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Body mass index, waist circumference, and cardiometabolic risk factors in young and middle-aged Chinese women

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Abstract: Objective: To assess the associations between body mass index (BMI), waist circumference (WC), and cardiometabolic risk factors in young and middle-aged Chinese women. Methods: A total of 3011 women (1938 young women, 1073 middle-aged women), who visited our health care center for a related health checkup, were eligible for study. BMI and WC were measured. The subjects were divided into normal and overweight/obesity groups based on BMI, and normal and abdominal obesity groups based on WC. Cardiometabolic variables included triglyceride (TG), high density lipoprotein cholesterol (HDL-C), fasting blood glucose (FBG), homeostasis model assessment of insulin resistance (HOMA-IR), and blood pressure (BP). Results: The prevalence of overweight/obesity was significantly higher in middle-aged women (32.4%) than in young women (12.0%). The prevalence of abdominal obesity was also higher in middle-aged women (60.3%) than in young women (36.2%). There were significant differences in the comparison of all related cardiometabolic variables between different BMI (or WC) categories in young and middle-aged women groups, respectively. After adjustment for age, partial correlation analysis indicated that both BMI and WC were correlated significantly with all related cardiometabolic variables. After adjustment for age and WC, although the correlation coefficient *r*′ was attenuated, BMI was still correlated significantly with all related cardiometabolic variables in young and middle-aged women. After adjustment for age and BMI, partial correlation analysis showed that WC was correlated significantly with TG, FBG, HOMA-IR, and HDL-C in young women and significantly with TG, HOMA-IR, and HDL-C in middle-aged women. Conclusions: The prevalence of overweight/obesity and abdominal obesity was high in Chinese young and middle-aged women. BMI was a better predictor of cardiovascular disease and diabetes than WC in young and middle-aged women, and moreover, measurement of both WC and BMI may be a better predictor of cardiovascular disease and diabetes mellitus than BMI or WC alone.

Key words: Body mass index, Waist circumference, Obesity, Cardiovascular disease, Diabetes mellitus, Women
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1 Introduction

The increasing prevalence of obesity is a major public health problem worldwide. In Europe, the prevalence of obesity [body mass index (BMI) ≥30.0 kg/m^2] in men ranges from 4.0% to 28.3% and in women from 6.2% to 36.5% (Berghöfer *et al.*, 2008). In the United States, the prevalence ranges from 17.8% to 30.9% (Brock *et al.*, 2009). The prevalence among adult women is 16.7% in Selangor, Malaysia (Sidik and Rampal, 2009). As in other countries, the prevalence of being overweight and obesity is increasing in China. Wu (2006) showed that 14.7% of Chinese were overweight (BMI 25.0–29.9 kg/m^2) and another 2.6% had obesity (BMI ≥30.0 kg/m^2).

Obesity has been recognized as a potential risk factor for cardiovascular disease (CVD), diabetes mellitus (DM), and cancer (Berghöfer *et al.*, 2008).

On the other hand, abdominal fat distribution is a strong risk factor for CVD (Wildman *et al*., 2005), and BMI may not indicate the level of central adiposity. At present, waist circumference (WC) has been recommended as a measure of abdominal obesity. Some studies have revealed an independent effect of WC on CVD risk factors (Ardern *et al*., 2003; Zhu *et al*., 2004). Nevertheless, little is known about the independent effects of BMI and WC, and the results remain controversial (Ho *et al*., 2001; Janiszewski *et al*., 2007).

The aim of this study was to assess the association between BMI, WC, and cardiometabolic risk factors and to confirm whether either or both BMI and WC are independently associated with cardiometabolic risk factors in young and middle-aged Chinese women.

2 Subjects and methods

2.1 Subjects

A total of 3011 young and middle-aged women visited our health care center for a related health checkup in the period from March to December 2008. In this population, there were 1938 young women (age range 19–44 years) and 1073 middle-aged women (age range 45–59 years).

