Original Article

Body Fat Distribution and the Risk of Hypertension and Diabetes among Japanese Men and Women

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To identify anthropometrical indices of body fat distribution for predicting the risk of hypertension and diabetes, a population-based prospective study was designed. Subjects in two communities (*n*=2,422 and 3,195), who were free of hypertension and diabetes, respectively, were followed-up. The area and gender-specific risk of hypertension and diabetes were compared among tertiles of body mass index (BMI) and body fat distribution, including waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and subscapular skinfold-thickness (SSF). During the 10-year follow-up for hypertension and diabetes, the incident cases of hypertension were 72 for Yao men, 125 for Kyowa men, 160 for Yao women and 193 for Kyowa women and those of diabetes were 27, 64, 37 and 77, respectively. One SD differences in BMI and WC were associated with 1.2 to1.6-fold higher risk of hypertension, and that of SSF was associated with 1.4 to 1.6-fold higher risk of diabetes for both men and women in Yao and for women, but not men, in Kyowa. One SD differences of BMI, WC and WHtR were also associated with 1.4 to 2.0-fold higher risk of diabetes for Yao and Kyowa women. In conclusion, the significant predictors for hypertension were BMI and WC and those for diabetes were BMI and SSF in both genders in both communities, except for men in Kyowa. WC and WHtR were also predictors for diabetes in women but not in men. (*Hypertens Res* 2008; 31: 851–857)

***Key Words*: hypertension, diabetes, body mass index, waist circumference, waist-to-height ratio**

Introduction

Cardiovascular disease mortality has been reported as the top-3 cause of deaths in Japan since 1958 (*1*). It is well known that the prevention and control of hypertension and diabetes could substantially reduce the risk of cardiovascular disease (*2*). Thus, it is important from the view of public health and clinical practice to find a simple and valid measurement to predict the risk of hypertension and diabetes. At present, cross-sectional studies have shown that waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and

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body mass index (BMI) are associated with the prevalence of hypertension and diabetes (*3–12*). However, the results have not been consistent between genders and among various ethnic groups (*3–12*). In Japan, cross-sectional studies have shown that WHtR was a stronger correlate for these cardiovascular risk factors than BMI and WC (*3*, *4*). A recent prospective study in the United States has reported that WC is a better predictor for the risk of diabetes than WHR and BMI (*13*). However, no prospective study has been undertaken to study systematically the association of WC, WHR, WHtR and subscapular skinfold thickness (SSF) with hypertension and diabetes in Asian populations.

To obtain better measures for the prediction of the risk of hypertension and diabetes for men and women in Asian communities, we examined gender and population-specific relationships between anthropometric measurements (BMI, WC, WHR, WHtR, SSF), and the risk of hypertension and diabetes in two populations in Japan.

Methods

Study Populations

The surveyed population included residents in two communities (aged 40–69 years) who participated in cardiovascular risk surveys between 1988 and 1993 in Minami-Takayasu, a southwest urban suburb, a district of Yao City of Osaka Prefecture, or between 1990 and 1993 in Kyowa, a rural community of Ibaraki Prefecture. After exclusion of persons with hypertension ($n=1,314$) or diabetes ($n=314$), and 353 persons who did not undergo anthropometric measurements at baseline, a total of 3,214 study subjects (Kyowa: 549 men and 992 women; Yao: 585 men and 1,088 women) and 4,214 study subjects (Kyowa: 763 men and 1,374 women; Yao: 700 men and 1,377 women) who were free of hypertension and diabetes at baseline, respectively, were followed. These subjects were followed between 1997 and 2001. The follow-up rate was 75.4% ($n=2,422$) for hypertension and 75.6% ($n=3,195$) for diabetes. The average follow-up period was 10.4 years (10.0 years for men and 10.6 years for women) for hypertension and 10.4 years (10.1 years for men and 10.6 years for women) for diabetes. The study protocol was approved by the Human Ethics Review Committee of the University of Tsukuba.

