Observational Study

Medicine

OPEN

Association between obesity indicators and cardiovascular risk factors among adults in low-income Han Chinese from southwest China

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Abstract

There may be differences in optimal anthropometric cut-offs for diagnosing obesity among different regions of China. However, there has been little studies about choosing effective obesity indicators in Han People of low-income Chinese adults in southwest China. The purpose of this study was to compare and evaluate the associations between different obesity indicators and cardiovascular disease risk factors (CVDRF) and choose the optimal cut-off values.

A cross-sectional study was carried out in southwest of China, with multi-stage sampling enrolling 2112 subjects aged 20 to 80 years old. Anthropometric measurements included Body mass index (BMI), waist circumference (WC), Hip circumference, waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR). We measured the percentage of body fat (PBF) by bioelectrical impedance analyzer to assess the body composition. The validity of different obesity indicators in assessing CVDRF risk were assessed through comparison area under curve of different indicators in assessing CVDRF risk in different gender. Logistic regression models were used to evaluate the association between the obesity indicators and CVDRF.

When both male and female were considered, the optimal indicators were WHtR and percentage of body fat PBF for hypertension, WHR and WHtR for dyslipidemia. Both WC and WHtR were optimal indicators in assessing metabolic syndrome risk for both genders. When both disease and gender were considered, WHtR was the best associated indicators with various CVDRF. The cut-off of BMI and WC were consistent to the definition of obesity in Working Group of China. The WHtR positively correlated with the CVDRF. The cut-off of WHtR to do what was approximately 0.50 for adults in both genders in southwest of China.

WHtR may be the best associated indicators for obesity-related CVDRF among the others (BMI, WC, Hip circumference, PBF, and WHR) in southwest of China. The cut-off of WHtR was approximately 0.50 for adults in both genders in southwest of China.

Abbreviations: AUC = area under curve, BF = body fat, BIA = bioelectrical impedance analyzer, BMI = Body mass index, CDC = centers for disease control and prevention, CIs = confidence intervals, CVDRF = cardiovascular disease risk factors, FPG = fasting plasma glucose, HC = Hip circumference, HDL-C = High-Density Lipoprotein Cholesterol, LDL-C = Low-Density Lipoprotein Cholesterol, MS = metabolic syndrome, ORs = odds ratios, PBF = percentage of body fat, TC = Total Cholesterol, WC = waist circumference, WHR = waist-to-hip ratio, WHtR = waist-to-height ratio.

Keywords: association, cardiovascular disease risk factors, obesity indicators

Editor: Bernhard Schaller.

This study was supported by the National Science and Technology Pillar Program during the Twelfth Five-Year Plan Period sponsored by the Ministry of Science and Technology of China (Grant No. 2012BAI37B02).

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

The authors have no conflicts of interest to disclose.

Supplemental Digital Content is available for this article.

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How to cite this article: Wang K, Pan L, Wang D, Dong F, Yu Y, Wang L, Li L, Liu T, Sun L, Zhu G, Feng K, Xu K, Pang X, Chen T, Pan H, Ma J, Zhong Y, Shan G. Association between obesity indicators and cardiovascular risk factors among adults in low-income Han Chinese from southwest China. Medicine 2020;99:30(e20176).

Received: 10 May 2019 / Received in final form: 13 March 2020 / Accepted: 7 April 2020

