■ ORIGINAL ARTICLES

Waist Circumference Measurements in Special Metabolic Syndrome Medical Checkups for Employees of a Japanese University: A Follow-up Study

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ABSTRACT: In April 2008, a system of special health checks and health guidance was initiated to identify those employees at a Japanese university with metabolic syndrome and pre-metabolic syndrome. With waist circumference measurement being considered an essential criterion for the diagnosis of metabolic syndrome, and because waist measurement error can affect judgments about metabolic syndrome, we also investigated the frequency of this measurement error. In addition, employee health was evaluated by special medical checkups. The relationships between blood test results and age were evaluated using the *p* value of mean/one-way analysis of variance for 385 men and 166 women. A scatter diagram was plotted with increases and decreases in body mass index against increases and decreases in waist circumference from 2008 to 2009. Data outside the 95% probability sphere or 95% confidence limits were considered to contain measurement error. Measurement error occurred with a frequency of 3.6% in males and 2.6% in females. In addition, blood test results showed that the mean triglyceride level in males had become higher than the standard value. Since error occurs in waist measurement, there is a need to create a system that can measure the waist accurately and to devise a framework for rechecks of health checkup data. Interventions are also needed to reduce triglyceride levels in men.

Key words: Waist circumference, Metabolic syndrome, Follow-up survey

INTRODUCTION

In Japan, lifestyle-related diseases account for about a third of total national medical expenditure. Many lifestyle-related diseases are chronic diseases, and persons with these diseases are prone to arteriosclerosis and various other complications. Once such conditions occur, continuous treatment is needed in many cases. Since 2000, Japan has promoted the "National Health Campaign for the 21st Century," which aims to maintain population health. However, the numbers of both diabetic patients and obese persons continue to increase [1, 2].

In 2008, a system of special health checkups and guidance was initiated for persons aged 40–74 years in Japan. The purpose was to identify persons with metabolic syndrome (MetS) and pre-metabolic syndrome (Pre-MetS) and provide them with guidance on to how to make lifestyle improvements to prevent the occurrence of lifestyle-related diseases.

The diagnostic criteria for MetS differ slightly in each country; in Japan, MetS is defined as a state in which a person has, in addition to excessive visceral fat, any 2 or more of the following: high blood sugar, hypertension, and lipid abnormalities. From the 2007 National Health and Nutrition Survey, the Ministry of Health, Labor and Welfare estimated that Japan has about 10.7 million people with MetS and 9.4 million with Pre-MetS among those aged 40–74 years[1]. However, although more than 2 years have passed since the special health checkups were introduced in Japan, there have been no reported follow-up surveys on MetS and Pre-MetS trends.

The most important diagnostic criterion for MetS is measurement of waist circumference. Waist circumference is the circumference of the abdomen at the level of the navel: the value measured at the standing umbilical level. Waist circumference should be measured when the person is standing straight and relaxed. Arms should hang naturally at the sides of the body, and breathing should be light. A measuring tape is then used to measure horizontally around the trunk at the level of the navel. In 2005, 8 organizations, including the Japan Society for the Study of Obesity, set the MetS diagnostic criterion of waist circumference at ≥85 cm for men and ≥90 cm for women[3]. Numbers thought to correspond to this visceral fat area are a waist circumference of ≥85 cm for men and ≥90 cm for women; thus, waist circumference is considered an essential diagnostic criterion. However, it has been reported that the standard values for waist circumference are not optimal[4-8], and that they are not related to the incidence of cardiovascular disease[9]. It has also been reported that when waist circumference was measured 5 times in the same subjects, measurement errors of 0.3–4.7 cm occurred[10]. Therefore, evaluating waist circumference measurement error is important. Special health checkups have been carried out for 2 years in Japan, but there have been no reports in which waist measurement error was evaluated from follow-up studies of waist circumference and body mass index (BMI).

The aim of this study was to obtain useful findings related to diagnostic criteria for MetS and special health checkups. A statistical analysis was conducted on the results of special health checkups, and the accuracy of waist measurements was evaluated. In addition, we conducted a follow-up study of MetS incidence, using the results of the special health checkups.