Measurement

Height in stocking feet and weight in light clothing were measured. BMI was calculated as weight (kg) divided by the square of the height (m^2). Subscapular skinfold thickness was measured to the nearest mm using keys calipers by trained physician epidemiologists with standard methods. Trained observers also measured WC and hip circumference in subjects in a standing position and breathing normally at the level of the umbilicus and at the symphysis pubis at the maximum protrusion of the hips, respectively, to the nearest 1 cm using a tape measure. These measurements were used to calculate WHR and WHtR.

Blood pressures were measured by trained technicians and/or physician epidemiologists with standardized methods, using mercury sphygmomanometers on the right arm of seated participants after at least 5 min of rest. Blood pressure was measured twice for the subjects with systolic blood pressure (SBP) of ≥140 mmHg, and/or diastolic blood pressure (DBP) of ≥90 mmHg. Hypertension was defined as SBP of ≥160 mmHg and/or DBP of ≥95 mmHg and/or current treatment with antihypertensive medication at the baseline and annual follow-up surveys.

Blood was drawn from seated participants into a plain, siliconized glass tube, and serum was separated. Serum glucose was measured by the hexokinase method. Diabetes was defined as a fasting glucose level of ≥126 mg/dL and/or a non-fasting glucose level of ≥200 mg/dL and/or use of medication for diabetes at the baseline and annual follow-up surveys.

An interview was conducted to ascertain the alcohol intake per day, the number of cigarettes smoked per day, use of medication for diabetes mellitus and hypertension, and past history of stroke and coronary heart disease. Persons who smoked ≥1 cigarette per day were defined as current smokers, and those who had not smoked for ≥3 months were defined as ex-smokers.

Statistical Analysis

The gender and population-specific area and gender-specific risks of hypertension and diabetes were compared among tertiles of BMI and body fat distribution including measurements of WC, WHtR, WHR and SSF. The odds ratio (OR) of hypertension and diabetes and their respective 95% confidence intervals (95% CI) were calculated with reference to the first tertile of each of these measurements, using the logistic regression model. We adjusted for age, alcohol intake (for men: never, former, current <23, 23–45, ≥46 g/d ethanol; for women: non-drinker and current drinker), and smoking status (for men: never, former, current 1–19, ≥20 cigarettes per day; for women: non-smoker and current smoker). Furthermore, we also adjusted baseline SBP for hypertension analysis and baseline glucose level and fasting status (yes or no) for diabetes analysis. The increased risks of hypertension and diabetes associated with a 1 SD difference of BMI and body fat distribution measurements were examined by using the logistic regression model, adjusted for age and other confounding variables. All statistical analyses were conducted using SAS, version 8.0 (SAS Japan Inc., Tokyo, Japan), and the statistical testing was two-tailed.

Results

During the average 10.4-year follow-up, we documented 550

Table 1. Gender and Population–Specific Means±SD and Proportions of Risk Characteristics and Anthropometric Measures among the Japanese Men and Women in Two Communities for Examining the Risk of Hypertension

	Men		Women	
	Yao	Kyowa	Yao	Kyowa
n	389	519	911	971
Age	56±6	56±9	56±7‡	54±9
Alcohol intake, g/d	32±20	32±22	9±9	9±11
Smoking, %	45	52	7†	4
Systolic blood pressure, mmHg	117±12‡	128±12	111±13‡	125±13
Diastolic blood pressure, mmHg	73±8‡	77±8	69±8‡	74±9
Glucose, mmol/L	6.27±1.49‡	6.97±2.27	5.91±1.09‡	6.26±1.61
Body mass index, kg/m^2	22.8±2.6†	23.2±2.7	22.6±2.8‡	23.3±2.9
Waist circumference, cm	82.7±7.6	82.9±8.0	81.6±8.9‡	79.9±9.0
Waist-to-height ratio	0.50±0.05*	0.51±0.05	0.54±0.06	0.53±0.06
Waist-to-hip ratio	0.92±0.05	0.91±0.06	0.91±0.07‡	0.87±0.07
Subscapular skinfold thickness, mm	14.4±5.8	14.6±5.6	18.2±6.6‡	21.5±7.8

Data are means±SD. Differences from the rural population: *$p<0.05$, †$p<0.01$,‡$p<0.0001$.

incident cases of hypertension (2.2%) and 205 incident cases of diabetes (0.6%).

