Measurement of Waist Circumference

Midabdominal or iliac crest?

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OBJECTIVE—Waist circumference (WC) is used to define central obesity. This study aimed to compare the performance of two recommended locations of WC measurement.

RESEARCH DESIGN AND METHODS— A cohort of 1,898 subjects who were without diabetes from 2006 to 2012 were followed for a median of 31 months (Taiwan Lifestyle Study). The WC-IC, recommended by the National Cholesterol Education Program Third Adult Treatment Panel, was measured at the superior border of the iliac crest, and the WC-mid, recommended by World Health Organization and International Diabetes Federation, was measured midway between the lowest ribs and the iliac crest. The abdominal subcutaneous fat area (SFA) and visceral fat area (VFA) were assessed by computed tomography.

RESULTS—There was greater difference between WC-IC and WC-mid measurements in women than in men ($P < 0.001$). Both WC-IC and WC-mid correlated significantly with BMI, VFA, and SFA (all $P < 0.001$). WC-mid was better correlated to VFA than WC-IC, particularly in women, and it correlated more strongly to blood pressure, plasma glucose, hemoglobin A_{1c}, triglyceride levels, HDL cholesterol, and C-reactive protein (all $P < 0.05$). The association of WC-mid with hypertension, diabetes, and metabolic syndrome was slightly better than that of WC-IC (area under the receiver operator curve 0.7 vs. 0.69, 0.71 vs. 0.68, and 0.75 vs. 0.7, respectively; all age-adjusted $P < 0.05$). With 90 cm (male)/80 cm (female) as criteria for central obesity, WC-mid, but not WC-IC, predicted the incidence of diabetes development (age-adjusted $P = 0.003$).

CONCLUSIONS—WC-mid is a better measurement to define central obesity than WC-IC, particularly in women.

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Central obesity is associated with clustering of cardiovascular risk factors. People with central obesity are known to be at higher risk of developing hypertension, diabetes, dyslipidemia, and metabolic syndrome (MS) (1). To measure central obesity, waist circumference (WC) appears to be a better indicator than BMI and waist-to-hip ratio. WC measurement is convenient, and it is more strongly correlated with intra-abdominal fat content and cardiovascular risk factors (2–5). However, the recommended locations for WC measurements vary (6–8). The World Health Organization and the International Diabetes Federation (IDF) suggest measuring WC in the horizontal plane midway between the lowest ribs and the iliac crest (WC-mid). In contrast, the National Cholesterol Education Program Third Adult Treatment Panel (NCEP ATP III) recommends measuring in the horizontal plane of the superior border of the iliac crest (WC-IC).

The recommended cutoff values of WC for central obesity vary among different ethnic groups (9–12). Asians tend to have more body fat per BMI than Caucasians (13), which indicates greater potential for Asians to develop hypertension, diabetes, and dyslipidemia at lower BMIs (14,15). In 2000, the Asia-Pacific Perspective: Redefining Obesity and its Treatment Conference recommended cutoff values for central obesity for Asians of 90 cm WC-mid for males and 80 cm WC-mid for females (16). In 2004, Tan et al. (17) tested these cutoffs in a cross-sectional study in an Asian population and found that the prevalence of MS using these cutoffs was comparable with that in developed countries. However, instead of WC-mid, WC was measured at the narrowest area below the costal region. These cutoff values have been adopted by the modified NCEP ATP III (7) and the IDF (8), which means that the criteria for WC association with metabolic disease in Asian populations are based on the proportion of cases identified rather than on the performance of WC in predicting risk. A number of different cutoff values for WC have been proposed based on correlations to visceral adiposity, disease identification, or disease prediction (10,11,18), and all are different.

The aim of the study is to comprehensively compare the performance of WC-IC and WC-mid to define central obesity. We investigated their performance in a large cohort including 1,898 subjects. We studied their relationship to abdominal visceral fat area (VFA) and

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metabolic abnormalities. We compared their associations with metabolic diseases. We also compared their ability to predict the future development of metabolic disease. The optimal cutoff values for central obesity were explored.