2.2 Classifications of BMI and WC

BMI is recognized as the measure of obesity. The criteria were as follows: underweight <18.5 kg/m^2, desirable weight 18.5–24.9 kg/m^2, overweight 25.0–29.9 kg/m^2, and obese ≥30.0 kg/m^2 (NHLBI Expert Panel on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults, 1998). WC was used as the measure of abdominal obesity, defined as WC≥80 cm for Asian women by the international diabetes federation (IDF) (Alberti *et al*., 2005). Weight, height, and WC were measured by qualified technicians.

2.3 Cardiometabolic variables

Venous blood samples were obtained after a minimum 8-h fast for the measurement of serum indexes: (1) Triglyceride (TG) and high density lipoprotein cholesterol (HDL-C) concentrations were measured by the terminal method, using an OLYMPUS AU machine; (2) Fasting blood glucose (FBG) concentration was measured by the hexokinase method, using an OLYMPUS AU machine; (3) Fasting insulin (FINS) concentration was measured by the antibody sandwich enzyme-linked immunosorbent assay (ELISA) method, using DPL IMMULITE automatic immunoanalyzer; (4) Homeostasis model assessment of insulin resistance (HOMA-IR), an index which represents insulin resistance, was calculated according to the following formula: HOMA-IR=[FINS (μU/ml)×FBG (mmol/L)]/ 22.5 (Matthews *et al*., 1985). Blood pressure (BP) was measured by qualified technicians.

2.4 Statistical analysis

The SPSS statistical package (Version 11.5) was used for the statistical analysis. P<0.05 was considered statistically significant. The normal-distribution data were expressed as the mean±standard deviation (SD). Skewed distribution data were expressed as the median with 25th and 75th percentiles (P_{25}–P_{75}). Chi-square test was used to compare the prevalence of overweight/obesity and abdominal obesity, respectively, based on BMI and WC between young and middle-aged women. The Mann-Whitney U test was used to compare the related cardiometabolic risk factors between normal weight and overweight/ obesity based on BMI (or normal WC and abdominal obesity based on WC) in young and middle-aged women, respectively. The SAS (Version 9.2) was used for Spearman partial correlation analysis after adjustment for age and adjustment for age and BMI (or WC). P<0.05 was considered statistically significant.

3 Results

The prevalence of overweight/obesity was significantly higher in middle-aged women (32.4%) than in young women (12.0%). The prevalence of abdominal obesity was also higher in middle-aged women than in young women (P<0.001). As shown in Table 1, normal BMI and WC predominated in young women, whereas normal BMI and abdominal obesity predominated in middle-aged women (abdominal obesity: 36.2% for young women, 60.3% for middle-aged women).

Comparisons of HDL-C, TG, FBG, HOMA-IR,

systolic BP (SBP), diastolic BP (DBP), and WC (or BMI) values between different BMI categories (or the normal WC and abdominal obesity groups) in young and middle-aged women are presented in Tables 2–5, respectively. The results showed that HDL-C concentration was significantly lower and other indexes were significantly higher (P<0.001) in the overweight/obesity group than in the normal BMI group. Similar findings were obtained in the comparison between the abdominal obesity group and the normal WC group.

Spearman partial correlation coefficients between BMI or WC and cardiometabolic risk factors in young and middle-aged women, respectively, are shown in Tables 6 and 7. In regard to young women (Table 6), after adjustment for age, the analysis indicated that BMI was correlated positively with TG, FBG, HOMA-IR, SBP, DBP, and WC, and correlated negatively with HDL-C (r=0.290, 0.220, 0.453, 0.250, 0.229, 0.635, and −0.294, all P<0.0001). After adjustment for age and WC, although the correlation coefficient r' was attenuated, BMI was correlated positively with TG, FBG, HOMA-IR, SBP, and DBP, and negatively correlated with HDL-C (r'=0.172, 0.110, 0.302, 0.176, 0.162, and −0.179, all P<0.0001). After adjustment for age, WC was positively correlated with TG, FBG, HOMA-IR, SBP, DBP, and BMI, and correlated negatively with HDL-C (r=0.255, 0.216, 0.373, 0.184, 0.167, 0.635, and −0.251, all P<0.0001). After adjustment for age and BMI, partial correlation analysis showed that WC was correlated positively with TG (r'=0.095, P<0.0001), FBG (r'=0.101, P<0.0001), HOMA-IR (r'=0.124, P<0.0001), and correlated negatively with HDL-C (r'=−0.087, P=0.0001). The r' value between WC and SBP or DBP was not statistically significant.