Table 1 shows the gender- and population-specific means±SD and proportions of risk characteristics and anthropometric parameters in the subjects for examining risk of hypertension. The mean levels of SBP, DBP and glucose were higher in the Kyowa than in the Yao population for both genders. The proportion of current smokers was higher among Kyowa men than Yao men, while the opposite trend was observed for women. There was no difference in mean alcohol intake between the two populations for either gender. The mean BMI was higher in the Kyowa population than the Yao population for both genders. The mean value of WHtR for Kyowa men was higher than that for Yao men. The mean values of WC and WHR were lower among Kyowa women than Yao women, while the mean SSF was higher among Kyowa women than Yao women. Similar trends were observed for the risk of diabetes (data not shown).

The incidence of hypertension was 72 for Yao men (2.2%), 125 for Kyowa men (2.8%), 160 for Yao women (2.0%) and 193 for Kyowa women (2.1%) (Table 2). For Yao men, the multivariable OR of hypertension for the highest *vs*. lowest tertiles of anthropometric measures was statistically significant for BMI (OR [95% CI]=2.28 [1.12–4.65], $p=0.02$), and marginally significant for WC (OR [95% CI]=1.88 [0.90–3.92], $p=0.09$). One SD differences of BMI, WC, WHtR, WHR and SSF were significantly associated with 1.3 to 1.6-fold higher risk of hypertension. The multivariable OR of hypertension in the highest *vs*. lowest tertiles of anthropometric measures and those associated with 1 SD difference of anthropometric measures were not statistically significant for Kyowa men. For Yao women, the multivariate OR for the highest *vs*. lowest tertiles of anthropometric measures was statistically significant for BMI (OR [95% CI]=1.68 [1.05–2.68], $p=0.03$) and marginally significant for WC (OR [95% CI]=1.60 [0.98–2.62], $p=0.06$). One SD differences of BMI and WC were marginally significantly or significantly associated with 1.2-fold higher risk of hypertension. For Kyowa women, the risk of hypertension increased with higher tertiles in most of the anthropometric parameters: the multivariable OR of hypertension in the highest *vs*. lowest tertiles of anthropometric measures was statistically significant for BMI (OR [95% CI]=1.81 [1.16–2.84], $p=0.001$), WHtR (OR [95% CI]=1.59 [1.05–2.39], $p=0.03$), and SSF (OR [95% CI]=1.60 [1.04–2.46], $p=0.03$), and marginally significant for WC (OR [95% CI]=1.45 [0.96–2.19], $p=0.08$), and WHR (OR [95% CI]=1.48 [0.96–2.30)], $p=0.08$). One SD differences of BMI, WC, WHtR, and SSF were significantly associated with 1.2 to 1.3-fold higher risk of hypertension.

The risk of hypertension for subjects with BMI ≥27.0 kg/m^2 compared to those with BMI<22.0 kg/m^2 was examined; the multivariate OR (95% CI) was 2.83 (0.96–8.31; $p=0.06$) for Yao men, 2.32 (1.14–4.73; $p=0.02$) for Yao women and 2.42 (1.33–4.40; $p=0.004$) for Kyowa women, but no significant association was observed for Kyowa men (data not shown).

