of high blood cholesterol in adults. Executive Summary of the Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA* 285 (2001): 2486-2497.
5. International Diabetes Federation: The IDF consensus worldwide definition of the metabolic syndrome. 1st International Congress on Prediabetes and the Metabolic Syndrome in Berlin, Germany (2005).
6. An examination committee for criterion of metabolic syndrome: Definition and criteria of metabolic syndrome. *Nippon Naika Gakkaï Zasshi* (2005) 94: 794-809 (in Japanese).
7. Miyatake N, Kawasaki Y, Nishikawa H, Takenami S and Numata T: Prevalence of metabolic syndrome in Okayama prefecture, Japan. *Intern Med* (2006) 45: 107-108.
8. Hara K, Matsushita Y, Horikoshi M, Yoshilike N, Yokoyama T, Tanaka H and Kadowaki T: A proposal for the cutoff point of waist circumference for the diagnosis of metabolic syndrome in the Japanese population. *Diabetes Care* (2006) 29: 1123-1124.
9. Miyazaki T, Hirata M, Moriyama K, Sasaki Y, Aono H, Saito N and Nakao K: Metabolic syndrome in Japanese diagnosed with visceral fat measurement by computed tomography. *Proc Japan Acad* (2005) 81 Ser. B: 471-479.
10. McNeill AM, Rosamond WD, Girman CJ, Golden SH, Schmidt MI, East HE, Ballantyne CM and Heiss G: The metabolic syndrome and 11-year risk of incident cardiovascular disease in the atherosclerosis risk in communities study. *Diabetes Care* (2005) 28: 385-390.



Short Communication

## Comparison of Muscle Strength between Japanese Men with and without Metabolic Syndrome

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We compared muscle strength between Japanese men with and without metabolic syndrome. We used data for 323 Japanese men with metabolic syndrome and 893 Japanese men without the syndrome. Metabolic syndrome was defined by a new criterion in Japan, and the parameters for muscle strength, *i.e.* grip strength, leg strength were measured. Leg strength was found to be significantly higher in subjects with metabolic syndrome than in those without, while muscle strength per body weight was significantly lower in subjects with the syndrome. Lower muscle strength per body weight may be one of the characteristic features in subjects with metabolic syndrome.

**Key words:** metabolic syndrome, grip strength, leg strength

**M**etabolic syndrome is a common disorder and has become a public challenge in Japan. For example, 30.7% of men and 3.6% of women have been diagnosed as having metabolic syndrome using the new criterion in Japan [1]. The metabolic syndrome has been associated with an increased risk of cardiovascular disease [2], proteinuria [3], and elevation of hepatic enzymes [4]. Lifestyle modifications, especially exercise, are important for preventing and improving metabolic syndrome. However, the link between metabolic syndrome using the new criterion in Japan and muscle strength remains to be investigated. In this study, we compared muscle

strength between Japanese men with and without metabolic syndrome.

### Subjects and Methods

**Subjects.** We used the data for 1,216 Japanese men, aged 20-79 years, who met the following criteria, 1) received annual health checkups from June 1997 to May 2005 at Okayama Southern Institute of Health, 2) received fasting blood examination and muscle strength measurements, and 3) obtained written informed consent.

**Anthropometric measurements.** Anthropometric parameters *i.e.* height, weight, and waist circumference were measured. The waist circumference was measured at the umbilical level.

**Definition of metabolic syndrome.** Meta-

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bolic syndrome was defined, among men with a waist circumference in excess of 85 cm, as having 2 or more components from the following: 1) Dyslipidemia: triglycerides  $\geq 150$  mg/dl and/or HDL cholesterol  $< 40$  mg/dl, 2) High blood pressure: blood pressure  $\geq 130/85$  mmHg, 3) Impaired glucose tolerance: fasting plasma glucose  $\geq 110$  mg/dl [5].