http://dx.doi.org/10.1097/MD.0000000000020176

1. Introduction

Obesity is one of the major risk factors of hypertension and diabetes, which cause cardiovascular diseases and mortality worldwide.[1,2] Thus, effective obesity indicators also could be a good associated indicator for the obesity-related health risks, especially cardiovascular disease risk factors (CVDRF) such as hypertension, dyslipidemia, diabetes, and metabolic syndrome (MS). The most frequently used obesity indicators are anthropometry and body composition measurements. Body mass index (BMI) is the most widely used anthropometry indicator. However, it does not differentiate between adipose tissues and muscle compartments. Other anthropometry indicators, such as waist to hip ratio (WHR) and waist circumference (WC), are used to reflect the distribution of central fat. WC indicates visceral and abdominal fat and was used to assess the CVDRF. Meanwhile, waist to height ratio (WHtR) as a screening tool for CVDRF was widely recognized. Body composition measurements assess the distributions of fat mass and Fat-free mass. The measurements include density analysis, body water content, dual energy X-ray absorptiometry, and bioelectrical impedance analyzer (BIA). All these measurements had similar power in assessing obesity at populational level.[3] Because BIA is easy to use and noninvasive, it is applicable to epidemiology studies.[4,5] Previous studies had used BIA to assess the validity of obesity indicators in assessing CVDRF. However, these studies yielded inconsistent conclusions regarding the sensitivity and specificity of multiple obesity indicators in assessing CVDRF.[3,6–9] Besides, it had been demonstrated that the obese Asians with lower BMI and WC measurement associated with increased CVDRF risks. Some studies had suggested that the distribution of adipose tissue was different among different genders, ages, and races. Thus, there may be differences in anthropometric measurements cut-offs to identify obesity between Chinese and Western populations. Recent years, there were studies in Chinese population using obesity indicators to estimate the risk of CVDRF,[10–12] but they focused on the parts of age groups. There were also studies that assessed optimal cut-offs of various obesity indices to assess CVDRF among Chinese adults, but they focused on populations in northeast[13] or east[14] of China. Han Chinese constitutes about 92% of Chinese population, and study showed that the Han Chinese in the southwest had shorter height than the Han Chinese from northeast regions.[15,16] So, there may be differences in index evaluation and optimal cut-offs between different regions. Consequently, we designed the present study on community-based Han Chinese in southwest China aged between 20 and 80 years old in order to explore and compare the validity of different obesity indicators to assess the CVDRF, and propose optimal cut-off for the best index of CVDRF for both genders.

2. Methods

2.1. Selection of participants

A cross-sectional study was conducted in Guizhou province in southwest China, with a multistage sampling to select representative participants aged between 20 and 80 years old with more than 1-year local resident. This cross-sectional study comes from the China National Health Survey (CNHS), which is a nationally representative and population based cross-sectional survey conducted from 2012 to 2017 and includes 53,895 people from 11 provinces of China.[17] The detailed sampling strategy, data collection and quality controls were described previously.[15] Total of 2421 Han Chinese participants completed the study procedures. After the exclusion of 309 subjects with hypertension, diabetes, dyslipidemia, or on-going medical treatments, 2112 subjects were analyzed in our study. Subjects were considered Han Chinese if both their parents were of Han ethnicity. The consent forms were obtained by local government agencies and centers for disease control and prevention (CDC). The study was approved by the bioethical committee of the Institute of Basic Medical Sciences, the Chinese Academy of Medical Sciences, Beijing, China (approval No. 028–2013).

2.2. Anthropometric measurements

All participants were interviewed face-to-face by local CDC staffs fluent in both local dialect and mandarin to obtain personal information of age, race, gender, area, educational level, income, physical activity, cigarette smoking, and alcohol consumption. The measurements of body height, weight, and WC were performed as previously described.[15] Hip circumference (HC) was measured to the nearest half centimeter at the widest part of the hip at the level of the greater trochanter.[18] The average of three measurement readings was taken for statistical analysis. Weight and Body composition was measured by bioelectrical impedance analysis (BIA) with a commercially available body composition analyzer (BC-420, TANITA, Japan). The subject was asked to wipe the sole of the feet with a wet tissue and then stand over the electrodes of the machine until the measurements were ready. We recorded body weight, body fat (BF) mass, percentage of body fat (PBF), fat-free mass, and bioelectrical impedance (BI) for every subject. The blood pressure was measured 3 times in the upper right arm using electronic sphygmomanometer (HEM-907, Omron, Dalian, China) in a sitting position. The blood samples were collected using vacuum tubes containing sodium fluoride in the morning from subjects after overnight fasting. They were then shipped to the Peking Union Medical College Hospital and kept at –40°C and used to determine fasting plasma glucose (FPG) and lipids.