SUBJECTS AND METHOD

SUBJECTS

This study is an "epidemiological study using as data only anonymous information that can no longer be connected," as described in the Ethical Guidelines for Epidemiological Research issued in July 2002. Thus, it is not

covered by the guidelines. However, in consideration of the principles of informed consent and the protection of personal information stipulated in the guidelines, the study (No. 08-001) obtained approval from the Kinki University Faculty of Pharmacy Ethics Committee. In the study, consent forms were collected on the day of the health checkup, and the results of blood tests for 385 male and 166 female faculty members who took the test for 2 consecutive years were used. Their mean ages were 40.5 ± 11.2 years for men and 40.1 ± 10.9 years for women. BMI was calculated as body weight divided by the square of the height. The diagnostic criteria for MetS conformed to the diagnostic criteria established by 8 associations, including the Japan Society for the Study of Obesity[3]. Waist circumference ≥85 cm for men and ≥90 cm for women was an essential criterion. Selection items were: (I) triglycerides (TG) ≥150 mg/dl, HDL cholesterol (HDL-C) 40 mg/dl, or hyperlipidemia treatment; (II) systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg, or hypertension treatment; and (III) fasting blood sugar (BS) ≥110 mg/dl or treatment for diabetes. Persons with 2 or more of these items were considered to have MetS, and those with 1 item were considered to have Pre-MetS.

Persons with HbA1c ≥6.5%, or who said that they were receiving treatment, were strongly suspected of having diabetes (probable diabetes), whereas the possibility of diabetes could not be ruled out in persons with HbA1c from 6.1% to less than 6.5% (possible diabetes). The relationship between each blood test item and age was evaluated by calculating the p value for mean/one-way analysis of variance (ANOVA). Statistical analysis and tests of significance were carried out using Windows JMP ver. 8.0.2 (SAS Institute Inc., Tokyo, Japan).

EVALUATION OF THE CORRECTNESS OF WAIST MEASUREMENTS

We made a scatter diagram of increases and decreases in BMI plotted against increases and decreases in waist circumference for 2008–2009. A linear relationship was seen between increases and decreases in waist circumference and increases and decreases in BMI. In addition, assuming that the risk for recurrent error was less than 5%, we drew 95% probability spheres[11] and obtained 95% confidence limits[12] for individual values; this was done using Windows JMP ver.8.0.2. Ninety-five percent probability spheres evaluate variation. They are spheres within which 95% of the data will exist. Probability spheres have been used to evaluate variation in BMI in different age groups[13]. Data outside the 95% probability sphere or beyond the 95% confidence limit for individual values were taken as data with measurement error.

RESULTS

SPECIAL HEALTH CHECKUPS FOR EACH AGE GROUP

The results of the special health checkups in each age group are shown in Table 1. Our findings showed that, in males, waist circumference increased significantly with age ($p < 0.05$), as did systolic and diastolic blood pressures ($p < 0.001$). Mean HDL-C was 55.2 ± 13.6 mg/dl in all age groups. No significant difference was seen with age, although levels decreased after the age of 40 years. Mean total cholesterol (T-Cho) was 211.6 ± 34.8 mg/dl, and this increased significantly with age ($p < 0.001$). Hypertriglyceridemia (≥150 mg/dl) was seen in 138 of 385 males, for a prevalence rate of 35.8%. In this study, BS increased significantly with age in males ($p < 0.001$), reaching the highest level of 106.0 ± 18.6 mg/dl in men in their 60s. The mean value for all ages was 100.1 ± 21.1 mg/dl. The percentages of persons in whom diabetes mellitus was strongly suspected or in

whom the possibility could not be ruled out were 6.8% and 13.5%, respectively. No abnormalities were seen in other blood test results as a group.