The incidence of diabetes was 27 for Yao men (0.7%), 64 for Kyowa men (1.0%), 37 for Yao women (0.4%) and 77 for Kyowa women (0.6%) (Table 3). For Yao men, the multivariable OR of diabetes for the highest *vs*. lowest tertiles of anthropometric measures was significant for BMI (OR [95% CI]=3.24 [1.08–9.71], $p=0.04$), but not for the other anthropometric measures. One SD difference of SSF was marginally significantly associated with 1.4-fold higher risk of diabetes. The multivariable OR of diabetes in highest *vs*. lowest tertiles of anthropometric measures and those associated with 1 SD difference of anthropometric measures was not statistically significant for Kyowa men. However, for Kyowa women, the multivariable OR of diabetes for the highest *vs*. lowest tertiles of anthropometric measures was statistically

Table 2. Multivariable-Adjusted Odds Ratio for Hypertension According to Anthropometric Measures among Japanese Men and Women in Two Communities

	Men							
	Yao				Kyowa			
	No. of case (n=72)	No. at risk (n=325)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD	No. of case (n=125)	No. at risk (n=452)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD
BMI								
T1 (15.3–22.0)	22	114	1.00		38	145	1.00	
T2 (22.0–24.1)	20	114	0.89 (0.43–1.85)	1.52 (1.12–2.05)‡	29	145	0.67 (0.37–1.22)	1.10 (0.88–1.37)
T3 (24.1–33.2)	30	97	2.28 (1.12–4.65)†		58	162	1.33 (0.78–2.28)	
Waist circumference								
T1 (60–79)	16	93	1.00		33	147	1.00	
T2 (80–86)	26	122	1.33 (0.63–2.81)	1.56 (1.14–2.14)‡	44	159	1.21 (0.69–2.11)	1.04 (0.83–1.29)
T3 (87–111)	30	110	1.88 (0.90–3.92)*		48	146	1.44 (0.82–2.53)	
Waist-to-height ratio								
T1 (0.38–0.49)	19	101	1.00		36	169	1.00	
T2 (0.49–0.53)	28	137	1.01 (0.50–2.03)	1.56 (1.11–2.19)†	34	111	1.51 (0.83–2.73)	1.09 (0.86–1.39)
T3 (0.53–0.66)	25	87	1.76 (0.84–3.70)		55	172	1.50 (0.89–2.55)	
Waist-to-hip ratio								
T1 (0.75–0.89)	21	98	1.00		37	161	1.00	
T2 (0.89–0.94)	23	118	0.91 (0.45–1.86)	1.38 (1.04–1.84)†	50	147	1.44 (0.83–2.50)	0.90 (0.73–1.10)
T3 (0.94–1.09)	28	109	1.22 (0.61–2.43)		38	144	1.04 (0.59–1.83)	
Subscapular skinfold thickness								
T1 (5.0–11.0)	22	102	1.00		35	145	1.00	
T2 (12.0–16.0)	25	129	0.97 (0.48–1.97)	1.34 (1.02–1.77)†	43	161	1.14 (0.65–2.00)	1.13 (0.90–1.42)
T3 (17.0–45.0)	25	94	1.40 (0.67–2.91)		47	146	1.51 (0.85–2.68)	