2.3. Definitions

The definition for smoking status, drinking status, and physical activity were described previously.[15] CVDRFs include hypertension, diabetes, dyslipidemia, and MS. Hypertension was defined by diastolic pressure ≥90 mmHg and/or systolic pressure ≥140 mmHg or the participant reported his/her individual history of hypertension. According to the American Diabetes Association criteria of 1997,[19] diabetes was defined as FPG ≥7.0 mmol/L, or the participant reported his/her individual history of diabetes. Dyslipidemia was defined according to Chinese criteria[20]: High Total Cholesterol (TC) was defined as serum level of TC equal to or greater than 6.22 mmol/L (≥240 mg/dL); Low High-Density Lipoprotein Cholesterol (HDL-C) was defined as serum level of HDL-C less than 1.04 mmol/L (<40 mg/dL); High Low-Density Lipoprotein Cholesterol (LDL-C) was defined as serum level of LDL-C equal to or greater than 4.14 mmol/L (160 mg/dL); High Triglycerides (TG) was defined as serum level of triglyceride equal to or greater than 2.26 mmol/L (≥200 mg/dL). Dyslipidemia was defined as High TC, and/or Low HDL-C, and/or High LDL-C, and/or High TG. MS is defined according to diabetes diagnostic criteria issued by the International Diabetes Federation (IDF) in 2005.[21]

Table 1

Basic characteristics of the study population by gender.

Characteristics	Male	Female	*P* value
Numbers	892	1220	
Age (years)	47.4±13.6	46.5±14.1	.1153
Smoking	682 (76.5)	38 (3.1)	<.0001*
Drinking	673 (75.4)	197 (16.1)	<.0001*
Physical activity [Moderate/ heavy]	352 (39.5)	271 (22.2)	<.0001*
Anthropometric measures			
Body Mass Index (kg/m^2)	23.5±3.3	22.9±3.5	<.0001*
Waist circumference (cm)	81.3±10.2	76.6±10.1	<.0001*
Hip circumference (cm)	87.2±6.2	86.5±6.3	.0108*
Waist to hip ratio	0.93±0.07	0.88±0.07	<.0001*
Wait to height ratio	0.49±0.06	0.50±0.07	.0150*
Percentage of body fat (%)	21.3±5.5	32.0±6.0	<.0001*
Body fat mass (kg)	14.0±5.4	17.5±5.9	<.0001*
Biochemical indicators			
Fasting plasma glucose (mmol/L)	5.2±1.1	5.0±0.9	<.0001*
Total Cholesterol (mmol/L)	5.0±1.0	4.9±1.0	.7259
Triglycerides (mmol/L)	2.0±1.7	1.5±1.3	<.0001*
High-Density Lipoprotein Cholesterol (mmol/L)	1.4±0.3	1.5±0.3	<.0001*
Low-Density Lipoprotein Cholesterol (mmol/L)	2.9±0.8	2.8±0.8	.0088*
Blood pressure			
Systolic blood pressure (mmHg)	130.7±17.8	124.4±19.3	<.0001*
Diastolic blood pressure (mmHg)	79.8±11.3	75.0±11.0	<.0001*

Data are expressed as means±SD or n(%).
* Significantly different between male and female (*P*<.05).

2.4. Statistical methods

Categorical data was described as numbers and percentages. Continuous data was shown as mean plus and minus (±) standard deviation (SD). The significance of difference between groups in subject characteristics were tested using *t* test for continuous variables and chi-square/Cochran–Mantel–Haenszel test for categorical variables. To analyze the validity of different obesity indicators to assess CVDRF, we calculated the area under curves (AUCs) and their confidence intervals (CIs) of receiver operating characteristic curves for different obesity indicators in assess CVDRF. Optimal cut-off value is calculated as the cutoff with maximum value of Youden index.[22] A nonparametric approach was used to compare the areas under 2 correlated receiver operating characteristic curves.[23] The risks of CVDRF were compared among the quartiles of different obesity indicator by gender. The odds ratios (ORs) of CVDRF and their 95% CIs were calculated using the logistic regression model with referencing to the first quartile of each measurement. All analyses were performed using SAS software (version 9.4). The *P* value less than.05 was considered statistically significant.