Table1. Special health checkups data of employee in each age group in 2008 and 2009

Age (year)	20-29	30-39	40-49	50-59	60-	Total	*p*
Male in 2009							
Number of male	14	92	97	95	87	385	
Average age (year)	26.5 ± 2.0	35.6 ± 2.6	44.6 ± 2.6	54.8 ± 2.8	63.0 ± 2.5	48.5 ± 11.2	
Height (cm)	172.3 ± 5.9	172.2 ± 5.7	170.5 ± 5.7	169.4 ± 6.1	167.8 ± 4.9	170.1 ± 5.8	
Weight (kg)	71.9 ± 18.1	73.4 ± 13.1	70.2 ± 12.6	69.8 ± 10.3	69.6 ± 9.0	70.8 ± 11.7	
BMI (kg/m^2)	24.1 ± 4.8	24.7 ± 4.1	24.1 ± 3.6	24.3 ± 3.0	24.7 ± 2.7	24.4 ± 3.5	
Waist circumference (cm)	—	—	83.5 ± 9.3	84.6 ± 8.6	86.8 ± 7.4	84.8 ± 9.1	*
Systolic BP (mmHg)	128.3 ± 9.9	128.3 ± 14.7	130.5 ± 18.6	136.9 ± 19.6	138.6 ± 18.4	133.3 ± 18.1	***
Diastolic BP (mmHg)	78.6 ± 11.4	79.3 ± 12.1	81.0 ± 12.6	86.2 ± 13.1	85.1 ± 9.4	82.7 ± 12.2	***
T-Cho (mg/dl)	183.4 ± 35.3	206.4 ± 36.4	218.4 ± 32.7	215.1 ± 36.8	210.4 ± 30.1	211.6 ± 34.8	**
TG (mg/dl)	108.4 ± 88.9	154.8 ± 170.7	138.5 ± 76.8	139.7 ± 84.8	136.4 ± 77.7	141.1 ± 108.9	
HDL-C (mg/dl)	55.9 ± 12.5	53.6 ± 13.7	57.0 ± 14.9	55.9 ± 13.6	54.2 ± 12.2	55.2 ± 13.6	
BS (mg/dl)	90.6 ± 12.5	94.0 ± 13.2	101.5 ± 29.9	100.6 ± 17.5	106.0 ± 18.6	100.1 ± 21.1	
HbA1c	5.5 ± 0.5	5.5 ± 0.5	5.7 ± 0.9	5.8 ± 0.7	6.1 ± 0.7	5.7 ± 0.7	***
Female in 2009							
Number of female	38	51	39	33	5	166	
Average age (year)	26.1 ± 2.0	35.6 ± 2.5	44.5 ± 2.5	54.5 ± 3.0	63.0 ± 2.4	40.1 ± 10.9	
Height (cm)	159.3 ± 5.1	159.0 ± 5.4	157.2 ± 5.8	157.3 ± 5.7	154.9 ± 4.9	158.2 ± 5.5	
Weight (kg)	51.5 ± 7.4	52.0 ± 6.2	55.1 ± 10.5	56.0 ± 9.2	55.3 ± 5.2	53.5 ± 8.4	
BMI (kg/m^2)	20.3 ± 2.5	20.5 ± 1.9	22.3 ± 3.8	22.6 ± 2.8	23.0 ± 1.2	22.4 ± 3.3	
Waist circumference (cm)	—	—	76.9 ± 9.6	79.8 ± 9.5	83.5 ± 5.0	77.1 ± 9.4	
Systolic BP (mmHg)	109.2 ± 11.2	106.0 ± 11.0	119.4 ± 17.9	127.7 ± 19.7	134.4 ± 13.5	115.1 ± 17.3	***
Diastolic BP (mmHg)	63.8 ± 7.5	64.6 ± 8.1	72.3 ± 13.2	79.1 ± 11.6	79.2 ± 11.1	69.6 ± 11.8	***
T-Cho (mg/dl)	177.7 ± 32.1	194.3 ± 30.2	207.6 ± 27.7	230.8 ± 32.9	232.2 ± 20.8	202.0 ± 35.5	***
TG (mg/dl)	52.0 ± 19.3	67.7 ± 29.7	85.9 ± 37.9	105.5 ± 72.0	95.0 ± 46.0	76.8 ± 45.8	***
HDL-C (mg/dl)	70.7 ± 13.0	70.2 ± 11.2	67.3 ± 14.9	68.5 ± 17.6	71.0 ± 14.2	69.3 ± 13.9	
BS (mg/dl)	88.1 ± 7.0	86.6 ± 8.7	90.8 ± 7.1	102.8 ± 42.3	100.6 ± 7.3	91.6 ± 20.8	
HbA1c	5.4 ± 0.3	5.4 ± 0.3	5.4 ± 0.4	5.9 ± 0.8	5.9 ± 0.3	5.5 ± 0.5	***