RESEARCH DESIGN AND METHODS

Participants

From 2006 to 2012, individuals aged ≥18 years who had received health examinations at the National Taiwan University Hospital Yun-Lin branch during the previous year and had fasting plasma glucose (FPG) levels <126 mg/dL (7 mmol/L) were invited to participate in the Taiwan Lifestyle Study (19–22). Diabetes status and medications were evaluated by a questionnaires completed with the aid of trained nurses. Participants who had FPG values >126 mg/dL (7 mmol/L) or who received medications for diabetes were excluded. The questionnaire, along with anthropometric measurement and risk-factor assessment, were used to assess participants' medical and metabolic status. Abdominal computed tomography (CT) was performed to measure abdominal fat areas. All study participants were contacted by telephone, e-mail, or postal mail 1–3 years after the initial visit, and follow-up visits were scheduled according to the respondent's availability. Written informed consent was obtained from each individual. The study was reviewed and approved by the institutional review board.

Anthropometry

Anthropometric measurement of each subject was performed by trained nurses in the morning after fasting for at least 8 h. Body height was recorded to the nearest 0.5 cm and body weight to the nearest 0.1 kg. BMI was defined as body weight (kilograms) divided by the square of body height (meters). WC-IC was measured in the horizontal plane at the superior border of the right iliac crest. WC-mid was measured in the horizontal plane midway between lowest rib and the iliac crest. Both WC-IC and WC-mid were measured to the nearest 0.1 cm at the end of a normal expiration. Before recording the measurement, the nurse would ensure that the tape was snug but did not compress the skin and was parallel to the floor. The reproducibility was assessed. WC-IC and WC-mid were measured repeatedly in 10 men and 10 women by 3 trained nurses on 3 consecutive days. The coefficients of variation for WC-IC were 0.8% (range 0.5–1.7%) for women and 0.6% (range 0.3–1.4%) for men. The coefficients of variation for WC-mid were 0.4% (range 0–0.7%) for men and 0.9% (range 0.5–1.9%) for women.

Risk factor measurements

Blood pressure was recorded to the nearest 2 mmHg by a mercury sphygmomanometer with the arm supported at heart level after sitting quietly for 10 min. Well-trained nurses took three separate readings at 1-min intervals. The average of the last two readings was used for analysis. FPG was measured after fasting for at least 8 h. A standard oral 75-g glucose tolerance test was performed to measure 2-h postprandial plasma glucose (2hPG). Plasma glucose and fasting serum total cholesterol, triglycerides (TG), HDL cholesterol (HDL-C), LDL cholesterol (LDL-C), and high-sensitivity C-reactive protein (hsCRP) concentrations were measured with an automatic analyzer (Toshiba TBA 120FR; Toshiba Medical Systems Co., Ltd., Tokyo, Japan). HbA_{1c} was measured by automatic analyzers (HLC-723 G7 HPLC systems; Tosoh Corporation, Tokyo, Japan). The HbA_{1c} assay was certified by the National Glycohemoglobin Standardization Program (23) and standardized to the Diabetes Control and Complications Trial reference assay.

Quantification of abdominal adipose tissue by CT

Imaging of each subject in a supine position was performed on a 16-MDCT scanner (LightSpeed 16; GE Healthcare, Milwaukee, WI) (120 kVp, 400 mAs, slice thickness 5 mm). Image analysis software (ImageJ, version 1.44; National Institutes of Health, Bethesda, MD) was used with an attenuation range of −50 to −250 Hounsfield units to quantify the abdominal subcutaneous fat area (SFA) and VFA, expressed in centimeters squared, on a single cross-sectional image obtained at the level of the umbilicus.

