Original Article

Gender Differences in the Association between Anthropometric Indices of Obesity and Blood Pressure in Japanese

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To investigate which of four anthropometric variables of obesity has the strongest association with blood pressure (BP), and to investigate whether there are gender differences in these relationships in Asian adults, we evaluated the associations of four anthropometric variables, body mass index (BMI), waist circumference, waist-to-hip ratio and waist-to-height ratio, with BP and the prevalence of hypertension in a cross-sectional study. A total of 4,557 employees of a metal-products factory in Toyama, Japan (2,935 men and 1,622 women, aged 35 to 59 years) were included in the study. Waist circumference in men and BMI in women had the strongest associations with BP. As for the age-adjusted rate ratio (RR) of the prevalence of hypertension for one standard deviation increase in each anthropometric variable, RR was the highest for waist circumference in men (RR, 1.44; 95% confidence interval [CI], 1.31–1.58), and for BMI in women (RR, 1.61; 95% CI, 1.38–1.88). The associations of waist circumference in men and BMI in women remained significant after adjustment for each of the other variables. The associations of waist-to-height ratio with BP and the prevalence of hypertension were a little weaker than those of waist circumference for both men and women. In conclusion, among four anthropometric variables of obesity—*i.e.*, BMI, waist circumference, waist-to-hip ratio, and waist-to-height ratio—waist circumference had the strongest association with BP and the prevalence of hypertension in men and BMI had the strongest association with BP and hypertension in women. Waist circumference in men and BMI in women should be given more importance in the screening of and guidelines on hypertension in Asians. (*Hypertens Res* 2006; 29: 75–80)

Key Words: blood pressure, epidemiology, gender, hypertension, obesity

Introduction

Obesity is an established risk factor for hypertension. Much epidemiologic evidence supports a link between obesity and

blood pressure (BP) (1–4), and clinical trials have shown the ability of weight loss to lower BP (5–8). Hypertension is also an important component of the metabolic syndrome (9), which is regarded as a risk factor for coronary heart disease (10, 11). An association between obesity and high BP has

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Table 1. Characteristics of the Study Participants

Characteristic	Men (<i>n</i> =2,935)	Women (<i>n</i> =1,622)	<i>p</i> [†]
Age (year)	45.5±6.5	45.3±6.4	0.357
Height (m)	1.68±0.06	1.54±0.05	<0.001
Body weight (kg)	65.6±9.0	54.1±8.3	<0.001
Body mass index (kg/m ²)	23.3±2.8	22.6±3.2	<0.001
Waist circumference (cm)	80.1±7.7	72.7±9.0	<0.001
Waist-to-hip ratio	0.87±0.05	0.80±0.08	<0.001
Waist-to-height ratio	0.48±0.05	0.47±0.06	<0.001
Systolic blood pressure (mmHg)	122.6±14.5	116.1±14.1	<0.001
Diastolic blood pressure (mmHg)	77.1±10.6	71.8±10.0	<0.001
Prevalence of obesity (%)			
Body mass index ≥25 kg/m ²	26.4	19.7	<0.001
Body mass index ≥30 kg/m ²	1.6	2.8	0.004
Prevalence of hypertension* (%)	19.3	9.7	<0.001

Data are mean±SD or %. *Hypertension was defined as a systolic blood pressure of 140 mmHg or over, a diastolic blood pressure of 90 mmHg or over, or taking antihypertensive medications. [†]*t*-test or χ^2 test were used to compare the variables between men and women.

Table 2. Age-Adjusted Relationship between Each Anthropometric Variable and Systolic Blood Pressure

Variable	Men			Women		
	Coefficient*	<i>t</i> -statistic	<i>p</i>	Coefficient*	<i>t</i> -statistic	<i>p</i>
Body mass index	0.86	9.2	<0.001	0.77	7.4	<0.001
Waist circumference	0.33	9.9	<0.001	0.23	6.0	<0.001
Waist-to-hip ratio	37.0	7.5	<0.001	14.3	3.2	0.002
Waist-to-height ratio	55.7	9.6	<0.001	31.9	5.6	<0.001
Body mass index [†]	0.28	1.6	0.120	0.69	4.3	<0.001
Waist circumference	0.25	3.9	<0.001	0.04	0.7	0.466
Body mass index [†]	0.30	1.6	0.121	0.78	4.8	<0.001
Waist-to-height ratio	39.2	3.2	0.001	-0.70	-0.1	0.938

*Coefficients were age-adjusted by multiple linear regression analysis. [†]Two anthropometric indices are included in the same model.

been shown in both men and women and in diverse racial/ethnic groups. In most of these previous studies on obesity and BP, body mass index (BMI) was the most cited index for obesity because it approximates adiposity and fat distribution.