*; $p<0.05$, **; $p<0.01$, ***; $p<0.001$

In females, no significant difference was seen in waist circumference with age, although this increased. Moreover, although systolic blood pressure decreased slightly in females in their 30s compared with females in their 20s, both systolic blood pressure and diastolic blood pressure increased significantly with age ($p < 0.001$). Mean HDL-C was lowest in females in their 40s, while the mean value for all ages was 69.3 ± 13.9 mg/dl. T-Cho increased significantly with age ($p < 0.001$), and the mean value was 202.0 ± 35.5 mg/dl. Although TG was slightly lower in females in their 60s than in those in their 50s, it increased significantly with age ($p < 0.001$). Hypertriglyceridemia was found in 4 of 166 females, for a prevalence rate of 2.4%. This was conspicuously lower than in men. BS was at its highest level in females in their 50s, and increased significantly with age ($p < 0.01$). Mean BS in all ages was 91.6 ± 20.8 mg/dl. The percentages of persons in whom diabetes mellitus was strongly suspected or in whom the possibility could not be ruled out were 1.2% and 9.0%, respectively. No abnormalities were seen in other blood test results as a group.

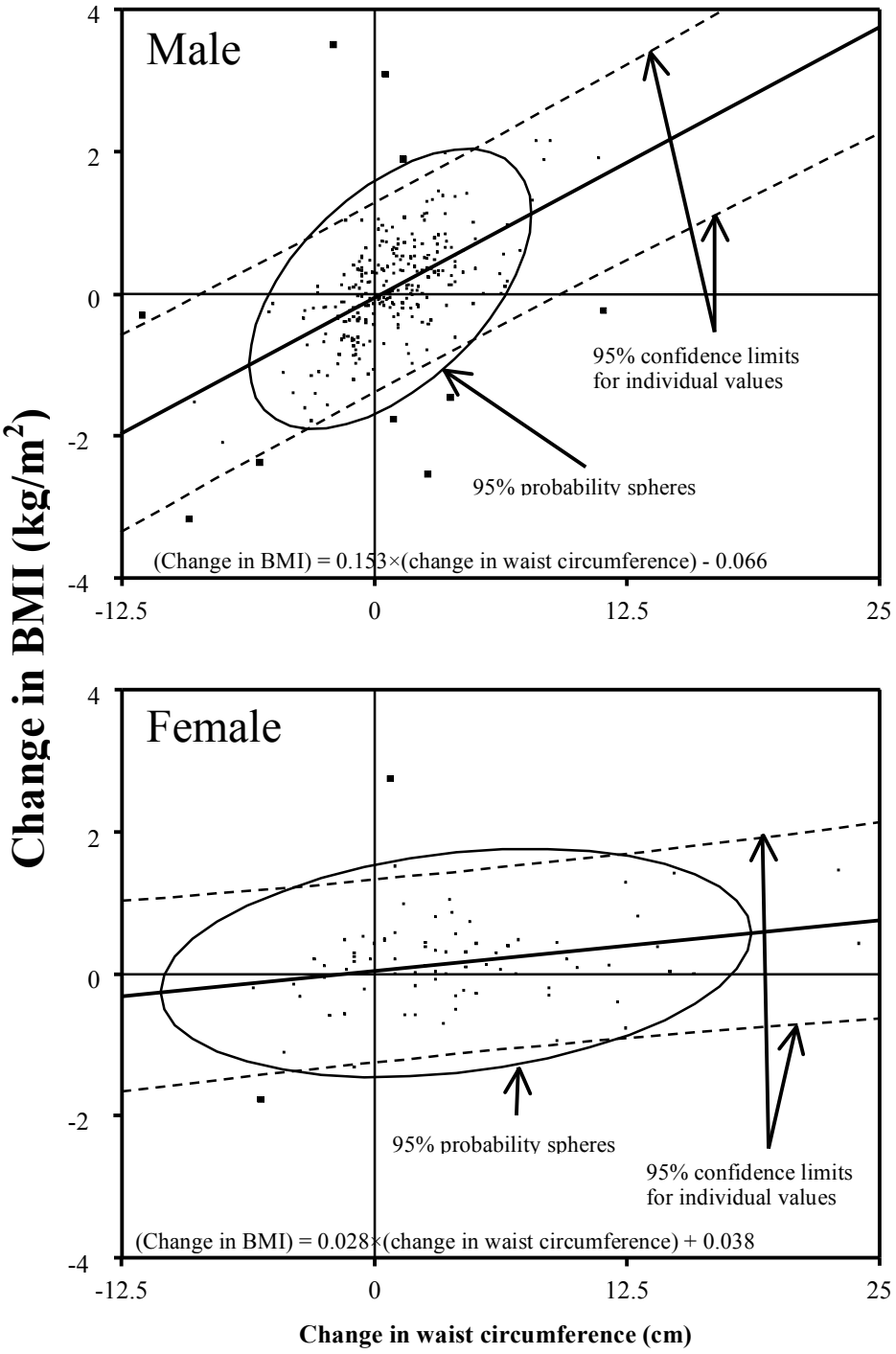

Fig. 1 Relationship between waist circumference and BMI of employee in 2008 and 2009

FOLLOW-UP SURVEY IN SPECIAL HEALTH CHECKUPS

To evaluate waist measurement error in special health checkups, changes in BMI in 2008–2009 were plotted against changes in waist circumference in men and women (Fig. 1). The results showed a positive correlation between changes in waist circumference and BMI in both men and women. The sphere in Fig. 1 is the 95% probability sphere, and the broken lines show the 95% confidence limits. In this