**Measurements of muscle strength.** To assess muscle strength, grip and leg strength were measured. Grip strength was measured by 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. They next extended the leg to 60 degrees [6]. In addition, to standardize the influence of the total body weight, we calculated the muscle strength (kg) per body weight (kg) [7].

**Statistical analysis.** Data are expressed as mean  $\pm$  standard deviation (SD) values. A comparison of parameters between the 2 groups was made using the unpaired t-test and covariance analysis:  $p < 0.05$  was considered to be statistically significant.

## Results

A total of 323 men (26.6%) were diagnosed as having metabolic syndrome, and the measurements of muscle strength in subjects with and without metabolic syndrome ( $n = 893$ ) are indicated in the Table. The age was significantly higher in subjects with metabolic syndrome and thus, to avoid the influence of age on muscle strength, we used the age as a covariate and compared the muscle strength using covariance analysis. In subjects with metabolic syndrome, leg strength was significantly higher compared with subjects without metabolic syndrome. However, muscle strength per body weight was significantly lower in subjects with metabolic syndrome.

We then analyzed the groups with and without each component of metabolic syndrome. The age was significantly higher in subjects with abdominal obesity, impaired glucose tolerance, dyslipidemia, and high blood pressure compared with the subjects with

out each component. Based on the comparison of muscle strength adjusting for age, leg strength was significantly higher in subjects with abdominal obesity, dyslipidemia, and high blood pressure. In subjects with impaired glucose tolerance, leg strength was significantly lower than in subjects without impaired glucose tolerance. In subjects with abdominal obesity, the left grip strength was significantly higher compared with subjects without abdominal obesity. However, the leg strength per body weight in subjects with abdominal obesity was significantly lower. In addition, the grip strength per body weight in subjects with abdominal obesity, dyslipidemia, and high blood pressure was also significantly lower.

## Discussion

We compared muscle strength in metabolic syndrome men with that in non-metabolic syndrome men using the criterion in Japan.

In some literature, cardiorespiratory fitness is closely associated with metabolic syndrome [8, 9]. However, the relationship between muscle strength and metabolic syndrome, especially using the new criterion in Japan, has not been clearly investigated. Jurca R *et al.* have reported examining the associations for muscle strength and cardiorespiratory fitness with the prevalence of metabolic syndrome by cross sectional [10] and longitudinal study [11]. They concluded that muscle strength has an inverse association with metabolic syndrome prevalence using the National Cholesterol Education Program (NCEP) definition. In this study, by using the new criterion in Japan, leg strength was found to be significantly higher in subjects with metabolic syndrome than in those without the syndrome. However, muscle strength per body weight was significantly lower in subjects with metabolic syndrome than that in those without the syndrome. Leg strength per body weight in subjects with abdominal obesity was significantly lower, and grip strength per body weight in subjects with abdominal obesity, dyslipidemia, and high blood pressure was also significantly lower. These findings may stress the clinical significance of such components on muscle strength per body weight in subjects with metabolic syndrome. Although aerobic exercise has been advocated as the most suitable exercise for metabolic syndrome, it is difficult for subjects with

Table 1 Comparison of parameters between subjects with and without metabolic syndrome