Definitions

Hypertension was present if blood pressure was ≥140/90 mmHg or if the subject was taking medication for hypertension. Diabetes was diagnosed when FPG was ≥126 mg/dL (7 mmol/L), 2hPG ≥200 mg/dL (11.1 mmol/L), and HbA_{1c} ≥6.5% or if the subject was taking medication for diabetes (24). MS was defined in accordance with the updated NCEP ATP III guideline (7).

Statistical analysis

Data are presented as means and SDs for continuous variables and as a percentage for categorical variables. Pearson correlation coefficients and partial correlation coefficients were used to assess the relationship among WC, abdominal fat areas, and metabolic variables. The association of the different diagnostic criteria for central obesity with high VFA and with metabolic disease was analyzed by receiver operating characteristic (ROC) curve analysis. ROC statistics were calculated by using percentile values of disease case measures relative to the corresponding marker distribution among controls (25,26). Age was adjusted with a linear regression approach. CIs were calculated by bootstrap methods. Optimal cutoffs were derived from the ROC curve with the shortest distance to sensitivity = 1 and 1 − specificity = 0. Kaplan-Meier failure curves were used to estimate the cumulative incidence of hypertension, diabetes, and MS in individuals with and without central obesity defined by WC-IC or WC-mid cutoff values. The results were tested by Cox proportional hazard model adjusted for age. A two-tailed P value <0.05 was considered significant. The statistical analyses were performed with STAT/SE 11 for Windows (StataCorp LP, College Station, TX).

RESULTS—The clinical characteristics of the participants (n = 1,898) are summarized in Table 1. WC-IC values were significantly higher than WC-mid in both sexes, and the differences between WC-IC and WC-mid were greater in women than in men ($P < 0.001$). WC-IC and WC-mid were less correlated in women. The partial correlation coefficients adjusted for age in men and women were 0.91 and 0.834, respectively.

There were 425 participants, including 150 males and 275 females, who underwent abdominal CT for assessment of abdominal fat areas. Comparing participants with and without CT measurements, those who had CT evaluations showed slightly higher HDL-C (52 ± 12 vs. 50 ± 13 mg/dL; $P < 0.05$) and LDL-C values (121 ± 34 vs. 117 ± 32 mg/dL; $P < 0.05$). Women with CT measurement had higher WC-IC than women without CT measurement (85 ± 9 vs. 83 ± 9 cm; $P < 0.05$). As shown in Table 2, both WC-IC and WC-mid correlated significantly with BMI, total abdominal fat area, VFA, and SFA. WC-mid predicted high VFA (VFA ≥50th percentile in the corresponding

Table 1—Clinical characteristics of the study subjects

Variables	Men	Women
n	758	1,140
Age (years)	52 ± 13.1	49.4 ± 12‡
BMI (kg/m^2)	25.2 ± 3.3	23.6 ± 3.5‡
WC-IC (cm)	90 ± 9*	83 ± 9*‡
WC-mid (cm)	88 ± 9	78 ± 8‡
Difference between WC-IC and WC-mid (cm)	1.7 ± 3.8	5.6 ± 4.8‡
Systolic blood pressure (mmHg)	130 ± 16	120 ± 17‡
Diastolic blood pressure (mmHg)	82 ± 10	77 ± 10‡
Use of medications for hypertension (%)	17	12.4‡
Hypertension (%)	37	23‡
FPG [mmol/L (mg/dL)]	5.4 ± 1.2 (97 ± 22)	5.2 ± 1.2 (93 ± 21)‡
OGTT 2-h plasma glucose [mmol/L (mg/dL)]	7.4 ± 3.7 (133 ± 67)	7 ± 3.3 (126 ± 59)†
HbA_{1c} (%)	5.9 ± 0.9	5.7 ± 0.9†
Use of medications for diabetes (%)	2.8	1.1†
Diabetes (%)	15	10‡
Total cholesterol [mmol/L (mg/dL)]	5 ± 0.9 (193 ± 37)	5.1 ± 0.9 (196 ± 36)†
HDL-C [mmol/L (mg/dL)]	1.2 ± 0.3 (45 ± 11)	1.4 ± 0.3 (54 ± 12)‡
LDC-C [mmol/L (mg/dL)]	3.1 ± 0.8 (120 ± 32)	3 ± 0.8 (116 ± 32)†
TG [mmol/L (mg/dL)]	1.6 ± 1.6 (145 ± 142)	1.2 ± 0.8 (103 ± 70)‡
Use of medication for dyslipidemia (%)	3.6	1.4†
Plasma hsCRP (mg/dL)	0.22 ± 0.66	0.17 ± 0.3†