3. Results

3.1. Characteristics of study participants

Characteristics of the study participants between male and female were shown in Table 1. Significant differences in several variables between male and female were observed ($P<0.05$). The male participants had higher weight, BMI, WC, HC, WHR, WHtR, PBF, BF, FPG, TG, LDL-C, systolic blood pressure, and diastolic blood pressure than female participants. About 39.5% of male engaged in moderate or heavy work and this proportion was 22.2% in female. Current smokers and alcohol drinker accounted for 76.5% and 75.4% in male participants, 3.1% and 16.1% in female participants, respectively. A 2-tailed *T* test/chi-square test showed that there are significant differences between 2 genders among all characteristics except age and TC.

3.2. Comparison of area the curve (AUC) for different indicators

As shown in Table 2 and Supplemental Digital Content (see Fig. S1, http://links.lww.com/MD/E235 and Fig. S2, http://links.

Table 2

The area under the curve of each adiposity variable for the presence of various CVDRF in both genders.

Group	BMI	WC	HC	WHR	WHtR	PBF	BF	Correlation orders
Male (n=892)								
Hypertension	0.60 (0.56, 0.64)	0.60 (0.56, 0.65)	0.54 (0.50, 0.58)	0.63 (0.59, 0.67)	0.62 (0.58, 0.66)	0.62 (0.58, 0.66)	0.60 (0.56, 0.64)	WHtR, WHR, PBF>BMI, WC, BF>HC
Diabetes	0.63 (0.54, 0.71)	0.63 (0.54,0.72)	0.56 (0.46, 0.66)	0.66 (0.59, 0.74)	0.65 (0.56, 0.73)	0.63 (0.54, 0.72)	0.62 (0.53, 0.71)	WHtR, WHR, WC, BMI, PBF, BF>HC
Dyslipidemia	0.71 (0.67, 0.74)	0.73 (0.70, 0.76)	0.67 (0.63, 0.70)	0.72 (0.69, 0.75)	0.73 (0.69, 0.76)	0.71 (0.68, 0.75)	0.72 (0.68, 0.75)	WHtR, WC, WHR>BMI, PBF, BF>HC
Metabolic syndrome	0.93 (0.91, 0.94)	0.97 (0.96, 0.98)	0.90 (0.87, 0.92)	0.90 (0.88, 0.92)	0.94 (0.92, 0.95)	0.93 (0.91, 0.94)	0.95 (0.93, 0.96)	WC, WHtR, BF>BMI, PBF>WHR, HC
Female (n=1220)								
Hypertension	0.67 (0.64, 0.71)	0.68 (0.64, 0.72)	0.60 (0.56, 0.64)	0.68 (0.64, 0.71)	0.70 (0.67, 0.74)	0.69 (0.65, 0.72)	0.66 (0.62, 0.69)	WHtR, PBF>BMI, WC, WHR, BF>HC
Diabetes	0.69 (0.57, 0.81)	0.71 (0.62, 0.81)	0.55 (0.42, 0.69)	0.77 (0.67, 0.86)	0.75 (0.65, 0.84)	0.70 (0.59, 0.81)	0.66 (0.55, 0.78)	WHtR, WHR, WC, BMI, PBF, BF>HC
Dyslipidemia	0.65 (0.62, 0.69)	0.66 (0.63, 0.69)	0.59 (0.56, 0.63)	0.67 (0.63, 0.70)	0.67 (0.64, 0.70)	0.68 (0.64, 0.71)	0.66 (0.63, 0.69)	WHtR, WHR, PBF>BMI, WC, BF>HC
Metabolic syndrome	0.88 (0.85, 0.90)	0.91 (0.90, 0.93)	0.80 (0.77, 0.83)	0.87 (0.85, 0.89)	0.90 (0.89, 0.92)	0.89 (0.87, 0.91)	0.88 (0.86, 0.90)	WHtR, WC>PBF, BMI, WHR, BF>HC

The area under the curve for BMI, WC, HC, WHR, WHtR, PBF, BF are presented as estimated AUC and 95% confidence interval. The correlation orders are the differences of the results of the difference test of the area under the receiver-operating characteristic curves for each obesity indicator in each disease for both males and females. For example: WC, BMI, WHtR>WHR means that the AUCs for WC, BMI, and WHtR are significantly higher than the AUC for WHR, the others are on the analogy of the example.
AUC=area under the curve, BF=body fat, BMI=Body mass index, CVDRF=cardiovascular disease risk factors, HC=Hip circumference, PBF=percentage of body fat, WC=waist circumference, WHR=waist-to-hip ratio, WHtR=waist-to-height ratio.

