Original Article

Comparisons between anthropometric indices for predicting the metabolic syndrome in Japanese

Masayuki Kato MD PhD[1], Yoshihiko Takahashi MD PhD[2], Manami Inoue MD PhD[3], Shoichiro Tsugane MD PhD[3], Takashi Kadowaki MD PhD[4] and Mitsuhiko Noda MD[2]; for JPHC study group

[1]*Japan Foundation for the Promotion of International Medical Research Cooperation, Tokyo, Japan*
[2]*Department of Diabetes and Metabolic Medicine, International Medical Center of Japan, Tokyo, Japan*
[3]*Epidemiology and Prevention Division, Research Center for Cancer Prevention and Screening, National Cancer Center, Tokyo, Japan*
[4]*Department of Metabolic Diseases, Graduate School of Medicine, University of Tokyo, Tokyo, Japan*

Aims: Most definitions of the metabolic syndrome (MS) employ waist circumference as an indicator of central obesity. However, several reports, mainly from Asia, argue that other indices, for example the waist/height ratio, are superior to waist circumference for identifying subjects with cardiovascular risk factors. We therefore investigated correlations between the predictive power of several anthropometric indices and risk factor accumulation (RFA) defined by the existence of two or more disorders among hypertension, dyslipidemia (high triglycerides and/or low levels of high density lipoprotein cholesterol) and fasting hyperglycemia; each of which is a component of MS. **Methods:** We conducted a cross-sectional analysis using data from a part of the Japan Public Health Center-based Cohort. A total of 315 men and 314 women, 51 to 70 years of age were examined for variables including waist and hip circumferences, blood pressure, fasting plasma glucose and lipids at an annual health check-up. **Results:** The prevalence of RFA increased almost linearly in parallel with increasing waist circumference up to 95 cm. Receiver operating characteristic analysis demonstrated that waist circumference was better than waist/ height ratio, waist/hip ratio and BMI at predicting RFA; but the differences were not statistically significant. However, even in the case of waist circumference, no clear cut-off point yields sufficiently high sensitivity and specificity simultaneously. **Conclusions:** The predictive power of waist circumference was not inferior to those of other indices. Therefore, waist circumference is practically the most convenient measure for predicting MS because of its simplicity.

Key Words: metabolic syndrome, waist circumference, waist/hip ratio, waist/height ratio, body-mass index

INTRODUCTION
In recent years, the concept, definition and criteria for the metabolic syndrome (MS) as a risk factor for cardiovascular diseases have been increasingly discussed. At present, there are several definitions of the MS, proposed by the World Health Organization,[1] American Heart Association/National Heart, Lung, and Blood Institute,[2] the European Group for the Study of Insulin Resistance[3] and the International Diabetes Federation (IDF). Recently, the IDF released a new definition of the MS[4] intended to take into account ethnic differences. The Japanese Society of Internal Medicine also announced a definition of the MS for the Japanese[5] which is now used in Japan. Most of these definitions employ waist circumference as an indicator of central or abdominal obesity. However, several reports have argued that other indices, for example the waist/height ratio[6-10] and waist/hip ratio,[11,12] are superior to waist circumference for identifying subjects with cardiovascular risk factors. In particular, reports from Japan have proposed using the waist/height ratio.[6, 9, 10] We therefore investigated correlations between anthropometric indices, such as waist circumference, waist/ height ratio, waist/hip ratio and body-mass index (BMI); and risk factor accumulation (RFA) defined as the existence of any two (or three) of the following disorders: hypertension, dyslipidemia (defined by high triglycerides [TG] and/or low levels of high density lipoprotein cholesterol [HDL-C]) and fasting hyperglycemia.

MATERIALS AND METHODS
Participants in this study were part of the Japan Public Health Center-based Prospective Study (JPHC Study) which is an ongoing longitudinal cohort study investigating cancer, cardiovascular diseases and other lifestyle-related diseases. The details of this cohort are described elsewhere.[13] The JPHC Study composes of two cohorts, I and II, and participants in this study are part of cohort I.