In the middle-aged women (Table 7), after adjustment for age, the analysis indicated that BMI was correlated positively with TG, FBG, HOMA-IR, SBP, DBP, and WC, and correlated negatively with HDL-C (r=0.281, 0.223, 0.498, 0.311, 0.264, 0.698, and −0.292, all P<0.0001). After adjustment for age and WC, partial correlation analysis showed that BMI was correlated positively with TG, FBG, HOMA-IR, SBP, and DBP, and correlated negatively with HDL-C (r'=0.136, 0.131, 0.289, 0.238, 0.195, and −0.166, all P<0.0001). After adjustment for age,

Table 1 Prevalence of overweight/obesity based on BMI and abdominal obesity based on WC in young and middle-aged women

Group	BMI			WC	
	Underweight	Normal	Overweight/obesity	Normal	Abdominal obesity
Young female (n=1938)	148 (7.7%)	1557 (80.3%)	233 (215/18) 12.0% (11.1%/0.9%)	1237 (63.8%)	701 (36.2%)
Middle-aged female (n=1073)	9 (0.8%)	717 (66.8%)	347 (311/36) 32.4% (29.0%/3.4%)	426 (39.7%)	647 (60.3%)

Chi-square test showed P<0.001 in the comparison of the prevalence of overweight/obesity and abdominal obesity between young and middle-aged women

Table 2 Comparison of age, HDL-C, TG, FBG, HOMA-IR, SBP, DBP, and WC between different BMI categories in young women

Parameter	BMI*		Z value	P value
	Normal (1557)	Overweight/obesity (233)		
Age (year)	37.0 (33.0–41.0)	39.0 (35.0–42.0)	−4.779	<0.001
HDL-C (mg/dl)	65.0 (57.0–73.0)	57.8±13.5	−8.288	<0.001
TG (mg/dl)	79.0 (62.0–106.0)	109.0 (84.5–157.5)	−10.265	<0.001
FBG (mg/dl)	86.0 (82.0–90.0)	89.0 (85.0–95.5)	−7.367	<0.001
HOMA-IR	1.26 (0.89–1.72)	2.19 (1.68–3.09)	−14.352	<0.001
SBP (mmHg)	110.0 (102.0–118.0)	121.0 (114.0–134.0)	−11.573	<0.001
DBP (mmHg)	66.0 (60.0–72.0)	75.6±11.3	−11.524	<0.001
BMI (kg/m^2)	21.5 (20.1–22.7)	26.4 (25.4–28.3)	−24.654	<0.001
WC (cm)	76.0 (72.0–80.0)	86.6±6.5	−18.499	<0.001

* Data are expressed as mean±SD or median (P_{25}–P_{75}). The Mann-Whitney U test was used to compare data within different BMI categories

Table 3 Comparison of age, HDL-C, TG, FBG, HOMA-IR, SBP, DBP, and BMI between the normal WC and abdominal obesity groups in young women