	Womem							
	Yao				Kyowa			
	No. of case (n=160)	No. at risk (n=772)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD	No. of case (n=193)	No. at risk (n=873)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD
BMI								
T1 (15.2–21.5)	46	298	1.00		37	250	1.00	
T2 (21.5–24.0)	55	248	1.64 (1.02–2.61)†	1.20 (0.99–1.45)*	59	301	1.16 (0.72–1.87)	1.29 (1.09–1.54)‡
T3 (24.0–36.8)	59	226	1.68 (1.05–2.68)†		97	322	1.81 (1.16–2.84)‡	
Waist circumference								
T1 (57–76)	32	225	1.00		60	357	1.00	
T2 (77–84)	51	257	1.28 (0.77–2.15)	1.21 (1.00–1.47)†	57	248	1.25 (0.81–1.92)	1.23 (1.03–1.47)†
T3 (85–110)	77	290	1.60 (0.98–2.62)*		76	268	1.45 (0.96–2.19)*	
Waist-to-height ratio								
T1 (0.38–0.50)	35	228	1.00		58	351	1.00	
T2 (0.50–0.56)	56	281	1.16 (0.71–1.91)	1.14 (0.94–1.38)	42	222	0.96 (0.60–1.53)	1.28 (1.08–1.53)‡
T3 (0.56–0.75)	69	263	1.40 (0.86–2.29)		93	300	1.59 (1.05–2.39)†	
Waist-to-hip ratio								
T1 (0.68–0.85)	29	182	1.00		66	368	1.00	
T2 (0.85–0.92)	44	256	1.04 (0.61–1.80)	1.11 (0.92–1.32)	66	299	1.12 (0.75–1.69)	1.16 (0.97–1.39)
T3 (0.92–1.15)	87	334	1.40 (0.84–2.31)		61	206	1.48 (0.96–2.30)*	
Subscapular skinfold thickness								
T1 (5.0–16.0)	60	337	1.00		42	245	1.00	
T2 (17.0–22.0)	54	257	1.05 (0.68–1.63)	1.16 (0.94–1.42)	43	267	0.73 (0.44–1.20)	1.27 (1.08–1.49)‡
T3 (23.0–60.0)	46	178	1.34 (0.83–2.15)		108	361	1.60 (1.04–2.46)†	

*p<0.1, †p<0.05, ‡p<0.01. OR, odds ratio; 95% CI, 95% confidence interval. Multivariate-adjusted: age (years), baseline systolic blood pressure levels (mmHg), alcohol intake (never, former, current <23, 23–45, ≥46 g/d ethanol for men; non-drinker and current-drinker for women) and smoking status (never, former, current 1–19 and ≥20 cigarettes per day for men; non-smoker and current smoker for women).

Table 3. Multivariable-Adjusted Odds Ratio for Diabetes According to Anthropometric Measures among Japanese Men and Women in Two Communities

	Men							
	Yao				Kyowa			
	No. of case (n=27)	No. at risk (n=392)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD	No. of case (n=64)	No.at risk (n=628)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD
BMI								
T1 (15.3–22.3)	6	137	1.00		23	205	1.00	
T2 (22.3–24.4)	7	140	1.16 (0.35–3.82)	1.33 (0.90–1.97)	16	197	0.74 (0.36–1.51)	1.08 (0.82–1.43)
T3 (24.4–34.5)	14	115	3.24 (1.08–9.71)†		25	226	1.22 (0.63–2.34)	
Waist circumference								
T1 (60–80)	5	129	1.00		16	215	1.00	
T2 (81–87)	11	139	2.65 (0.81–8.65)	1.39 (0.90–2.13)	22	216	1.56 (0.76–3.22)	1.15 (0.87–1.51)
T3 (88–112)	11	124	2.10 (0.65–6.79)		26	197	1.71 (0.85–3.42)	
Waist-to-height ratio								
T1 (0.38–0.49)	4	130	1.00		17	209	1.00	
T2 (0.49–0.54)	13	150	3.56 (1.01–12.56)†	1.27 (0.81–2.00)	20	191	1.22 (0.59–2.54)	1.12 (0.83–1.50)
T3 (0.54–0.67)	10	112	3.09 (0.84–11.44)*		27	228	1.30 (0.66–2.56)	
Waist-to-hip ratio								
T1 (0.71–0.90)	7	131	1.00		16	202	1.00	
T2 (0.90–0.94)	8	137	1.01 (0.33–3.10)	1.19 (0.78–1.82)	22	213	1.22 (0.59–2.51)	1.04 (0.82–1.34)
T3 (0.94–1.09)	12	124	1.70 (0.61–4.73)		26	213	1.34 (0.66–2.70)	
Subscapular skinfold thickness								
T1 (5.0–11.0)	4	114	1.00		18	181	1.00	
T2 (12.0–16.0)	12	156	2.81 (0.82–9.67)	1.35 (0.95–1.93)*	24	220	1.19 (0.59–2.40)	1.10 (0.83–1.46)
T3 (17.0–40.0)	11	122	3.01 (0.84–10.77)*		22	227	1.13 (0.55–2.32)	