The JPHC Cohort I was initiated in 1990 and the study population was defined as all registered Japanese inhabitants of the five public health center areas, 40–59 of age at the beginning of the baseline survey (year 1990). A self-administered follow-up questionnaire was sent to the enrolled participants,[14] some of whom voluntarily underwent an annual health check-up conducted by the Public Health Center (PHC) of their county and agreed to donate their laboratory and anthropometric data. In the year 2000, a 10-year follow-up survey was conducted and the present study is linked to this follow-up survey. We analyzed participants in the Saku PHC area, a PHC area of cohort I, who underwent annual health check-ups at one of the major hospitals in this area in 2000. In this hospital, participants also had their waist and hip circumferences measured by public health nurses trained in the standardized method. Waist and hip circumferences were measured with the subject in a standing position. Waist circumference was measured at the umbilical level[5] and hip circumference at the widest part of the hip. The waist and hip measurements were read to the nearest 1 cm. We excluded subjects who answered "yes" to the question "Do you take any cholesterol lowering drugs?" because this self-reported history may include medications for high TG (and/or low HDL-C) in addition to high levels of low density lipoprotein cholesterol.

We defined subjects with RFA as those who met two or three of the following criteria; 1) systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg, or taking medication(s) for blood pressure; 2) fasting TG ≥ 150 mg/dL, HDL-C < 40 mg/dL; and 3) fasting plasma glucose ≥ 6.1 mmol/L or taking medication(s) for hyperglycemia. These definitions of high blood pressure, dyslipidemia and fasting glycemia met those announced by the Japanese Society of Internal Medicine.[5] We examined the associations of RFA with anthropometric indices, including waist circumference, waist/height ratio, waist/hip ratio and BMI, using receiver operating characteristic (ROC) analyses. Data analyses were performed with STATA version 9.2 (StataCorp, Texas, USA). Written informed consent was obtained from all participants whose data were analyzed.

Table 1. Characteristics of the participants

	Men (n=315)		Women (n=314)	
Age†	62	(56-66)	62	(57-67)
BMI (kg/m^2) ‡	23.5	(3.2)	23.4	(3.1)
Waist (cm) ‡	84.8	(8.0)	80.4	(8.5)
Waist/height ratio‡	0.52	(0.05)	0.53	(0.06)
Waist/hip ratio‡	0.91	(0.05)	0.87	(0.07)
FPG (mg/dl) ‡	106.2	(17.5)	101.6	(14.8)
TG (mg/dl) †	114	(83-172)	95	(72-135)
HDL-C (mg/dl) ‡	60.2	(13.9)	68.4	(14.6)
SBP (mmHg) ‡	129.9	(16.7)	126.8	(15.0)
DBP (mmHg) ‡	79.8	(9.5)	75.8	(8.9)
Diabetes§	42	(13.3%)	22	(7.0%)
Medication for hypertension§	65	(20.6%)	62	(19.7%)
Components of RFA§				
Lipid	106	(33.7%)	55	(17.5%)
Blood pressure	187	(59.4%)	163	(51.9%)
Glycemia	92	(29.2%)	65	(20.7%)

†Age and TG are shown as medians with inter-quartile ranges in the parentheses; ‡BMI, waist circumference, waist/height ratio, waist/hip ratio, FPG, HDL-C, SBP and DBP are shown as means with standard deviations in the parentheses; §Diabetes, medication for hypertension and components of RFA are shown as numbers with proportions in the parentheses; Abbreviations: BMI, body-mass index; FPG, fasting plasma glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; RFA, risk factor accumulation.
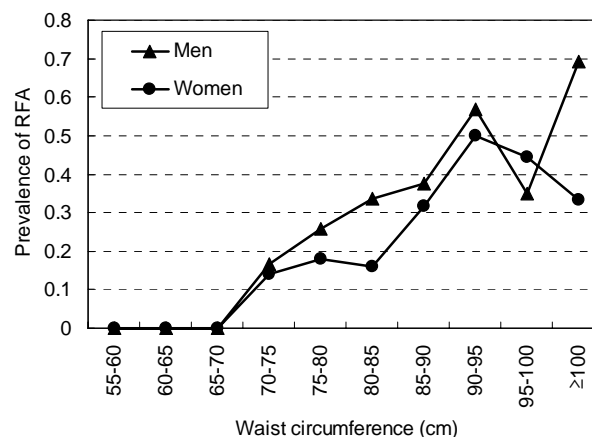

Figure1. Prevalence of RFA (defined as two or three of the following disorders: hypertension, dyslipidemia and fasting hyperglycemia) against waist circumference. Waist circumference was categorized by 5 cm intervals. Line with triangle markers for men and line with circle markers for women.