Parameter	WC*		*Z* value	*P* value
	Normal (1237)	Abdominal obesity (701)		
Age (year)	36.0 (31.0–40.0)	39.0 (34.0–42.0)	−8.907	<0.001
HDL-C (mg/dl)	66.0 (58.0–75.0)	61.7±13.3	−8.550	<0.001
TG (mg/dl)	76.0 (60.0–101.0)	93.0 (71.0–132.0)	−9.635	<0.001
FBG (mg/dl)	85.0 (81.0–89.5)	88.0 (84.0–92.5)	−9.109	<0.001
HOMA-IR	1.15 (0.80–1.59)	1.64 (1.12–2.26)	−13.370	<0.001
SBP (mmHg)	110.0 (102.0–118.0)	115.0 (105.0–124.0)	−7.403	<0.001
DBP (mmHg)	65.0 (59.0–72.0)	69.0 (62.0–76.0)	−7.251	<0.001
BMI (kg/m^2)	20.6 (19.4–22.1)	23.5 (22.0–25.3)	−24.069	<0.001
WC (cm)	73.0 (70.0–76.0)	84.0 (81.0–87.0)	−36.662	<0.001

* Data are expressed as mean±SD or median (P_{25}–P_{75}). The Mann-Whitney *U* test was used to compare data within the normal WC and abdominal obesity groups

Table 4 Comparison of age, HDL-C, TG, FBG, HOMA-IR, SBP, DBP, and WC between different BMI categories in middle-aged women

Parameter	BMI*		*Z* value	*P* value
	Normal (717)	Overweight/obesity (347)		
Age (year)	48.0 (46.0–52.0)	51.0 (47.0–55.0)	−5.723	<0.001
HDL-C (mg/dl)	65.0 (56.0–76.0)	59.3±13.6	−7.257	<0.001
TG (mg/dl)	98.0 (74.0–134.5)	121.0 (89.0–177.0)	−6.974	<0.001
FBG (mg/dl)	89.0 (84.0–95.0)	92.0 (87.0–101.0)	−6.089	<0.001
HOMA-IR	1.25 (0.85–1.76)	2.08 (1.47–3.03)	−13.608	<0.001
SBP (mmHg)	120.0 (112.0–133.0)	132.0 (122.0–143.0)	−9.658	<0.001
DBP (mmHg)	73.0 (67.0–81.0)	79.6±10.8	−7.728	<0.001
BMI (kg/m^2)	22.4 (21.2–23.6)	26.8 (25.8–28.4)	−26.475	<0.001
WC (cm)	79.0 (74.0–83.0)	89.0 (85.0–92.0)	−19.576	<0.001

* Data are expressed as mean±SD or median (P_{25}–P_{75}). The Mann-Whitney *U* test was used to compare data within different BMI categories

Table 5 Comparison of age, HDL-C, TG, FBG, HOMA-IR, SBP, DBP, and BMI between the normal WC and abdominal obesity groups in middle-aged women

Parameter	WC*		*Z* value	*P* value
	Normal (426)	Abdominal obestiy (647)		
Age (year)	47.5 (46.0–51.3)	50.0 (47.0–54.0)	−6.966	<0.001
HDL-C (mg/dl)	67.6±14.5	60.0 (52.0–70.0)	−6.812	<0.001
TG (mg/dl)	90.0 (69.8–119.3)	115.0 (85.0–167.0)	−8.502	<0.001
FBG (mg/dl)	89.0 (83.0–93.0)	92.0 (86.0–98.0)	−6.172	<0.001
HOMA-IR	1.14 (0.75–1.68)	1.68 (1.17–2.55)	−11.526	<0.001
SBP (mmHg)	122.0±16.5	126.0 (117.0–139.0)	−6.335	<0.001
DBP (mmHg)	73.6±11.2	76.0 (69.0–84.0)	−5.267	<0.001
BMI (kg/m^2)	21.9±2.0	24.9 (23.3–26.9)	−18.573	<0.001
WC (cm)	75.0 (72.0–77.0)	87.0 (83.0–91.0)	−27.767	<0.001

* Data are expressed as mean±SD or median (P_{25}–P_{75}). The Mann-Whitney *U* test was used to compare data within the normal WC and abdominal obesity groups

Table 6 Spearman partial correlation analysis between BMI or WC and cardiometabolic risk factors in young women

