Body Mass Index can Similarly Predict the Presence of Multiple Cardiovascular Risk Factors in Middle-aged Japanese Subjects as Waist Circumference

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Abstract

Objective Adiposity is closely associated with the clustering of metabolic risk factors such as high blood pressure, dyslipidemia, and glucose intolerance. Waist circumference and body mass index (BMI) are the established markers of abdominal adiposity and general adiposity, respectively. However, it has not been examined whether these two markers can detect the clustering of metabolic risk factors in Japanese subjects.

Methods and Results We studied 5,796 Japanese middle-aged subjects aged 40-60 years (4,344 males and 1,452 females). Metabolic risk factors including high blood pressure, dyslipidemia, and glucose intolerance were identified according to the diagnostic criteria for metabolic syndrome in Japan. The number of metabolic risk factors was significantly associated with the BMI values in both male and female subjects. The prevalence of subjects with multiple (two or more) metabolic risk factors was 29.4% and 7.6% in males and females, respectively. According to receiver operating characteristic (ROC) analysis, the area under curve values of BMI and waist circumference did not differ in male (0.658 vs. 0.671, $p=n.s.$) and female (0.776 vs. 0.790, $p=n.s.$) subjects, indicating that the waist circumference as well as the BMI could be useful in detecting the occurrence of multiple metabolic risk factors. The appropriate cut-off values of BMI to predict the presence of multiple metabolic risk factors were 24.7 and 23.4 kg/m² in males and females, respectively. The sensitivity and specificity using these cut-off values were 58 and 65% in males and 65 and 77% in females, respectively.

Conclusion The BMI values can similarly predict the presence of multiple metabolic risk factors just as the waist circumference in Japanese middle-aged subjects.

Key words: body mass index, waist circumference, risk factor, epidemiology, middle-aged Japanese subjects

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Introduction

Adiposity is associated with the accumulation of metabolic risk factors such as high blood pressure, dyslipidemia, and glucose intolerance, which may increase the risk of cardiovascular morbidity and mortality (1-6). Adiposity can be generally assessed by the measurement of waist circumference and body mass index (BMI). Previous studies have demonstrated that the waist circumference is the superior marker to predict cardiovascular risk factors than

BMI (7-10). In contrast, other studies have reported that both BMI and waist circumference values can equally identify cardiovascular risk factors (11-13). The American Diabetes Association has stated that it is unclear whether waist circumference can predict cardiovascular risk factors beyond BMI (14). These results indicate that the validity of these two markers to detect cardiovascular risk factors is a controversial issue. This is considered to be of clinical importance particularly because Asian populations have a higher proportion of percentage of body fat than Caucasians for a given BMI (15). Nevertheless, the relationship between adiposity

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markers such as BMI and waist circumference and cardiovascular risk factors has not been fully established in Japanese populations. Moreover, the association between these two markers and the clustering of cardiovascular risk factors has not been studied.

In this study, we compared the ability of waist circumference and BMI values to predict the occurrence and clustering of cardiovascular risk factors in middle-aged Japanese subjects.

Methods

Study subjects

The present study included 6,056 Japanese subjects who were employed in food and telephone service company in Hokkaido, aged from 40 to 60 years old [50 ± 8 years, mean $\pm$ standard deviation (SD)], and had an annual health check-up during the period between April 2008 and March 2009. A total of 260 subjects (199 males and 61 females) were excluded due to prior coronary artery disease (CAD) or stroke. Thus, a total of 5,796 subjects remained in the present analysis. The study protocol was approved at two study companies and informed consent was obtained from all subjects.

Data collection

Blood samples were obtained from antecubital vein in the morning after overnight fasting and serum samples were separated after centrifugation. HDL-C was measured after precipitation of apo B-containing lipoproteins with a commercial reagent containing phosphotungstate and magnesium chloride (Daiichi Pure Chemicals, Tokyo, Japan). Triglyceride was measured enzymatically (Kyowa Medex, Tokyo, Japan). Fasting plasma glucose was enzymatically determined by the hexokinase method (Shino-Test, Tokyo, Japan). Blood pressure was measured by a trained nurse using a standard mercury sphygmomanometer with the study subjects in the sitting position after at least a 5-minute rest. Body weight, height, and waist circumference were measured in the morning in the fasting state. Waist circumference was measured around the abdomen at the level of the navel at the late expiratory phase by using a tape measure. BMI was calculated as body weight (kg) divided by squared height (m^2).

Metabolic risk factors were diagnosed based on the new definition released by the Japanese Committee for the Diagnostic Criteria of Metabolic Syndrome in April 2005 (16); 1) high blood pressure; systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg, 2) dyslipidemia; triglyceride ≥ 150 mg/dl and/or HDL-C < 40 mg/dL, and 3) glucose intolerance; fasting plasma glucose ≥ 110 mg/dl. Each factor was considered to be present when the subject was under medication. Two or more risk factors were defined as "multiple" risk factors.