	Mean $\pm$ SD		$\rho$ Unpaired t test	$\rho$ Adjusting for age
	Metabolic syndrome (+)	Metabolic syndrome (-)		
Number of subjects	323	893		
Age	49.4 $\pm$ 11.0	45.4 $\pm$ 12.5	< 0.0001	
Right grip strength (kg)	44.3 $\pm$ 8.2	43.7 $\pm$ 8.4		0.3232
Left grip strength (kg)	42.3 $\pm$ 8.0	41.9 $\pm$ 7.6		0.1779
Leg strength (kg)	67.8 $\pm$ 17.7	65.2 $\pm$ 17.0		0.0016
Right grip strength(kg)/body weight(kg)	0.56 $\pm$ 0.10	0.65 $\pm$ 0.12		< 0.0001
Left grip strength(kg)/body weight(kg)	0.54 $\pm$ 0.10	0.62 $\pm$ 0.11		< 0.0001
Leg strength(kg)/body weight(kg)	0.86 $\pm$ 0.20	0.96 $\pm$ 0.22		0.0058
	Waist circumference (+)	Waist circumference (-)		
Number of subjects	600	616		
Age	47.6 $\pm$ 11.1	45.3 $\pm$ 13.1	0.0013	
Right grip strength (kg)	45.0 $\pm$ 8.3	42.7 $\pm$ 8.3		0.2376
Left grip strength (kg)	43.1 $\pm$ 7.8	40.9 $\pm$ 7.5		0.0130
Leg strength (kg)	69.0 $\pm$ 17.2	62.9 $\pm$ 16.6		0.0002
Right grip strength(kg)/body weight(kg)	0.68 $\pm$ 0.10	0.67 $\pm$ 0.12		< 0.0001
Left grip strength(kg)/body weight(kg)	0.55 $\pm$ 0.11	0.64 $\pm$ 0.11		< 0.0001
Leg strength(kg)/body weight(kg)	0.88 $\pm$ 0.20	0.99 $\pm$ 0.23		< 0.0001
	Impaired glucose tolerance (+)	Impaired glucose tolerance (-)		
Number of subjects	282	934		
Age	51.5 $\pm$ 10.7	44.9 $\pm$ 12.2	< 0.0001	
Right grip strength (kg)	41.7 $\pm$ 8.0	44.5 $\pm$ 8.3		0.0553
Left grip strength (kg)	39.9 $\pm$ 7.9	42.6 $\pm$ 7.6		0.1340
Leg strength (kg)	62.7 $\pm$ 17.7	66.9 $\pm$ 16.9		0.0221
Right grip strength(kg)/body weight(kg)	0.58 $\pm$ 0.11	0.64 $\pm$ 0.12		0.1935
Left grip strength(kg)/body weight(kg)	0.56 $\pm$ 0.11	0.61 $\pm$ 0.11		0.0565
Leg strength(kg)/body weight(kg)	0.87 $\pm$ 0.21	0.95 $\pm$ 0.22		0.4832
	Dyslipidemia (+)	Dyslipidemia (-)		
Number of subjects	577	639		
Age	47.6 $\pm$ 11.7	45.4 $\pm$ 12.6	0.0014	
Right grip strength (kg)	43.2 $\pm$ 8.5	44.4 $\pm$ 8.1		0.3572
Left grip strength (kg)	41.5 $\pm$ 8.0	42.4 $\pm$ 7.5		0.2205
Leg strength (kg)	65.3 $\pm$ 17.8	66.4 $\pm$ 16.6		0.0155
Right grip strength(kg)/body weight(kg)	0.60 $\pm$ 0.11	0.65 $\pm$ 0.11		0.0034
Left grip strength(kg)/body weight(kg)	0.57 $\pm$ 0.11	0.62 $\pm$ 0.11		0.0055
Leg strength(kg)/body weight(kg)	0.90 $\pm$ 0.22	0.97 $\pm$ 0.22		0.3452
	High blood pressure (+)	High blood pressure (-)		
Number of subjects	703	513		
Age	48.9 $\pm$ 11.8	43.1 $\pm$ 11.9	< 0.0001	
Right grip strength (kg)	43.7 $\pm$ 8.4	44.0 $\pm$ 8.2		0.2065
Left grip strength (kg)	42.0 $\pm$ 8.0	42.0 $\pm$ 7.4		0.0843
Leg strength (kg)	65.9 $\pm$ 17.7	65.9 $\pm$ 16.5		0.0001
Right grip strength(kg)/body weight(kg)	0.61 $\pm$ 0.11	0.65 $\pm$ 0.12		0.0006
Left grip strength(kg)/body weight(kg)	0.58 $\pm$ 0.11	0.62 $\pm$ 0.11		0.0020
Leg strength(kg)/body weight(kg)	0.91 $\pm$ 0.22	0.97 $\pm$ 0.22		0.8945

lower leg strength per body weight to support their entire body weight, and it is also difficult to carry out aerobic exercise *i.e.* walking and jogging. In addition, resistance training increases muscle quantity and insulin action [12, 13] and reduces visceral adipose tissue [14]. These findings suggest that resistance exercise training should be considered in primary prevention of metabolic syndrome.