Parameter	BMI				WC			
	r	*P* value	*r′*#	*P* value	*r*	*P* value	*r′**	*P* value
HDL-C	−0.294	<0.0001	−0.179	<0.0001	−0.251	<0.0001	−0.087	0.0001
TG	0.290	<0.0001	0.172	<0.0001	0.255	<0.0001	0.095	<0.0001
FBG	0.220	<0.0001	0.110	<0.0001	0.216	<0.0001	0.101	<0.0001
HOMA-IR	0.453	<0.0001	0.302	<0.0001	0.373	<0.0001	0.124	<0.0001
SBP	0.250	<0.0001	0.176	<0.0001	0.184	<0.0001	0.033	0.1423
DBP	0.229	<0.0001	0.162	<0.0001	0.167	<0.0001	0.028	0.2108
BMI	−	−	−	−	0.635	<0.0001	−	−
WC	0.635	<0.0001	−	−	−	−	−	−

r: Spearman partial correlation coefficient after adjustment for age; *r′*: Spearman partial correlation coefficient after adjustment for age and WC (#) or after adjustment for age and BMI (*)

Table 7 Spearman partial correlation analysis between BMI or WC and cardiometabolic risk factors in middle-aged women

Parameter	BMI				WC			
	r	*P* value	*r′*#	*P* value	*r*	*P* value	*r′**	*P* value
HDL-C	−0.292	<0.0001	−0.166	<0.0001	−0.254	<0.0001	−0.073	0.0173
TG	0.281	<0.0001	0.136	<0.0001	0.268	<0.0001	0.105	0.0006
FBG	0.223	<0.0001	0.131	<0.0001	0.188	<0.0001	0.046	0.1339
HOMA-IR	0.498	<0.0001	0.289	<0.0001	0.448	<0.0001	0.162	<0.0001
SBP	0.311	<0.0001	0.238	<0.0001	0.207	<0.0001	−0.015	0.6324
DBP	0.264	<0.0001	0.195	<0.0001	0.181	<0.0001	−0.004	0.8939
BMI	−	−	−	−	0.698	<0.0001	−	−
WC	0.698	<0.0001	−	−	−	−	−	−

r: Spearman partial correlation coefficient after adjustment for age; *r′*: Spearman partial correlation coefficient after adjustment for age and WC (#) or after adjustment for age and BMI (*)

WC was correlated positively with TG, FBG, HOMA-IR, SBP, DBP, and BMI, and correlated negatively with HDL-C (r=0.268, 0.188, 0.448, 0.207, 0.181, 0.698, and −0.254, all P<0.0001). After adjustment for age and BMI, partial correlation analysis showed that WC was correlated positively with TG (r'=0.105, P=0.0006), HOMA-IR (r'=0.162, P<0.0001), and correlated negatively with HDL-C (r'=−0.073, P=0.0173). The r' value between WC and FBG, SBP, or DBP was not statistically significant.

4 Discussion

The prevalence of obesity is increasing rapidly in both developing and developed countries. In the present study, the prevalence of obesity was 0.9% in young Chinese women and 3.4% in middle-aged Chinese women. This is lower than the prevalence in the United States and other countries (Ogden *et al*., 2006; Berghöfer *et al*., 2008; Sidik and Rampal, 2009). The differences in prevalence from various reports could be due to subject selection.

The percentage of abdominal obesity was 36.2% in young women and 60.3% in middle-aged women, which was higher than percentage of overweight/obesity based on BMI. Hauner *et al*. (2008) has also reported that women more often have an increased WC. Abdominal obesity has been shown to be a risk factor for CVD and diabetes (Balkau *et al*., 2007a; Janiszewski *et al*., 2007). A large cohort study (Koster *et al*., 2008) showed that increased WC should be considered a risk factor for mortality, in addition to BMI. In our study, the prevalence of abdominal obesity in middle-aged women was obviously higher than that in young women. This was plausible because trunk fat mass, the proportion of android fat, was lower and the proportion of gynoid fat was greater in premenopausal women than in postmenopausal women (Ley *et al*., 1992). Thus, middle-aged women in particular should be aware of their WC.