Table 1. Clinical Characteristics of the Study Subjects

	Male (n=4,344)	Female (n=1,452)
Age (years)	52 ± 8	$50 \pm 7^*$
Waist circumference (cm)	85 ± 9	$78 \pm 9^*$
Body mass index (kg/m^2)	23.9 ± 3.4	$21.9 \pm 3.5^*$
Systolic blood pressure (mmHg)	126 ± 19	$118 \pm 18^*$
Diastolic blood pressure (mmHg)	79 ± 12	$71 \pm 12^*$
Triglyceride (mg/dL)	112 (81 - 156)	73 (53 - 101)*
HDL-cholesterol (mg/dL)	55 ± 14	$70 \pm 16^*$
Fasting plasma glucose (mg/dL)	100 ± 28	$90 \pm 15^*$
Medical history		
Hypertension (%)	16.8	8.4*
Diabetes mellitus (%)	6.0	1.2*
Dyslipidemia (%)	1.8	2.1

Values are presented as mean $\pm$ SD, median (interquartile range) for skewed variables,

or percentage.

HDL; high-density lipoprotein cholesterol.

* $p < 0.05$ vs. male.

Statistical analysis

All analyses were performed separately according to gender. The clinical and biochemical data of the study subjects were expressed as means $\pm$ SD, a median (and interquartile range) for variables with a skewed distribution, and percentages. The differences between two groups were examined by the Student unpaired t test for variables distributed normally, or by the Wilcoxon rank-sum test for triglyceride, and by the χ^2 -test for the categorical variables. A one-way analysis of variance (ANOVA) was used to calculate the differences in continuous variables among the multiple groups. Receiver operating characteristic curve (ROC) analysis was used to determine the appropriate waist circumference according to male and female. We calculated the maximal sensitivity and specificity between waist circumference and multiple risk factors. According to the ROC curve, the appropriate point was defined as the closest point on the ROC curves to the point at 1-specificity of 0 and sensitivity of 100%. A p value of less than 0.05 was considered to indicate statistical significance. All statistical analyses were performed by using the Statistical Package for Social Science (version 11.0).

Results

Table 1 shows the clinical characteristics of the study subjects. Male subjects were older and had greater waist circumference, BMI, systolic and diastolic blood pressure, triglyceride, fasting plasma glucose, and lower high density lipoprotein cholesterol than female subjects. The prevalence of medical history for hypertension and diabetes mellitus was significantly higher in males than in females.

Figure 1 shows the relationship between BMI values and the numbers of metabolic risk factors among the study subjects. The BMI values were significantly greater according to the increase in the numbers of metabolic risk factors in

Figure 1. Body mass index values according to the numbers of metabolic risk factors in male (A) and female (B) subjects.

Figure 2. Waist circumference values according to the numbers of metabolic risk factors in male (A) and female (B) subjects.

both males and females. The BMI values of the study subjects who had multiple risk factors were 25.0 ± 3.5 and 25.2 ± 4.2 kg/m² in males and females, respectively.

Figure 2 shows the relationship between waist circumference values and the numbers of metabolic risk factors among the study subjects. The waist circumference values were significantly greater according to the increase in the numbers of metabolic risk factors in both male and female subjects. The waist circumference values of the study subjects who had multiple risk factors were 89 ± 6 and 88 ± 9 cm in males and females, respectively.

Figure 3 shows the ROC curve to determine the appropriate BMI values for detecting the presence of multiple risk factors in males and females. In male subjects with the cut-off value of 24.7 kg/m², the sensitivity and specificity were 58% and 65%, respectively, which were found to be the maximal values. In female subjects with the cut-off value of 23.4 kg/m², the sensitivity and specificity were 65% and 77%, respectively, which were the maximal values. The sensitivity became as low as 47% and specificity was 88%, when the cut-off value of 25 kg/m² was used in female sub-

jects.

Figure 4 shows the ROC curve to determine the appropriate waist circumference values for detecting the presence of multiple risk factors in males and females. In male subjects with the cut-off values of 86 cm, the sensitivity and specificity were 62% and 64%, respectively, which were found to be the maximal values. In female subjects with the cut-off value of 83 cm, the sensitivity and specificity were 71% and 75%, respectively, which were the maximal values. The sensitivity became as low as 47% and specificity was 88% when the waist circumference cut-off value of 90 cm was used in female subjects.

Table 2 shows the area under curve (AUC) values of waist circumference and BMI by using ROC analysis to detect multiple risk factors in both genders. AUC values did not differ between waist circumference and BMI in either males or females.

Discussion

The present study demonstrated that both waist circumfer-

Figure 3. The ROC (receiver operating characteristic) curve for body mass index to detect multiple metabolic risk factors in male (A) and female (B) subjects. AUC: area under curve

Figure 4. The ROC (receiver operating characteristic) curve for the waist circumference to detect multiple metabolic risk factors in male (A) and female (B) subjects. AUC: area under curve

ence and BMI values were equally useful markers to identify the presence of multiple cardiovascular risk factors in middle-aged Japanese subjects. The cut off values of waist circumference to predict multiple cardiovascular metabolic risk factors were 86 cm and 83 cm in males and females, respectively. Those of BMI were 24.7 kg/m² and 23.4 kg/m² in males and females, respectively.