Data are mean ± SD unless otherwise indicated. OGTT, oral glucose tolerance test. *$P < 0.001$ vs. WC-mid; †$P < 0.05$ vs. men; ‡$P < 0.001$ vs. men.

sex) more often than WC-IC in women (area under the ROC [AUC] 0.825 for WC-IC, 0.860 for WC-mid; $P = 0.0142$), but not in men (AUC 0.855 WC-IC, 0.865 WC-mid; $P = 0.454$).

The data presented in Supplementary Table 1 show that both WC-IC and WC-mid correlated significantly with systolic and diastolic blood pressure, FPG, 2hPG, HbA_{1c}, TG, HDL-C, and hsCRP in both sexes, and WC-mid was better correlated than WC-IC with these metabolic variables in both sexes. Similar findings were noted after adjusting for age (data not shown).

Results in Table 3 show that the identification of individuals with hypertension, diabetes, and MS by WC-IC and WC-mid was fair (AUC 0.68–0.7 for WC-IC and 0.7–0.75 for WC-mid). WC-mid had slightly better association with hypertension, diabetes, and MS than WC-IC ($P < 0.05$ comparing AUC). The optimal cutoffs for WC-IC and WC-mid varied, depending on which disease to identify. Generally, WC-IC was more sensitive, whereas WC-mid was more specific. WC-mid had a higher age-adjusted AUC than WC-IC for diabetes in men, hypertension in women, and MS in both sexes (Supplementary Table 2). The data in Supplementary Table 3 show that WC-mid at its optimal cutoffs had the highest AUC for hypertension in females and diabetes and MS in both sexes. Using the cutoffs of 90 and 80 cm (males and females, respectively), WC-mid had significantly higher AUC for hypertension and diabetes in women and for MS in both sexes (all age-adjusted $P <$ 0.05) (Supplementary Table 3). The differences in AUC for hypertension, diabetes, and MS among four criteria were larger in women (0.04–0.07) than in men (0.02–0.05).

There were 1,503 subjects who stayed in the study for at least 12 months. Among them, 901 (60%) were successfully followed for medical and metabolic status. The median follow-up period was 31 months. The data in Table 3 indicate that the performance of WC-IC and WC-mid to predict incident hypertension, diabetes, and MS was fair (AUC 0.62–0.68 for WC-IC, 0.65–0.68 for WC-mid). The AUCs for WC-IC and WC-mid for hypertension, diabetes, and MS were not statistically different (age-adjusted $P > 0.05$). The optimal cutoff values for WC-IC and WC-mid to predict different diseases varied, and WC-IC was more sensitive, whereas WC-mid was more specific. As demonstrated by the data in Supplementary Table 2, there was no significant

Table 2—Associations between WC-IC and WC-mid, BMI, and abdominal fat areas

	Men		Women	
	WC-IC	WC-mid	WC-IC	WC-mid
Partial correlation coefficients, adjusted for age				
BMI (kg/m^2)	0.76	0.85	0.7	0.83
Total abdominal fat (cm^2)	0.81	0.81	0.75	0.79
Visceral abdominal fat (cm^2)	0.73	0.75	0.63	0.7
Subcutaneous abdominal fat (cm^2)	0.78	0.75	0.7	0.72
To identify high VFA†				
AUC (95% CI)	0.855 (0.796–0.913)	0.865 (0.809–0.92)	0.825 (0.778–0.872)	0.86* (0.817–0.902)
Optimal cutoffs (cm)	88	88	81	77
Sensitivity (%)	76	76	72	73
Specificity (%)	79	80	75	82