The young and middle-aged women were divided into two groups: normal BMI and overweight/obesity based on BMI, and also normal WC and abdominal obesity based on WC. Comparisons of HDL-C, TG, FBG, HOMA-IR, SBP, DBP, and WC between different BMI groups indicated that the results of related indexes were all significantly different. Likewise, there were similar results in the comparison between different WC groups. The results showed that overweight/obesity and abdominal obesity were associated with increased risks of CVD and DM in this young and middle-aged population. Other studies have also shown that BMI and/or WC were strongly linked to CVD and diabetes (Rexrode *et al*., 1998; Balkau *et al*., 2007b; Christian *et al*., 2009; Yoshida *et al*., 2009). However, the pathophysiological mechanism of this association was uncertain. Previous studies have demonstrated that this possibility was biologically plausible as obesity was associated with insulin resistance, which appeared to be the underlying cause of metabolic syndrome and type 2 diabetes (Kip *et al*., 2004). On the other hand, whether WC or BMI was closely related with cardiometabolic risk factors in young and middle-aged women was unknown. Therefore, in this study, the data were further analyzed.

The results of this study indicated that both BMI and WC were significantly related to cardiometabolic risk factors in young and middle-aged women. After adjustment for age, the correlated coefficient between WC and BMI was the largest. Among related cardiometabolic risk factors, correlated coefficient between BMI (or WC) and HOMA-IR was also the largest. This illustrates that BMI and WC were closed related with insulin resistance in young and middle-aged women. Previous research has shown that persons with overweight or obesity run a higher risk of developing insulin resistance (Mokdad *et al*., 2003). It is already known that insulin resistance is an important pathogenic factor in common metabolic disorders (Wahrenberg *et al*., 2005) and a cardiometabolic risk factor (de Rooij *et al*., 2009). The strong correlation with BMI, WC, and HOMA-IR indicates that measurement of BMI and WC may be important in prevention of CVD and DM.

In young women, after adjustment for age and WC, BMI was significantly related with HDL-C, TG, FBG, HOMA-IR, SBP, and DBP; however, after adjustment for age and BMI, WC was significantly related with HDL-C, TG, FBG, and HOMA-IR, and not significantly related with SBP and DBP. In middle-aged women, after adjustment for age and WC, BMI was also significantly related with HDL-C, TG, FBG, HOMA-IR, SBP, and DBP, the same as in young women. But after adjustment for age and BMI, WC was only significantly related with HDL-C, TG, and HOMA-IR. Previous research has similarly indicated that WC is not a significant predictor of hypertension among non-whites (Christian *et al*., 2009). Other research has shown contrary results, suggesting that WC was a better predictor than BMI of CVD, diabetes, or metabolic disorders (Zhu *et al*., 2002; Janssen *et al*., 2004; Lofgren *et al*., 2004; Park *et al*., 2009). On the other hand, consistent with previous research (Wildman *et al*., 2005), our results show that the partial correlation coefficients after adjustment for age and BMI (or WC) were all smaller than corresponding correlation coefficient *r* values after adjustment for age. Thus, the combination of BMI and WC may be a better predictor of CVD and DM than BMI or WC alone.

The present study has limitations. The subjects were not a general female population, but visitors to our health care center. The prevalence of overweight/obesity in the general population may be overestimated due to selection bias. Further studies are required among more general populations. Another limitation is that we did not have self-reported information on smoking at baseline. Previous research has shown that smoking is a major risk factor for CVD (Ckene and Miller, 1997). However, the present subjects are from a female population, and the prevalence of female smokers is low in China (He *et al*., 2008). A further limitation is that because the present data were based solely on young and middle-aged women, the extent to which our findings can be generalized to men and other ages of women is unclear.

In conclusion, the prevalence of overweight/obesity and abdominal obesity was high in young and middle-aged Chinese women. Our study showed that BMI was a better predictor of CVD and DM than WC among this population; moreover, the measurement of both WC and BMI in young and middle-aged Chinese women may be a better predictor of CVD and DM than BMI or WC alone.

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