study, we assumed the risk of error occurring was less than 5%; thus we judged values outside the 95% probability sphere or beyond the 95% confidence limits with respect to individual values to be data with measurement error. The results suggested that measurement error may have occurred in 10 of 279 men and 2 of 77 women. Thus measurement error occurred with a rate of 3.6% in males and 2.6% in females.

The MetS and Pre-MetS trends for the 269 men and 75 women judged to have no measurement error in 2008–2009 are shown in Table 2. The results show an increase with age in the percentage of men who were Healthy in 2008 but no longer Healthy in 2009. In addition, the percentage of MetS men in 2008 who became Pre-MetS was 3.0%. Similarly, the percentage of Pre-MetS men who became MetS also increased with age. In males, the percentage of persons who saw a change in status from Healthy to MetS or Pre-MetS in 2008–2009 (7.8%) was lower in total compared with females (5.3%).

Table 2. Change in health condition from 2008 to 2009 of employee in each age group

	in 2009 (%)											
	Health	Pre-MetS	MetS	Health	Pre-MetS	MetS	Health	Pre-MetS	MetS	Health	Pre-MetS	MetS
Male in 2008												
Age (year)	40-49 (n=95)			50-59 (n=92)			60- (n=82)			Total (n=269)		
Health	67.4	6.3	2.1	59.8	5.4	3.2	43.9	4.9	1.2	57.6	5.6	2.2
Pre-MetS	2.1	6.3	3.2	2.2	9.8	7.6	1.2	13.4	8.5	1.8	9.7	6.3
MetS	1.0	2.1	9.5	0	2.2	9.8	0	4.9	22.0	0.4	3.0	13.4
Female in 2008												
Age (year)	40-49 (n=39)			50-59 (n=31)			60- (n=5)			Total (n=75)		
Health	94.8	2.6	0	77.4	6.5	3.2	100.0	0	0	88.0	4.0	1.3
Pre-MetS	0	2.6	0	0	3.2	3.2	0	0	0	0	2.7	1.3
MetS	0	0	0	0	0	6.5	0	0	0	0	0	2.7

The trends in health status in the 10 men and 2 women for whom measurement error was judged to have occurred in 2008–2009 are shown in Table 3. 4 men and 2 women were Healthy in 2008–2009. 1 man who was healthy in 2008 became Pre-MetS and one man who was healthy in 2008 became MetS. Of the men who were Pre-MetS in 2008, 1 man became Healthy and 1 man who was MetS became Pre-MetS.