	Women							
	Yao				Kyowa			
	No. of case (n=37)	No. at risk (n=970)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD	No. of case (n=77)	No. at risk (n=1,205)	Multivariable OR (95% CI)	OR (95% CI) changed per 1 SD
BMI								
T1 (15.2–21.8)	8	386	1.00		17	339	1.00	
T2 (21.9–24.4)	10	317	1.44 (0.54–3.81)	2.00 (1.48–2.70)‡	16	406	0.81 (0.39–1.68)	1.53 (1.21–1.93)‡
T3 (24.4–36.8)	19	267	3.34 (1.40–7.95)‡		44	460	1.64 (0.89–3.03)	
Waist circumference								
T1 (57–77)	8	302	1.00		15	454	1.00	
T2 (78–85)	11	322	1.32 (0.51–3.42)	1.67 (1.19–2.35)‡	21	354	1.58 (0.78–3.19)	1.68 (1.31–2.16)‡
T3 (86–120)	18	346	2.07 (0.85–5.06)		41	397	2.83 (1.49–5.39)‡	
Waist-to-height ratio								
T1 (0.38–0.51)	11	307	1.00		16	406	1.00	
T2 (0.51–0.57)	11	358	0.82 (0.34–1.97)	1.59 (1.14–2.22)‡	16	376	0.96 (0.46–2.01)	1.46 (1.16–1.84)‡
T3 (0.57–0.81)	15	305	1.39 (0.59–3.28)		45	423	2.26 (1.19–4.29)†	
Waist-to-hip ratio								
T1 (0.68–0.86)	7	246	1.00		14	449	1.00	
T2 (0.86–0.93)	14	321	1.43 (0.55–3.69)	1.26 (0.89–1.78)	25	414	1.90 (0.95–3.90)*	1.56 (1.21–2.02)‡
T3 (0.93–1.15)	16	403	1.46 (0.56–3.82)		38	342	3.21 (1.63–6.30)‡	
Subscapular skinfold thickness								
T1 (5.0–16.0)	6	399	1.00		13	316	1.00	
T2 (17.0–23.0)	17	351	3.10 (1.19–8.09)†	1.61 (1.15–2.27)‡	23	391	1.44 (0.69–2.98)	1.38 (1.10–1.73)‡
T3 (24.0–60.0)	14	220	3.58 (1.33–9.64)†		41	498	2.06 (1.05–4.04)†	

*$p<0.1$, †$p<0.05$, ‡$p<0.01$. OR, odds ratio; 95% CI, 95% confidence interval. Multivariate-adjusted: age (years), baseline glucose levels (mmol/L), fasting status (yes or no), alcohol intake (never, former, current <23, 23–45, ≥46 g/d ethanol for men; non-drinker and current-drinker for women) and smoking status (never, former, current 1–19 and ≥20 cigarettes per day for men; non-smoker and current smoker for women).

significant for WC (OR [95% CI]=2.83 [1.49–5.39], $p=0.002$), WHtR (OR [95% CI]=2.26 [1.19–4.29], $p=0.01$), WHR (OR [95% CI]=3.21 [1.63–6.30], $p<0.001$) and SSF (OR [95% CI]=2.06 [1.05–4.04], $p=0.04$), and 1 SD differences of BMI, WC, WHtR, WHR and SSF were significantly associated with 1.4 to 1.7-fold higher risk of diabetes. For Yao women, the multivariable OR of diabetes for the highest *vs*. lowest tertiles of anthropometric measures was statistically significant for BMI (OR [95% CI]=3.34 [1.40–7.95], $p=0.007$) and SSF (OR [95% CI]=3.58 [1.33–9.64], $p=0.01$). One SD difference of BMI was significantly associated with 2-fold, and that of WC, WHtR and SSF was significantly associated with 1.3 to 1.7-fold higher risk of diabetes.