Abdominal fat areas were measured by CT. Fat areas were logarithmically transformed for the analyses. All *P* values for correlation coefficients and partial correlation coefficients were <0.001. *$P < 0.05$. †High VFA: VFA ≥50th percentile in the corresponding sex.

Table 3—*Different definitions of central obesity to identify or predict hypertension, diabetes, or MS*

	To identify disease				To predict disease			
	WC-IC		WC-mid		WC-IC		WC-mid	
AUC (95% CI)								
Hypertension	0.69 (0.66–0.71)		0.7 (0.68–0.73)*		0.68 (0.63–0.74)		0.66 (0.60–0.72)	
Diabetes	0.68 (0.65–0.72)		0.71 (0.67–0.74)*		0.62 (0.56–0.69)		0.65 (0.59–0.72)	
≥2 MS components[a]	0.7 (0.68–0.73)		0.75 (0.72–0.77)*		0.65 (0.61–0.7)		0.68 (0.63–0.73)	
Hypertension								
Cutoffs, male/female (cm)	90/80	88/83	90/80	87/78	90/80	89/84	90/80	90/77
Sensitivity (%)	71	73	58	71	70	66	48	55
Specificity (%)	48	53	66	57	45	58	72	64
Diabetes								
Cutoffs, male/female (cm)	90/80	90/84	90/80	88/79	90/80	90/84	90/80	89/80
Sensitivity (%)	74	71	65	74	78	65	57	58
Specificity (%)	45	56	63	57	42	55	68	67
≥2 MS components[a]								
Cutoffs, male/female (cm)	90/80	89/84	90/80	89/78	90/80	91/84	90/80	85/76
Sensitivity (%)	70	68	60	68	69	54	44	64
Specificity (%)	49	61	71	64	49	65	78	62

[a]Clustering of two or more components of MS, including fasting plasma glucose ≥100 mg/dL, blood pressure ≥130/85 mmHg, TG ≥150 mg/dL, and low HDL-C (<40 mg/dL in men; <50 mg/dL in women). Subjects taking medications for hypertension, diabetes, or dyslipidemia were considered as meeting the corresponding criteria. *Age-adjusted $P < 0.05$ compared with the AUC of WC-IC.

difference between WC-IC and WC-mid to predict hypertension, diabetes, or MS. However, WC-mid had slightly higher AUCs than WC-IC for diabetes and for hypertension in women (both age-adjusted P values 0.05–0.1). Data in Supplementary Table 3 show that the best criteria for highest AUC depended on the disease to be predicted and the sex to be considered. Using the cutoffs of 90/80 cm (male/female), WC-IC and WC-mid showed similar AUC for hypertension, diabetes, and MS in both sexes (all age-adjusted $P > 0.05$; Supplementary Table 3).

There were 639 subjects, including 206 men and 433 women, who did not have hypertension at baseline. During the follow-up period (median 31.7 months, interquartile range 16.1–45.6), 87 subjects developed hypertension. As shown in Fig. 1*A* and *B*, there was no difference in the incidence of hypertension in subjects with or without central obesity, neither by WC-IC or WC-mid criteria (both $P > 0.05$). There were 801 subjects, including 292 men and 509 women, who did not have diabetes at baseline. During follow-up (median 30.8 months, interquartile range 16.0–46.3), 60 developed diabetes. As shown in Fig. 1*C* and *D*, the cumulative incidence of diabetes was significantly higher in the individuals who met WC-mid criteria for central obesity ($P = 0.003$) and not for those with WC-IC criteria ($P = 0.112$). There were 587 subjects, including 179 men and 408 women, who had less than two components of MS at baseline. During follow-up (median 31.4 months, interquartile range 16.1–49.6), 162 subjects clustered three or more components of MS. Figure 1*E* and *F* shows that the cumulative incidence of MS was not significantly different in subjects who had central obesity by WC-IC criteria ($P = 0.988$) or WC-mid criteria ($P = 0.223$).