Recently, several studies have demonstrated that, compared with total body fat, visceral fat accumulation is more closely related to metabolic syndrome (12, 13). Waist circumference is a convenient measure of abdominal adipose tissue (14, 15), and is used for the index of abdominal adiposity in the diagnosis of metabolic syndrome. Waist-to-hip ratio and waist-to-height ratio are also simple anthropometric parameters, and are sometimes used as markers for abdominal adiposity. However, few studies have clarified which of these anthropometric parameters has the strongest relationship with BP or hypertension (16–20). Furthermore, although patterns of fat distribution differ between men and women, with visceral fat being predominant in men and subcutaneous fat being predominant in women (21), it is still unclear whether there is a

gender difference in the relationship between obesity and BP.

In this large-scale cross-sectional study of middle-aged Japanese men and women, we aimed to determine which of the four variables, BMI, waist circumference, waist-to-hip ratio and waist-to-height ratio, is the most strongly associated with BP and the prevalence of hypertension, and to investigate whether there are gender differences in these relationships.

Methods

The subjects of this study were 35- to 59-year-old employees of a zipper and aluminum sash-producing factory in Toyama Prefecture, Japan. Detailed information of this study population has been provided elsewhere (22, 23). Clinical examinations for inclusion in this analysis were held in 1996. Height, weight and waist circumference of all the subjects, except the women who were pregnant, were measured during a routine

Table 3. Age-Adjusted Relationship between Each Anthropometric Variable and Diastolic Blood Pressure

Variable	Men			Women		
	Coefficient*	<i>t</i> -statistic	<i>p</i>	Coefficient*	<i>t</i> -statistic	<i>p</i>
Body mass index	0.69	10.1	<0.001	0.69	9.4	<0.001
Waist circumference	0.27	10.7	<0.001	0.15	5.7	<0.001
Waist-to-hip ratio	26.4	7.3	<0.001	1.8	0.5	0.587
Waist-to-height ratio	42.9	10.1	<0.001	20.3	5.0	<0.001
Body mass index [†]	0.24	1.9	0.063	0.86	7.7	<0.001
Waist circumference	0.19	4.0	<0.001	-0.08	-2.0	0.051
Body mass index [†]	0.36	2.5	0.012	0.98	8.6	<0.001
Waist-to-height ratio	23.2	2.6	0.009	-20.6	-3.3	<0.001

*Coefficients were age-adjusted by multiple linear regression analysis. [†]Two anthropometric indices are included in the same model.

Table 4. Age-Adjusted Risk Ratios* of the Prevalence of Hypertension for Each Anthropometric Variable

Variable	Men			Women		
	χ^2	RR	95% CI	χ^2	RR	95% CI
Body mass index	46.3	1.38	1.26–1.52	36.4	1.61	1.38–1.88
Waist circumference	57.8	1.44	1.31–1.58	19.0	1.41	1.21–1.65
Waist-to-hip ratio	44.2	1.39	1.26–1.53	5.2	1.20	1.03–1.41
Waist-to-height ratio	53.7	1.43	1.30–1.57	18.0	1.40	1.20–1.64
Body mass index [†]	0.3	1.05	0.88–1.25	16.1	1.67	1.30–2.15
Waist circumference	12.7	1.38	1.16–1.65	0.1	0.95	0.74–1.22
Body mass index [†]	0.5	1.07	0.88–1.30	17.3	1.72	1.33–2.22
Waist-to-height ratio	8.6	1.35	1.10–1.64	0.4	0.92	0.71–1.19

RR, risk ratio; 95% CI, 95% confidence interval. *RRs are calculated for each anthropometric variable higher by 1 SD. [†]Two anthropometric indices are included in the same model.