General and abdominal adiposity were closely associated with the risk of death and the occurrence of cardiovascular disease (17, 18). Insulin resistance due to adiposity is the pathophysiological basis for the presence of cardiovascular metabolic risk factors such as high blood pressure, dyslipidemia, and glucose intolerance (19). Clustering of these risk factors is now recognized as an emerging risk for coronary artery disease (20, 21). The adiposity was generally identified by the measurement of waist circumference and BMI. The World Health Organization and the National Institutes of Health provided guidelines for classifying body weight status based on BMI and demonstrated a close relation between BMI and cardiovascular risk factors (22, 23). Recently, waist circumference has been widely used as a surrogate marker of abdominal adiposity, because waist circumference is correlated with abdominal fat mass and it is more associated with cardiovascular risk factors than BMI (7-10). However, the validity of these two markers to detect the presence of cardiovascular risk factors has been controver-

Table 2. Area under Curves of Waist Circumference and Body Mass Index for Multiple Risk Factors

	Body mass index	Waist circumference	p-value
Male			
AUC	0.658	0.671	n.s.
95% CI	0.636 - 0.692	0.650 - 0.692	
Female			
AUC	0.776	0.790	n.s.
95% CI	0.719 - 0.834	0.734 - 0.847	

AUC, area under curves; CI, confidence interval.

sial among the reports. Shen et al reported that both waist circumference and BMI were closely correlated with total body adipose tissue mass, but waist circumference was a better predictor to detect visceral obesity than BMI in Caucasians (24). Similarly, Klein et al demonstrated that adipose fat mass was more associated with waist circumference than BMI (14). However, Lear et al reported that Asians had a higher percentage of body fat than Caucasians despite a given BMI (15). These results suggested that the distribution of body fat mass in Asians differed from Caucasians and

BMI might be superior to detect visceral obesity in Asians than in Caucasians. The present study demonstrated that both BMI and waist circumference could equally predict the presence of multiple cardiovascular risk factors in Japanese population.

The World Health Organization Western Pacific Region and others proposed the definition of obesity as BMI ≥ 25 kg/m² on the Asia-Pacific region (25). Ishikawa-Takata et al demonstrated the degrees of BMI associated with cardiovascular risk factors were lower than those in Caucasians (26). Thus, the appropriate cut-off BMI values to detect the presence of multiple cardiovascular risk factors may be lower than 25 kg/m². The present study has demonstrated that this is the case.

Specific health examination has been newly started in Japan, in which the cut-off values of waist circumference were 85 cm in males and 90 cm in females (16, 27). However, Miyawaki et al analyzed data from 3,574 employees of a telephone company and their family members (2,947 males and 627 females) obtained from health examinations and demonstrated that the appropriate cut-off waist circumference values were 86 cm for males and 77 cm for females to detect multiple risk components by using Japanese criteria based on their visceral-fat area cut-off levels of 100 cm² in males and 65 cm² in females (28), in which the appropriate cut-off values of waist circumference were lower than those in specific health examination. Our results also confirmed these previous findings.

Baik demonstrated optimal waist circumference values of 84-86 cm for men and of 78-80 cm for women to detect multiple cardiovascular risk factors in Korean populations (29). Takahashi et al indicated that cut-off values to detect multiple cardiovascular risk factors were 85 cm (men) and 80 cm (women) in waist circumference and 24 kg/m² (men) and 23 kg/m² (women) in BMI in Japanese popula-

tions and the combination of both waist circumference and BMI was more useful than using only one of these parameters (30). Both sensitivity and specificity increased by using the combination of these two markers; however, the equivalent interaction as a trade off was generally present in evaluating a screening test and the statistical accuracy might be limited in using this strategy. The appropriate cut-off values of waist circumference and BMI in our study confirmed the results of these previous studies. However, these studies could not investigate the comparison and superiority between waist circumference and BMI as a screening tool to identify the presence of multiple cardiovascular risk factors, which differed from the present study.

There are several limitations that should be acknowledged in this study. First, our study subjects ranged from 40 to 60 years old. Therefore, we have to be cautious in extending the present results to the general population. Second, even though visceral obesity is considered to be associated with CAD, we did not obtain the outcome data including the occurrence of CAD in this study. Further studies are needed to evaluate the association between BMI or waist circumference and future occurrence of cardiovascular events to define the appropriate cut-off values of waist circumference in the Japanese population.

Conclusions

The present study concluded that both BMI and waist circumference values were associated with cardiovascular risk factors, and BMI values can equally predict multiple cardiovascular risk factors as waist circumference in middle-aged Japanese subjects. It is one of the important instructions for health promotion strategy to maintain appropriate BMI and waist circumference values by lifestyle modification including diet and exercise.

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