CONCLUSIONS—To the best of our knowledge, this is the first comprehensive study to compare different measurements of WC to define central obesity. We showed that WC-mid predicts high VFA better than WC-IC in women. Correlation, as compared by AUC, with hypertension, diabetes, and MS was better by WC-mid criteria than WC-IC criteria. However, the performance of WC-IC and WC-mid to predict hypertension, diabetes, and MS was similar, although only central obesity by WC-mid criteria, and not WC-IC criteria, predicted future diabetes incidence. Overall, our findings suggest that WC-mid is a better measurement of central obesity than WC-IC.

It is practical to keep the current cutoffs for central obesity (i.e., 90 [males]/80 [females] cm). Using these cutoffs, in the current study, we found that the sensitivity of WC-IC measurement values for identifying or predicting hypertension, diabetes, and MS was greater than that of WC-mid measurements. Since central obesity is a screening tool for metabolic diseases, higher sensitivity of WC-IC values may be a desirable attribute. Furthermore, WC-IC can be more precisely located than WC-mid, which may make it more consistent during follow-up. Therefore, in a recent scientific statement of the American Heart Association, WC-IC with cutoffs at 90/80 (male/female) cm for Asians has been recommended to define central obesity (2). In contrast, WC-mid correlated better to VFA and metabolic variables and worked better to identify and predict metabolic diseases in the current study. These findings suggest that WC-mid is a better measurement for central obesity. Indeed, when optimal cutoffs were used, WC-mid showed better performance than WC-IC did, with more balanced sensitivity and specificity. Furthermore, although measurement of WC-mid is a slightly more complex procedure, findings from the current study and from Mason and Katzmarzyk (27) have shown that the reproducibility of WC-mid measurement is also high. Thus, if modification of the cutoffs for central obesity is to be considered, WC-mid is a better location of measurement than WC-IC.

The impact of the location of WC measurement varies by sex. In the current study, the difference between WC-IC and WC-mid was larger in women (5.6 cm)