annual medical check-up. Height was measured to the nearest 0.1 cm without shoes using a stadiometer. Weight was measured in light clothing without shoes using a standard scale, and was recorded to the nearest 0.1 kg. BMI was calculated as weight/height² (kg/m²). Waist circumference was measured to the nearest 0.5 cm above the iliac crests and below the lowest rib margin at minimal respiration in a standing position. BP was measured once with a mercury sphygmomanometer after the subjects had rested for 5 min in a seated position. Trained staff took the measurements. A self-administered questionnaire was used to collect information about history of hypertension, dyslipidemia or diabetes, and use of antihypertensive medicine. Hypertension was defined as a systolic BP (SBP) of 140 mmHg or over, a diastolic BP (DBP) of 90 mmHg or over, or current use of antihypertensive medications. Of a total of 5,226 employees aged 35–59, 4,949 (95%) underwent these health examinations, of whom 392 were excluded from this study because of missing data. This report is therefore based on a total of 4,557 employees (2,935 men and 1,622 women).

Characteristics of the study participants were compared between men and women by *t*-test or χ^2 test. Multiple linear regression analysis was used to calculate age-adjusted coefficients between each anthropometric parameter and SBP or DBP. Multiple logistic regression analysis was used to calculate age-adjusted rate ratios (RR) of the prevalence of hypertension for a 1 SD increase in each anthropometric index. The *t*-statistics and Wald χ^2 were used to compare the strength of relationships. Two-sided *p* < 0.05 were considered statistically significant. The Japanese Windows Edition of the Statistical Package for Social Science (SPSS) Ver. 9.0 was used for statistical analysis.

Results

Characteristics of the study population are given in Table 1. The mean age was 45.5 years for men, and 45.3 years for women, and was not significantly different between men and women.

A significant difference between men and women was

Fig. 1. Comparison of the predictive performance of four anthropometric indices for the presence of hypertension. Receiver operating characteristic curves for hypertension in men (A) and in women (B) are shown. The estimates of the area under the curves and their 95% confidence intervals are shown in C. BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

observed in BMI, waist circumference, waist-to-hip ratio, waist-to-height ratio, SBP and DBP. The prevalence of overweight or obesity ($\text{BMI} \geq 25 \text{ kg/m}^2$) and obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$) was 26.4% and 1.6% for men, and 19.7% and 2.8% for women, respectively. The prevalence of hypertension was 19.3% for men and 9.7% for women.

Multiple linear regression models were computed to assess the age-adjusted relative influence of each anthropometric variable on SBP (Table 2). The *t*-statistics showed that, of the four variables, waist circumference had the strongest association with SBP in men, while BMI had the strongest in women. The waist-to-hip ratio had the weakest association with SBP in both men and women. After BMI and waist circumference were adjusted for each other in a model that included them both, only waist circumference in men and BMI in women showed significant relationships with SBP. After adjusting BMI and waist-to-height ratio for each other, only waist-to-height ratio in men and BMI in women showed a significant relationship with SBP. Similar relationships were observed

between anthropometric variables and DBP (Table 3). Results were similar even after excluding participants who used anti-hypertensive medications (165 men and 50 women) (data not shown). Results were also similar both in pre-menopausal women ($n=1,424$) and postmenopausal women ($n=198$) (data not shown).

Table 4 shows age-adjusted RRs of hypertension for a 1 SD increase in each anthropometric variable using the multiple logistic regression analysis. Of the four anthropometric variables, the RR of hypertension for waist circumference was the highest in men, and the RR of BMI was the highest in women. When BMI and waist circumference were included in the same model, the relationship between waist circumference and hypertension was significant and independent in men, and the RR of BMI was no longer significant. On the other hand, in women, the relationship between BMI and hypertension was significantly stronger, while the RR for waist circumference was not significant. Results were also similar both in pre-menopausal women and in postmenopausal

women (data not shown).

Receiver operating characteristic curves for the prevalence of hypertension in each sex are shown in Fig. 1. Among the four anthropometric variables, the area under the curve was the highest for waist-to-height ratio in men and for BMI in women.

Discussion

In this study of a relatively lean Asian population, waist circumference showed the strongest association with BP in men, and BMI showed the strongest association with BP in women, in a mutually independent manner. The associations of waist-to-height ratio with BP were similar to, but somewhat weaker than, those of waist circumference with BP. Of the four anthropometric parameters, the waist-to-hip ratio showed the weakest associations with BP in both men and women. Similar associations were also observed between all four anthropometric variables and the prevalence of hypertension.