Potential limitations remain in our study. First, the cross-sectional study design in our study makes it difficult to infer causality between metabolic syndrome and muscle strength. Second, although reductions in basal leg blood flow [15] and resting metabolic rate [16] have been implicated in the pathogenesis of metabolic syndrome, we could not prove the mechanism of the link between metabolic syndrome and muscle strength. Therefore, our findings are applicable to clinical and public health practice settings. In conclusion, lower muscle strength per body weight is characteristic in Japanese men with metabolic syndrome. Further intervention studies are necessary to test the effects of the prevention and treatment of metabolic syndrome.

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## References

- Miyatake N, Kawasaki Y, Nishikawa H, Takenami S and Numata T: Prevalence of metabolic syndrome in Okayama prefecture, Japan. *Intern Med* (2006) 45: 107-108.
- Wilson PW, Kannel WB, Silbershatz H and D'Agostino RB: Clustering of metabolic factors and coronary heart disease. *Arch Intern Med* (1999) 159: 1104-1109.
- Miyatake N, Wada J, Kawasaki Y, Matsumoto S, Makino H and Numata T: Relationship between metabolic syndrome and proteinuria in the Japanese population. *Intern Med* (2006) 45: 599-603.
- Miyatake N, Matsumoto S, Makino H and Numata T: Comparison of hepatic enzymes between Japanese men with and without metabolic syndrome. *Acta Med Okayama* (2007) 61: 31-34.
- Definition and the diagnostic standard for metabolic syndrome-Committee to evaluate diagnostic standards for metabolic syndrome. *Nippon Naika Gakkai Zasshi* (2005) 94: 794-809 (in Japanese).
- Kigawa A, Yamamoto T, Koyama Y, Kageyama S and Arima K: Evaluation of knee extensor strength for prevention of sports injury. *Japan Ortho Soc Sports Med* (1987) 6: 141-145 (in Japanese).
- Miyatake N, Takahashi K, Wada J, Nishikawa H, Morishita A, Suzuki H, Kunitomi M, Makino H, Kira S and Fujii M: Changes in serum leptin concentrations in overweight men after exercise. *Diabetes Obes Metab* (2004) 6: 332-337.
- Laaksonen DE, Lakka HM, Salonen JT, Niskanen LK, Rauramaa R and Lakka T: Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. *Diabetes Care* (2002) 25: 1612-1618.
- Katzmarzyk PT, Lenon AS, Wilmore JH, Skinner JS, Rao DC, Rankinen T and Boucharde C: Targeting the metabolic syndrome with exercise: evidence from the HERITAGE Family Study. *Med Sci Sports Exerc* (2003) 35: 1703-1709.
- Jurca R, Lamonte MJ, Church TS, Earnest CP, Fitzgerald SJ, Barlow CE, Jordan AN, Kampert JB and Blair SN: Associations of muscle strength and fitness with metabolic syndrome in men. *Med Sci Sports Exerc* (2004) 36: 1301-1307.
- Jurca R, Lamonte MJ, Barlow CE, Kampert JB, Church TS and Blair SN: Association of muscular strength with incidence of metabolic syndrome. *Med Sci Sports Exerc* (2005); 37: 1849-1855.
- Andersen JL, Schjerling P, Andersen LL and Dela F: Resistance training and insulin action in humans: effects of de-training. *J Physiol* (2003) 551: 1049-1058.
- Holten MK, Zacho M, Gaster M, Juel C, Wojtaszewski JF and Dela F: Strength training increases insulin-mediated glucose uptake, GLUT4 content, and insulin signaling in skeletal muscle in patients with type 2 diabetes. *Diabetes* (2004) 294-305.
- Park SK, Park JH, Kwon YC, Kim HS, Yoon MS and Park HT: The effect of combined aerobic and resistance exercise training on abdominal fat in obese middle-aged women. *J Physiol Anthropol Appl Human Sci* (2003) 22: 129-135.
- Miyachi M, Tanaka H, Kawano H, Okajima M and Tabata I: Lack of age-related decreases in basal whole leg blood flow in resistance-trained men. *J Appl Physiol* (2005) 99: 1384-1390.
- Toth MJ and Poehlman ET: Resting metabolic rate and cardiovascular disease risk in resistance- and aerobic-trained middle-aged women. *Int J Obes Relat Metab Disord* (1995) 19: 691-698.