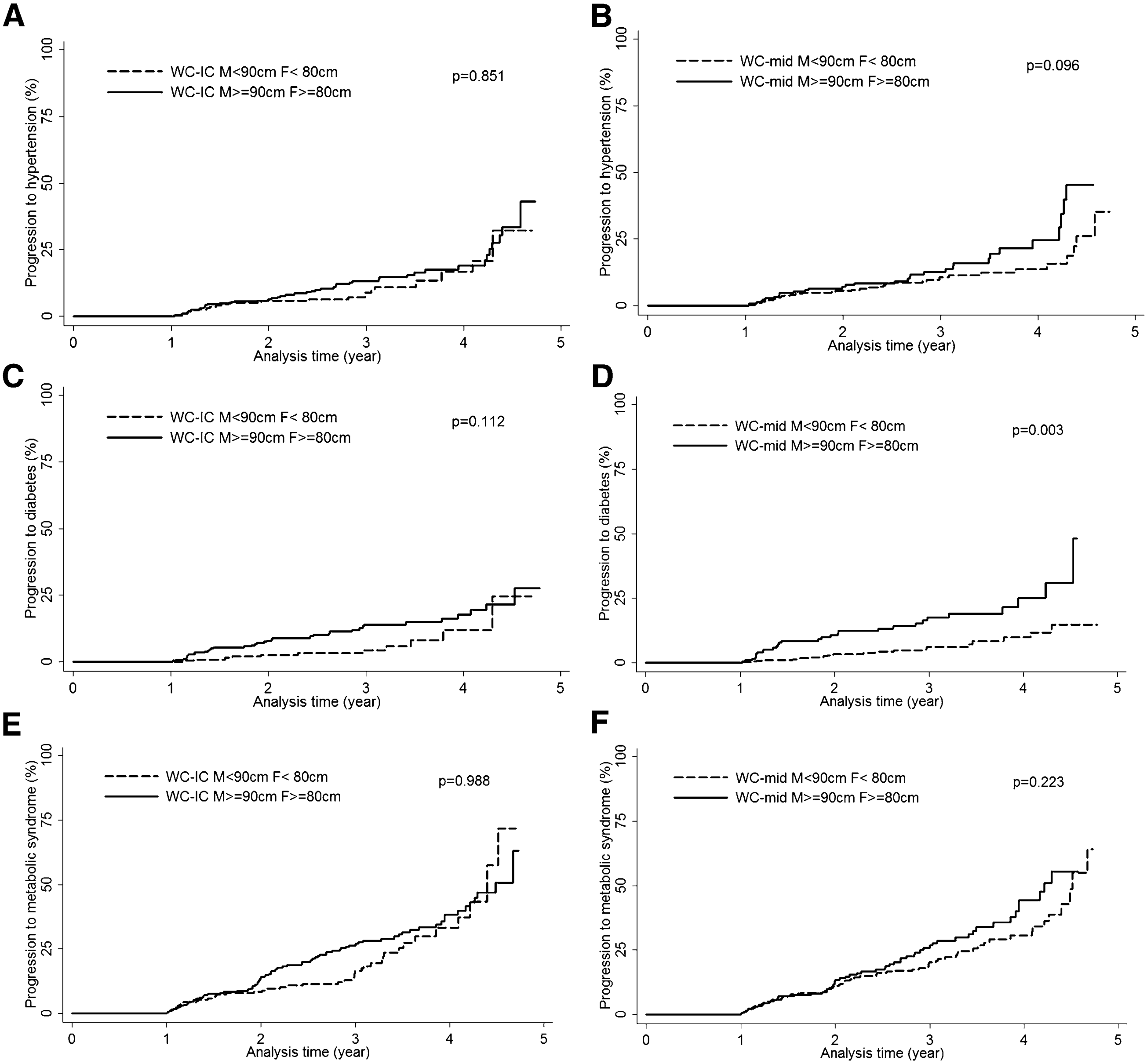

Figure 1—*Different definitions of central obesity to predict metabolic diseases. Kaplan-Meier curves for the cumulative incidence of developing hypertension* (A *and* B)*, diabetes* (C *and* D)*, or MS* (E *and* F) *by WC-IC* (A, C, *and* E) *or WC-mid* (B, D, *and* F) *to define central obesity. Age-adjusted* P *values are shown. F, female; M, male.*

than in men (1.7 cm), which is in concordance with a report in Caucasians (28). This may explain why the differences between the correlation coefficients of VFA to WC-IC and WC-mid were larger in women than in men in present study (Table 2). It could also explain why WC-mid in women, but not in men, showed significantly higher AUCs than WC-IC for hypertension, diabetes, and MS when cutoffs of 90/80 (male/female) cm were used (Supplementary Table 3). Also, the differences in AUC among the four WC criteria used to identify these diseases were larger in women than in men (Supplementary Table 3), and similar findings were also reported in the previous study in Caucasians (29). In that study, the differences between WC-IC and WC-mid were 0.4 cm in men and 1.1 cm in women, and the differences in AUC for components of MS among WC-IC, WC-mid, WC at umbilicus, and minimal WC were larger in women (0.053–0.088) than in men (0.003–0.029). All of these findings suggest that the location of WC measurement has greater impact in women than in men.