Table 3. Change in health condition from 2008 to 2009 of employee with unusual BMI or waist circumference data in each age group

	Numbers of employee in 2009											
	Health	Pre-MetS	MetS	Health	Pre-MetS	MetS	Health	Pre-MetS	MetS	Health	Pre-MetS	MetS
Male in 2008												
Age (year)	40-49 (n=2)			50-59 (n=3)			60- (n=5)			Total (n=10)		
Health	0	0	0	3	0	0	1	1	1	4	1	1
Pre-MetS	1	0	0	0	0	0	0	1	0	1	1	0
MetS	0	0	1	0	0	0	0	1	0	0	1	1
Female in 2008												
Age (year)	40-49 (n=0)			50-59 (n=2)			60- (n=0)			Total (n=2)		
Health	0	0	0	2	0	0	0	0	0	2	0	0
Pre-MetS	0	0	0	0	0	0	0	0	0	0	0	0
MetS	0	0	0	0	0	0	0	0	0	0	0	0

DISCUSSION

SPECIAL HEALTH CHECKUP IN EACH AGE GROUP

In the results of blood tests, we focused on waist circumference, blood pressure, TG, HDL-C, BS, and T-Cho, which are the indicators most closely related to lifestyle-related diseases. All of these values are necessary in MetS. In the 2003 National Health and Nutrition Survey, it was reported that the mean systolic blood pressure in males above the age of 20 years was 120–139 mmHg[2]. In the special health checkup in this study, the mean systolic blood pressure was 133.3 ± 18.1 mmHg, a similar value. In addition, in the 2003 National Health and Nutrition Survey, HDL-C was measured in roughly 5,000 adult males above the age of 20 years and was reported to be 50–59 mg/dl. [2] In the present checkups, mean HDL-C was 55.2 ± 13.6 mg/dl, similar to the national average. Meanwhile, the mean T-Cho level reported in the 2003 National Health and Nutrition Survey was 180–199 mg/dl[2]; thus, the present subjects were found to have high T-Cho. Hypercholesterolemia has been shown to be a risk factor for ischemic heart disease. In addition, T-Cho shows the most rapid increase among the major risk factors for ischemic heart disease, and there is concern about its effect on mortality because of the onset of ischemic heart disease in the future[14]. Therefore, we believe that education on lifestyle improvements to reduce T-Cho will be necessary.

In the 2003 National Health and Nutrition Survey, the prevalence of hypertriglyceridemia in males was found to be 35.8%. This demonstrated the need to lower TG by implementing interventions to improve lifestyle, including eating and exercise habits.

According to the Ministry of Health, Labor and Welfare, medical costs for diabetes mellitus in Japan in 2002, accounted for 4.7% of Japan's general medical care costs of about 1 trillion,

100 billion yen[15, 16]. The number of patients in 1987 was about 950,000, but in 2002 this reached about 2.29 million. This was a noteworthy increase of 1.3 million people in 18 years[17]. In a diabetes survey conducted by the Ministry of Health, Labour and Welfare in 2002, the percentages of all males with probable or possible diabetes were 12.8% and 10.0%, respectively[18]. Similarly, in a survey of diabetes in the 2007 National Health and Nutrition Survey, the percentages with probable or possible diabetes were calculated to be 15.3% and 14.0%, respectively. Thus, 29.3% of males were either diabetic or pre-diabetic[19]. In a survey of diabetes in the present special health checkups, the percentages of persons with probable or possible diabetes were 6.8% and 13.5%, respectively. This indicates a positive trend, with fewer persons strongly suspected of having diabetes.