Table 3

The optimal cut-off anthropometric indices predictive of cardiovascular disease risk factors.

	Hypertension				Dyslipidemia				Diabetes				Metabolic syndrome				
	cutoff	SEN	SPE	LR	Cutoff	SEN	SPE	LR	Cutoff	SEN	SPE	LR	Cutoff	SEN	SPE	LR	Mean cut-off value*
Male																	
BMI (kg/m^2)	25.4	72.8	62.2	1.9	23.7	65.1	65.1	1.9	26.6	66.7	65.4	1.9	26.0	85.7	84.9	5.7	25
WC (cm)	81.7	63.4	55.3	1.4	81.8	70.8	66.3	2.1	85.9	55.5	66.2	1.6	90.0	100	90.4	10.4	85
HC (cm)	91.2	33.6	75.3	1.4	88.7	58.4	69.2	1.9	89.5	53.3	63.9	1.5	90.0	100	92.6	13.5	90
WHR	0.97	44.4	75.5	1.8	0.92	75.9	58.8	1.8	0.98	57.8	74.9	2.3	0.96	94.0	72.3	3.4	0.96
WHtR	0.50	59.3	60.9	1.5	0.50	70.2	65.4	2.0	0.52	62.2	62.3	1.6	0.52	91.0	84.8	6.0	0.51
PBF (%)	22.2	60.8	57.2	1.4	22.4	64.1	67.1	1.9	21.9	73.3	50.2	1.5	24.8	91.0	81.4	4.9	22.83
BF (kg)	17.5	36.9	79.2	1.8	15.0	60.3	72.6	2.2	18.0	44.4	77.9	2.0	17.8	90.2	87.4	7.2	17.1
Female																0.0	
BMI (kg/m^2)	23.6	61.3	68.1	1.9	25.6	72.9	57.4	1.7	24.5	66.7	70.0	2.0	24.1	84.7	76.5	3.6	24
WC (cm)	78.5	62.3	67.0	1.9	78.0	63.5	61.4	1.6	80.5	66.7	66.8	2.0	81.2	93.0	81.6	5.1	80
HC (cm)	89.3	44.0	74.5	1.7	87.0	53.9	61.4	1.4	88.1	52.4	63.9	1.5	87.4	80.9	68.5	2.6	88
WHR	0.90	63.0	65.8	1.8	0.90	57.7	67.4	1.8	0.90	81.0	61.8	2.1	0.90	92.6	70.1	3.1	0.90
WHtR	0.52	62.3	70.1	2.1	0.47	84.5	41.5	1.4	0.48	95.2	44.5	1.7	0.52	96.3	76.4	4.1	0.50
PBF (%)	32.5	69.4	61.2	1.8	30.2	84.2	44.7	1.5	36.2	61.9	76.2	2.6	33.4	94.4	72.3	3.4	33.1
BF (kg)	17.9	61.6	63.8	1.7	15.5	78.7	48.6	1.5	20.2	57.1	71.6	2.0	19.2	87.0	77.1	3.8	18.2

BF = body fat, BMI = Body mass index, CVDRF = cardiovascular disease risk factors, HC = Hip circumference, LR = likelihood ratios, PBF = percentage of body fat, SEN = sensitivity, SPE = specificity, WC = waist circumference, WHR = waist-to-hip ratio, WHtR = waist-to-height ratio.

* Mean: the cut-off values for different risk factors were different, we calculate the mean of the cut-off values for each index. BMI, WC, and HC keep integer, and other index keep 2 digits after the dot in order to compare it to other recommended values.

lww.com/MD/E236, which illustrates area under the curve of each adiposity variable for the presence of various CVDRF), the best assessing indicators for hypertension were WHR, WHtR, and PBF in male, and WHtR and PBF in female. The best associated indicator for dyslipidemia were WHtR, WC, and WHR in male, and WHtR, WHR, and PBF in female. Except for HC, there is no statistically significant differences between all of indicators for assessing diabetes in male. The best associated indicator for MS were WC, WHtR, and BF in male, and WHtR and WC in female. It appeared that WHtR was the best indicator for different disease in both genders.