The risk of diabetes for subjects with BMI $\geq$27.0 kg/m^2 compared to those with BMI$<$22.0 kg/m^2 was also examined; the multivariate OR (95% CI) was 3.24 (1.08–9.71; $p=0.04$) for Yao men and 3.34 (1.40–7.95; $p=0.007$) for Yao women. However, no significant association was observed in either Kyowa men or women (data not shown).

Discussion

In the present follow-up study, increased BMI and WC were positively associated with risk of hypertension in men and women in the city of Yao in Osaka Prefecture and in women in the rural community of Kyowa in Ibaraki Prefecture, Japan. In Yao men and women, and Kyowa women, BMI and SSF were associated with risk of diabetes. WC and WHtR were also associated with risk of diabetes in Yao and Kyowa women, but not in men.

Previous cross-sectional studies have indicated that BMI, WC, and WHR or WHtR were equally correlated with the prevalence of hypertension in both genders (*7*, *8*, *11*, *14*), while other studies showed that WC was the best single correlate for hypertension (*10*, *12*). Many prospective studies have shown that BMI, a measure of overall obesity, is associated with hypertension (*15–17*), while other follow-up studies have shown that WC, WHtR and WHR, measures of abdominal adiposity, were significantly associated with the risk of hypertension (*18*). Our results were consistent with the findings from those studies that both overall obesity and abdominal adiposity were associated with hypertension.

Previous cross-sectional studies showed that WHtR (*3*, *4*, *8*), WHR (*11*) and WC (*19*) were associated with the prevalence of diabetes in both genders. Follow-up studies in Germany and the United States found that overall obesity measured by BMI and abdominal adiposity measured by WC and WHR are useful in predicting the risk of diabetes (*3*, *20*), while another 6-year follow-up study in the United States showed that WHR and the waist-to-thigh ratio were better measures for diabetes than BMI in both genders (*21*). In the present study, BMI and SSF were marginally significant or significant indicator for risk of diabetes in both populations and both genders, with the exception of men in Kyowa, and WC and WHtR were also significant indicators for the risk of diabetes in women. Our finding for women agrees with the results from a study of Pima Indians showing that BMI, WC, WHR and waist-to-thigh ratio were equally good predictors for the risk of diabetes (*22*), and also with the results from the MONICA/KORA Augsburg Study showing that BMI and WC were equally good predictors for the risk of diabetes (*20*).

One strength of the present study was that the incidence of hypertension and diabetes was ascertained by repeated standardized measurements of blood pressure and blood glucose levels. The anthropometrics measurements were conducted according to a standard protocol by trained technicians. We had good reproducibility and validity for the measurements. For example, the Spearman correlation coefficients of SSF, measured 1 year apart for the same subject ranged from 0.7 to 0.9, as shown in a previous study (*23*). In that study, SSF was correlated with central fat mass estimated by dual-energy X-ray absorptiometry scanning for men ($r=0.80$) and women ($r=0.82$) (*23*). These study characteristics allowed us to examine carefully the relationships of anthropometrics measures with established and modifiable cardiovascular risk factors, such as hypertension and diabetes.

The reason for the lack of significant association between anthropometric measures and risks of hypertension and diabetes in Kyowa men was uncertain. We may have had limited statistical power to detect real associations and/or residual confounders of the associations. We adjusted for selected cardiovascular risk factors, but we could not exclude the possible influence of other risk factors, such as lifestyle and psychosocial factors.

In summary, the significant predictors for hypertension were BMI and WC and those for diabetes were BMI and SSF in both populations and genders, with the exception of men in Kyowa. WC and WHtR were also predictors for diabetes in women but not in men.

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