RESULTS

Among 675 subjects (332 men and 343 women) participating in this study whose data were available, we excluded those who had not fasted (one man and three women). We further excluded subjects who answered "yes" to the question "Do you take any cholesterol lowering drugs?" (16 men and 26 women) The analysis included the remaining 629 subjects (315 men and 314 women). Their characteristics are presented in Table 1. Age was calculated at the end of 2000. Among these subjects, 117 men (37.1%) and 70 women (22.3%) were defined as having RFA in this study. We categorized these subjects by 5 cm waist circumference intervals and calculated the prevalence of RFA in each category (Figure 1). RFA prevalence rose almost linearly from the category of 65-70cm up to the category of 90-95cm, for

waist circumference. We conducted the ROC analysis of anthropometric indices, *i.e.*, waist circumference, waist/height ratio, waist/hip ratio and BMI, to identify subjects with RFA. ROC curves and areas under the curve (AUC) for these anthropometric indices are shown in Figure 2. Comparing the AUC suggested waist circumference to be the best index for RFA in both men and women, although the differences were not statistically significant. Two-graph ROC curves for RFA against waist circumference are shown in Figure 3.

These graphs indicate changes in the sensitivity and specificity according to the cut-off value for waist circumference. Youden's index[15] (sensitivity + specificity - 1) and cut-off values for the current Japanese criteria (85cm for men and 90cm for women) are also shown in Figure 3. Sensitivity and specificity for the cut-off values
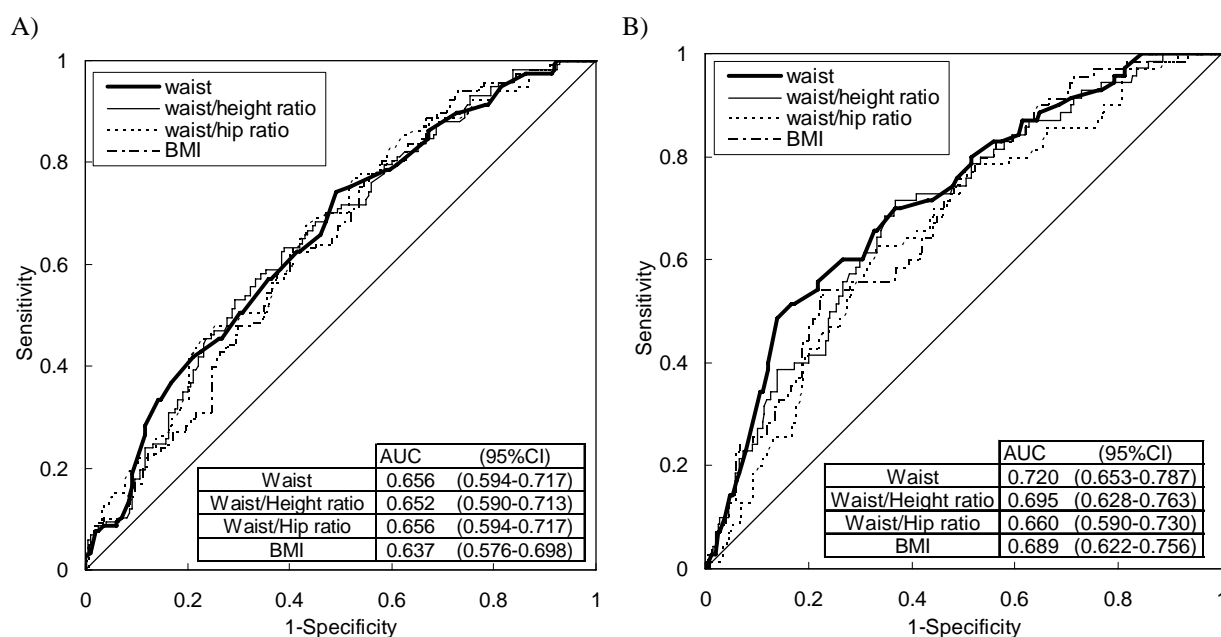
Figure 2. ROC curves for RFA against waist circumference, waist/height ratio, waist/hip ratio and BMI.
A) men, and B) women. Thick line indicates waist circumference, thin line waist/height ratio, thin broken line waist/hip ratio and thin dash-dotted line BMI. AUC and its 95% confidence intervals for each anthropometric index are also shown.
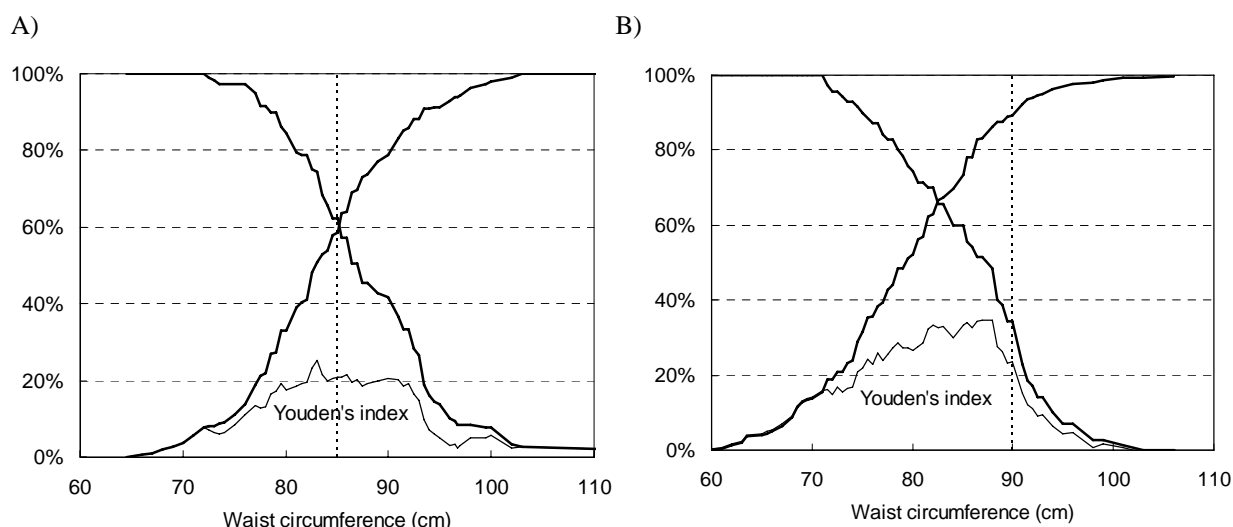
Figure 3. Two-graph ROC curves for RFA against waist circumference.
A) men, and B) women. These graphs indicate changes in sensitivity and specificity according to changes in the waist circumference cut-off value. Youden's index (sensitivity + specificity - 1) is also shown. Vertical dotted line represents the current Japanese cut-off values (85cm for men and 90cm for women).