3.3. The optimal cut-off values for various anthropometric indices

Table 3 showed the optimal cut-offs, sensitivities and specificities of the anthropometric indices for each CVDRF in male and female. The optimal cut-offs to assess hypertension, diabetes, dyslipidemia or MS were 23.7 to 26.6 kg/m^2 for BMI, 81.7 to 90.0 cm for WC, 0.92 to 0.98 for WHR, 0.50 to 0.52 for WHtR, 21.9 to 24.8 for PBF, and 15.0 to 18.0 kg for BF for male participants; 23.6 to 25.6 kg/m^2 for BMI, 78.0 to 81.2 cm for WC, 0.90 for WHR, 0.47 to 0.52 for WHtR, 30.2 to 36.2 for PBF and 15.5 to 20.2 kg for BF for female participants. The mean cutoff values were BMI = 25, WC = 85, HC = 90, WHR = 0.96, WHtR = 0.51, PBF = 22.8 and BF = 17.1 in male; BMI = 24, WC = 80, HC = 88, WHR = 0.90, WHtR = 0.50, PBF = 33.1 and BF = 18.2 in female.

3.4. The relationship between different obesity indicators and the odds ratio of having at least 1 CVDRF

The subjects were classified into 4 quartiles for each obesity indicators. Multivariate-adjusted ORs for having at least 1 CVDRF in the 3 upper quartiles vs the lowest quartile for each obesity indicator were shown in Table 4. As the obesity indicators increased, the ORs of corresponding quartile (vs lowest quartile) also increased. Only WHtR had the same quartiles for different genders.

For BMI, the odds of having at least 1 CVD risk factor were 7.19-fold (95% CI 5.36–9.65) higher for those in the highest (25.9 in male or 25.2 in female) compared with the lowest (21.0 in male or 20.4 in female) quartiles. The odds ratio was substantially attenuated after adjustment for WHR (3.69, 2.59–5.26) and was not significant for the other 3 obesity indicators in Q3 and Q2 vs Q1 group.

Waist positively correlated with CVDRF risk. This correlation was continuous and persistent even after adjustment for other obesity indicators except WHtR. The OR was 7.68 (5.73–10.29) for waist in the highest quartile (88.9 cm females and 83.1 cm males) compared with the lowest quartile (73.3 cm in male and 69.4 cm in female). After adjustment for WHtR, this association was not significant in Q2 vs Q1 group (1.32, 0.88–1.97).

Like waist, the WHR was strongly correlated to CVDRF. This association was continuous and persistent even after adjustment for other obesity indicators except WHtR.

PBF was positively correlated with CVDRF risk. This association was highly significant after adjustment for BMI and WHR. However, this association was not significant after adjustment for waist and WHtR (1.32, 1.32–1.85; 1.21, 0.85–1.72).

WHtR also positively correlated with CVDRF risk. It was the strongest correlation among all of obesity indicators. The odds ratio increased significantly in the successive quartiles, even after adjustment for any other risk indicators (highest vs lowest quartiles, 8.17, 5.98–11.15). This association was consistent in male and female.

4. Discussion

To our knowledge, this is the first study that compared the validity and assessed the optimal cut-off points of different

Table 4

The odds ratios for men and women combined using sex-specific cut-points before and after adjustment for other obesity indicators.