In several previous studies, compared with BMI, waist circumference had a stronger association with SBP and DBP in both men and women in the United States (18) and Australia (16), in men in Italy (19), and in women on a Caribbean island (20). These results are similar to ours for men, but are different from our results for women. These differences may be due to differences in the distribution of BMI in the study populations. In our study, the mean BMI was 23.2 kg/m² for men and 22.6 kg/m² for women, compared with 26.7 kg/m² for men and 26.2 kg/m² for women in the USA (18), 26.7 kg/m² for Italian men (19), and 26.3 kg/m² for Caribbean women (20). The differences between the results may also be due to the difference in race, since it has been reported that the percentage of body fat in Asians, as measured by dual energy X-ray absorptiometry, is greater than that in African Americans and whites with similar BMI (24). Furthermore, because the average BMI of patients with metabolic abnormalities in Asia was reported as being below WHO's current cut-off point of 25 kg/m² for the classification of "overweight," WHO experts have proposed a cut-off point of 23 kg/m² for Asians (25). Therefore, the relationship between obesity and hypertension would be different in Asian and non-Asian people.

There has been only one similar report in Asians, namely, in Hong Kong Chinese, in which waist circumference and BMI showed similar correlations with BP in both men and women (17). The mean BMI in those subjects was 24.3 kg/m² for men and 23.9 kg/m² for women, and the mean waist circumference was 83.1 cm for men and 75.3 cm for women, all of which are somewhat higher values than those of our participants. Furthermore, their participants included younger and older people ranging in age from 25 to 74 years. These differences may have caused the difference in the association with BP.

It is still uncertain whether there is a gender difference in the relationship between obesity and BP. In the present study, a gender difference was observed in the relationship between

anthropometric parameters and BP, and also between anthropometric parameters and the presence of hypertension. The gender difference in body fat distribution, with visceral fat being predominant in men and subcutaneous fat being predominant in women, might provide evidence for the existence of such a gender difference. Visceral fat has a stronger association with metabolic abnormalities than does subcutaneous fat (12, 13), and, moreover, visceral adiposity measured by CT scans has also been positively associated with the prevalence of hypertension (26). In lean Asian men, who have less subcutaneous fat, waist circumference may be a more appropriate index for visceral fat than BMI. On the other hand, in lean Asian women, for whom subcutaneous fat has a stronger influence on waist circumference, BMI may be more appropriate than waist circumference as an index for total and abdominal fat accumulation.

The associations of waist-to-height ratio with BP were similar to those of waist circumference with BP in this study. Taking height into account, the waist-to-height ratio might be a more useful anthropometric marker than waist circumference when comparing these anthropometric variables among populations with a wide range of heights. For example, a person with a waist circumference of 100 cm and a height of 200 cm has a waist-to-height ratio of 0.5, as does a person with a waist circumference of 75 cm and a height of 150 cm. Furthermore, it has been reported that the cut-off point of the waist-to-height ratio considered to be associated with higher cardiovascular risk was 0.48 in Hong Kong Chinese (17) and 0.5 in Japanese (27), and these values were not significantly different between men and women. Therefore, if the waist-to-height ratio is used to assess higher cardiovascular risk, there might be no need to consider the gender difference.

The strength of this study is that the sample size was relatively large compared with other Asian studies. However, the role of the "healthy worker effect" should be considered, because this cohort was chosen at a work place. Because working populations tend to be healthier than the general populations, the prevalence of obesity and hypertension may be lower in this study than in the general population.

There may be gender and race differences in the association between BP and anthropometric variables of obesity. Prospective cohort studies should also be carried out to compare the potential of anthropometric variables to predict the development of hypertension in many races and in both men and women.

In conclusion, among the four anthropometric variables of obesity, waist circumference in men and BMI in women showed the strongest associations with BP and the prevalence of hypertension, and these associations were independent. Waist circumference in men and BMI in women should be given more importance in the screening of and guidelines on hypertension and metabolic abnormalities in Asians. The waist-to-height ratio would also be useful for assessing hypertension risk among populations with various body sizes.

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