# Comparison of Whole Body Reaction Time between Japanese Men with and without Metabolic Syndrome

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**We investigated the relation between metabolic syndrome and whole body reaction time. We used data for 169 men with metabolic syndrome and 398 men without. Metabolic syndrome was defined by a new criteria developed in Japan. Whole body reaction time was also measured by THP-15 (Sakai, Tokyo, Japan). Whole body reaction time in men with metabolic syndrome was significantly longer than without the syndrome. In addition, the clinical impact of dyslipidemia and body mass index (BMI) was also noted. Longer whole body reaction time was noted in Japanese men with metabolic syndrome.**

**Keywords:** Whole body reaction time, Metabolic syndrome, Dyslipidemia

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## 1. Introduction

We have reported that lower oxygen uptake at ventilatory threshold (Miyatake, et al., 2007) and lower muscle strength per body weight (Miyatake, et al., 2007) were characteristic in subjects with metabolic syndrome. For preventing life-style related diseases, the level of maximal oxygen uptake and muscle strength was recommended in the Exercise and Physical Activity Reference Quantity for Health Promotion 2006 (EPARQ2006) by the Ministry of Health, Labor and Welfare of Japan. However, in relation to other types of physical fitness *i.e.* agility, there are no studies that focused on reductions in mortality or the prevention of lifestyle-related diseases, and an optimal level has not been defined. In addition, although it is reported that neuropathy which may affect agility is caused by type 2 diabetes mellitus and hyper triglyceridemia, the relation between metabolic syndrome and agility still remains to be investigated.

In this study, to investigate the relation between metabolic syndrome and agility using the criteria developed in Japan, we measured whole body reaction time which is one of the common parameters of agility in subjects with metabolic syndrome and

compared it with those without the syndrome.

## 2. Methods

We used data for 169 men (49.9±10.6 years) with metabolic syndrome and 398 men (48.6±12.4 years) without the syndrome with written informed consent.

The anthropometric measurements were performed by using the following parameters such as height, body weight, body mass index (BMI) and waist circumference. BMI was calculated by  $\text{weight}/[\text{height}]^2$  (kg/m<sup>2</sup>). Waist circumference was measured at the umbilical level.

Metabolic syndrome was defined, among men with a waist circumference in excess of 85 cm, as having 2 or more components from the following: 1) Dyslipidemia: triglycerides  $\geq 150$  mg/dl and/or HDL cholesterol  $< 40$  mg/dl, 2) High blood pressure: blood pressure  $\geq 130/85$  mmHg, 3) Impaired glucose tolerance: fasting plasma glucose  $\geq 110$  mg/dl (2005).

Whole body reaction time was measured by using THP-15 (Sakai, Tokyo, Japan) (Figure 1) as follows. Subjects stood still with a posture to be able to change immediately and concentrated their attention on a lamp. When the lamp was lit, the subjects jumped as quickly as possible. The average reaction