In the 2003 National Health and Nutrition Survey, the mean systolic blood pressure of women above the age of 20 years was reported to be 110–129 mmHg[2]. In the special health checkup in this study, the mean systolic blood pressure was 115.1 ± 17.3 mmHg, or similar to the national average. Similarly, HDL-C was reported to be 60–69 mg/dl[2], and in the special health checkups, the lowest mean value was seen in those aged in their 40s. The mean value for women in their 20s–60s was 69.3 ± 13.9 mg/dl, somewhat higher than the national average. In addition, T-Cho was reported to be 200–219 mg/dl in the 2003 National Health and Nutrition Survey[2], and we found a value very close to the national average in the special health checkups. However, the standard value for T-Cho is 150–219 mg/dl or less, and since T-Cho can be a risk factor for hypertension and arteriosclerosis, education on lifestyle improvements with a focus on T-Cho is believed to be needed. The mean value for females in their 50s, in particular, exceeded the standard value, and thus interventions to improve lifestyle were also found to be necessary. TG, one of the diagnostic criteria for MetS, increased significantly with age although there was a slight decrease in TG in females in their 60s compared with level seen in women in their 50s. However, the prevalence of hyper-triglyceridemia was, at 7.2%, lower than in men.

The 2007 National Health and Nutrition Survey found that the percentages for probable and possible diabetes were 6.5% and 11.0%, respectively, with a calculated value of 17.5% of females. However, the results of the special health checkups showed that the percentages of females with probable or possible diabetes were 1.2% and 9.0%, respectively, or lower than the national average. This result, similar to that for males, may be considered a positive trend.

FOLLOW-UP SURVEY OF SPECIAL HEALTH CHECKUPS

MetS diagnosis began in 2008 in Japan. However, there have been no reported detailed evaluations of the percentage of healthy persons who become Pre-MetS or MetS. In the special checkups in this study, the percentage of males who changed with age from Healthy in 2008 to not Healthy in 2009 and the percentage who changed from Pre-MetS to MetS both increased. The proportion that changed from MetS to Healthy was 0%. Therefore, when Healthy persons change to Pre-MetS, it is thought that the prevalence rate of MetS can be decreased by providing guidance that focuses on lifestyle improvements. Once a person becomes MetS, however, it is thought to be very difficult to make improvements.

For MetS, similar trends were seen among women, with the proportion changing from MetS to Healthy or Pre-MetS being 0%. However, the percentage of females who changed from Healthy to Pre-MetS or MetS was lower than that for males. This indicates the possibility that, among the diagnostic

criteria for MetS in Japan, measuring waist circumference is more difficult and inaccurate in males than in females. With respect to the diagnostic criteria for MetS in Japan, Ohkubo et al. reported that, when investigating insulin resistance as a diagnostic criterion for MetS, a waist circumference ≥87 cm for men and ≥80 cm for women was reasonable[5].

In the current diagnostic criteria for MetS in Japan, waist circumference is the most important indicator. However, a Ministry of Health, Labor and Welfare study group analyzed data for more than 30,000 people in Japan and noted the difficulty of determining the best value[20]. Similarly, after analyzing results from a special university health checkup in 2008, we reported that different standards for waist circumference lead to a decrease in the proportion of MetS and Pre-MetS of 6.0% for males and an increase of 17.9% for females[20]. Problems in the statistical analyses for standard waist circumference values in Japan have also been found[21]. In a study that measured waist circumference 5 times in the same subjects, the measurement error was reported to be 0.3–4.7 cm[10]. Since MetS is closely related to obesity, it has also been claimed that BMI rather than waist circumference should be used as a diagnostic criterion[22]. Evaluating the measurement error in waist circumference is very important in diagnosing MetS and Pre-MetS. In the present study, changes in waist circumference and BMI in males and females in 2008–2009 showed a positive correlation between waist circumference and BMI (correlation coefficient, males: 0.590, females: 0.590). Also, in this study, we assumed the risk of error was less than 5% and values outside the 95% probability sphere or outside the 95% confidence interval were judged to be data with measurement error. The results of a follow-up survey of data in the present special health checkups suggested that the measurement error rate is 3.6% in men and 2.6% in women. These results demonstrated that, while waist circumference is an important item, measurement error also needs to be evaluated.

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