in the current Japanese criteria were 62% and 59% for men and 34% and 89% for women, respectively. Therefore, current Japanese cut-off values for waist circumference potentially miss many subjects, especially women, with RFA. These results were essentially unchanged when we included subjects taking "cholesterol lowering drugs" in the analysis.

DISCUSSION

Our analysis revealed the prevalence of RFA to increase as waist circumference increased. Waist circumference was a better index for RFA in both men and women than the waist/height ratio, waist/hip ratio and BMI, though the differences were not statistically significant. The predictive power of waist circumference was not less than those of the other indices and possibly is somewhat better. Given its simplicity, waist circumference is the most practical and convenient measure for predicting RFA. The concept of metabolic syndrome relies on anthropometric indices as surrogates of central obesity. Waist circumference was found to correlate with intra-abdominal fat better than the other three indices.[16] In addition, waist circumference is more precise than the waist/hip or the waist/height ratio, since ratios generally have larger measurement errors than both their numerators and denominators.[17,18] These findings also support the use of waist circumference.

Recently, the IDF released a new definition of the MS[4] intended to be applicable to various ethnic groups. The most crucial aspect of the new version of the IDF criteria is that central obesity (quantified by waist circumference) has become a mandatory component of MS. Prior to revision of the IDF criteria, the Japanese Society of Internal Medicine also announced the MS criteria for the Japanese[5], with intra-abdominal fat accumulation being considered a fundamental element of the MS and waist circumference $\geq$ 85cm in men or $\geq$ 90cm in women as a requirement for diagnosis. Our analysis may pose the question of whether it is reasonable to make waist circumference a mandatory component of the MS. There was no apparent meaningful waist circumference threshold for RFA (Figure 1) and no clear cut-off point yielded sufficiently high sensitivity and specificity simultaneously (Figures 2 and 3). As shown in Figure 3, it was revealed that no cut-off point gave values larger than 70% for sensitivity and specificity simultaneously and that the same sensitivity (*e.g.*, 60%) gave a larger waist circumference for men (~85 cm) than for women (~80 cm). Therefore, employing waist circumference as a mandatory diagnostic criterion for the MS may confer little advantage in identifying high risk subjects. In fact, a recent cohort study revealed that the risk of CHD with RFA is similar irrespective of the presence of central obesity defined by waist circumference.[19]

Nevertheless, the above observation does not mean that waist circumference is of minor importance. Although there is no clear cut-off value as described above, the prevalence of RFA increases as waist circumference increases and it should especially be emphasized that waist circumference can be used as a convenient indicator and practical self-monitoring tool for abdominal obesity, which can be called a "self-modifiable" risk, in both daily and clinical settings. It should be further emphasized that it is important to utilize this index while fully recognizing the above described limitations.

Our study has some limitations. This study was conducted at one hospital and the number of subjects was relatively small (although their characteristics were fairly well representative of the whole JPHC Cohort I with health check-ups whose, for example, mean systolic and diastolic blood pressure and percentage having medication for hypertension was 131.5 and 79.9 mmHg and 21.8%, respectively, for men and 129.0 and 76.5 mmHg and 22.4% for women). Therefore, it is not clear whether our results can be generalized to other populations. In addition, this study is cross-sectional and predictive power of anthropometric indices was examined not for cardiovascular events but rather for risk factors. A longitudinal study is needed to examine the predictive power of anthropometric indices for cardiovascular events.

AUTHOR DISCLOSURES

Masayuki Kato, Yoshihiko Takahashi, Manami Inoue, Shoichiro Tsugane, Takashi Kadowaki and Mitsuhiko Noda, no conflicts of interest.

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[1]*Japan Foundation for the Promotion of International Medical Research Cooperation, Tokyo, Japan.*
[2]*Department of Diabetes and Metabolic Medicine, International Medical Center of Japan, Tokyo, Japan.*
[3]*Epidemiology and Prevention Division, Research Center for Cancer Prevention and Screening, National Cancer Center, Tokyo, Japan.*
[4]*Department of Metabolic Diseases, Graduate School of Medicine, University of Tokyo, Tokyo, Japan.*

以日本人为对象的人体测量指标预测代谢综合症之比较

目的：代谢综合症（MS）的大多数定义，均以腰围作为中心性肥胖的测定指标。但也有某些主要来自亚洲的报告主张：在判别受试者是否具有心血管疾病危险因素时，使用腰/身高比率这类指数优于采用腰围。由此，我们针对两种或更多些的症候，如高血压、血脂异常（高甘油三酯和/或低水平高密度脂蛋白）与空腹高血糖；对部分人体指标预测力与危险因素积累（RFA）间的相关要素，做了一项调查。上述症候，无论何种皆为代谢综合症的病状之一。**方法**：根据由日本公众健康中心分组所得到的数据，我们进行了横断面分析调研。对于年龄在51至70岁之间的315名男性和314名女性，就其年度体检所获得的腰与臀围、血压、空腹血糖与脂状的数据，实施了变量检测。**结果**：腰围在95厘米以下时，危险因素积累的增加趋势几乎是与腰围的增加，呈线状平行。从受试者操作特性的分析中得以验证：与利用腰/身高比率、腰/臀比率及身体质量指数(BMI)来预测危险因素积累相比，腰围是一个更好的指标，但其间在统计学上无显著差异。然而，即使利用腰围进行测定，也还不能产生明晰的断开点能同时符合高灵敏度与高特异性。**结论**：利用腰围实施预测，其预测力并不亚于其他指数。因此，对于预测代谢综合症而言，事实上腰围是一种最方便的指数，因为该测试方法最为简单易行。

关键词：代谢综合症，腰围，腰/臀比率，腰/身高比率，身体质量指数