The optimal cutoffs depend on the diseases to be identified or predicted. In the current study, the optimal cutoffs for both WC-IC and WC-mid were all different (Table 3). Supporting our findings, the optimal cutoffs for WC were also different for different metabolic diseases in another large cross-sectional study in Taiwan that included 55,563 people (11). In that study, optimal cutoffs were determined based on the performance for identifying at least one disease, including hypertension, diabetes, and dyslipidemia. Moreover, there have been two Chinese studies investigating the optimal cutoffs based on the relationship of WC to VFA (18,30). Bao et al. (30) reported that individuals in a cross-sectional study with VFA >80 cm^2 had higher risk of MS. The corresponding WC cutoffs were 90 (male)/85 (female) cm. Ye et al. (18) showed that subjects with VFA >90 cm^2 have a higher risk of future incidence of diabetes. The corresponding WC cutoffs were 88 (male)/82 (female) cm. In summary, it seems essential to have a consensus for the use of WC before optimal cutoffs can be determined. Questions that should be addressed include the following: for which diseases are associations with WC most important? Are the cutoffs based on disease identification or disease prediction? Should VFA be considered?

In the current study, WC-mid was better correlated to VFA than WC-IC. Various reports have shown that visceral adipose tissue (VAT) produces and releases adipokines, which are linked to the development of metabolic abnormalities (31–33). Fatty acids from VAT drain to the liver, and the increased fat influx may increase hepatic TG content, resulting in increased hepatic glucose output and VLDL TG production (34,35). VAT also secretes higher levels of proinflammatory cytokines than subcutaneous adipose tissue (36,37). All of these mechanisms provide for a potentially pathogenic role of VAT in the development of metabolic abnormalities, and indeed, increased VFA has been associated with increased risk of hypertension, diabetes, and dyslipidemia in humans (38,39). However, WC has been shown to have a stronger correlation to SFA than VFA in Caucasians, indicating that WC is a better index of SFA (28). In present study, although WC also showed stronger correlation with SFA than VFA, the differences in the correlation coefficients were small, especially for WC-mid (0.01–0.04 in men and 0–0.03 in women; Table 2). These findings suggest that WC, particularly WC-mid, can be viewed as an index of both SFA and abdominal VFA in Asians.

The strength of this study is in the completeness of its comparison of WC-IC and WC-mid. We compared the biologic roles of WC-mid and WC-IC through their relationships to VFA and metabolic variables. We also investigated their potential for identifying and predicting metabolic diseases. In contrast, this study was limited in that only WC-IC and WC-mid were compared and evaluated. From the literature, there are at least eight different measurement locations for WC (40). However, since WC-IC or WC-mid have been the recommended locations by World Health Organization, NCEP ATP III, and IDF (6–8), the findings of the current study are practical. Moreover, the study subjects were not a random sample because the incidence of hypertension and diabetes were higher (5.1%/person-year and 2.8%/person-year, respectively). This may be due to a higher percentage of subjects who had prehypertension and prediabetes in the cohort (24 and 39%, respectively), since people at risk are more willing to be followed. However, this did not confound the relationship between WC and metabolic diseases.

In conclusion, WC-mid proved in this study to be a better measurement to define central obesity than WC-IC in Asians, since WC-mid was more closely related to abdominal VFA and metabolic variables and had better results for identifying and predicting metabolic diseases. The impact of location of WC measurement is greater in women. The optimal cutoffs are different when different metabolic diseases are considered. Our data further indicate that there is a need to re-evaluate the location of WC measurement and cutoffs for central obesity in different ethnic groups.

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W.-Y.M. wrote the manuscript and researched data. C.-Y.Y. researched data. S.-R.S. wrote the manuscript. H.-J.H., C.S.H., F.-C.C., M.-S.L., P.-H.L., and L.-M.C. contributed to the discussion. C.-H.H. and Y.-C.H. researched data. J.-W.L. and J.-N.W. reviewed and edited the manuscript. H.-Y.L. researched data and reviewed and edited manuscript. H.-Y.L. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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