OR		Adjusted for a*	Adjusted for a and BMI	Adjusted for a and Waist	Adjusted for a and WHR	Adjusted for a and WHtR	Adjusted for a and PBF
BMI	(Q2 VS. Q1)	1.93(1.46, 2.56)		1.28(0.91, 1.79)	1.50(1.11, 2.02)	1.17(0.83, 1.65)	1.35(0.92, 1.98)
	(Q3 VS. Q1)	3.15(2.38, 4.16)		1.44(0.97, 2.14)	1.97(1.43, 2.71)	1.36(0.91, 2.04)	1.49(0.91, 2.43)
	(Q4 VS. Q1)	7.19(5.36, 9.65)		2.35(1.47, 3.77)	3.69(2.59, 5.26)	2.39(1.48, 3.87)	2.42(1.30, 4.49)
Waist	(Q2 VS. Q1)	2.07(1.56, 2.75)	1.75(1.25, 2.46)		1.67(1.19, 2.34)	1.32(0.88, 1.97)	1.65(1.18, 2.32)
	(Q3 VS. Q1)	3.73(2.81, 4.96)	2.60(1.74, 3.88)		2.60(1.75, 3.85)	1.86(1.14, 3.03)	2.35(1.58, 3.48)
	(Q4 VS. Q1)	7.68(5.73, 10.29)	4.01(2.51, 6.41)		4.44(2.82, 7.00)	3.16(1.74, 5.71)	3.62(2.27, 5.76)
WHR	(Q2 VS. Q1)	2.12(1.60, 2.81)	1.66(1.23, 2.24)	1.41(1.00, 1.98)		1.29(0.91, 1.83)	1.64(1.21, 2.212)
	(Q3 VS. Q1)	3.37(2.55, 4.45)	2.01(1.46, 2.77)	1.48(1.00, 2.18)		1.38(0.92, 2.08)	1.93(1.39, 2.67)
	(Q4 VS. Q1)	6.97(5.18, 9.31)	3.29(2.31, 4.71)	2.14(1.36, 3.38)		2.07(1.28, 3.35)	3.06(2.13, 4.41)
WHtR	(Q2 VS. Q1)	2.36(1.78, 3.13)	2.05(1.45, 2.91)	1.79(1.19, 2.69)	1.96(1.38, 2.78)		1.94(1.36, 2.76)
	(Q3 VS. Q1)	4.55(3.42, 6.06)	3.10(2.03, 4.74)	2.36(1.42, 3.93)	3.18(2.08, 4.86)		2.78(1.82, 4.25)
	(Q4 VS. Q1)	8.17(5.98, 11.15)	4.03(2.44, 6.66)	2.84(1.53, 5.28)	4.63(2.82, 7.61)		3.58(2.15, 5.97)
PBF	(Q2 VS. Q1)	1.90(1.43, 2.521)	1.53(1.04, 2.24)	1.32(0.94, 1.85)	1.47(1.08, 1.99)	1.21(0.85, 1.72)	
	(Q3 VS. Q1)	3.42(2.58, 4.531)	2.35(1.43, 3.85)	1.69(1.14, 2.51)	2.18(1.57, 3.01)	1.60(1.06, 2.41)	
	(Q4 VS. Q1)	7.28(5.42, 9.769)	3.39(1.83, 6.28)	2.61(1.64, 4.16)	3.76(2.61, 5.42)	2.64(1.62, 4.32)	

Colour key: OR<1; 1≤OR<2; 2≤OR<3; 3≤OR<4; 4≤OR<5; 5≤OR<8; OR≥8

The obesity indicators were classified to 4 subgroups according to quartiles in different gender:

Male/Female	BMI	WC	WHR	WHtR	PBF
Q1	BMI (<21.0) / (<20.4)	WC (<73.3) / (<69.4)	WHR (<0.88) / (<0.83)	WHtR (<0.45) / (<0.45)	PBF (<17.8) / (<28.2)
Q2	BMI (21.0-23.3) / (20.4-22.3)	WC (73.3-81.6) / (69.4-75.3)	WHR (0.88-0.92) / (0.83-0.87)	WHtR (0.45-0.49) / (0.45-0.49)	PBF (17.8-22.0) / (28.2-31.8)
Q3	BMI (23.4-25.9) / (22.4-25.1)	WC (81.7-88.8) / (75.4-83.0)	WHR (0.93-0.98) / (0.88-0.93)	WHtR (0.50-0.54) / (0.50-0.54)	PBF (22.1-25.4) / (31.9-36.0)
Q4	BMI (≧25.9) / (≧25.2)	WC (≧88.9) / (≧83.1)	WHR (≧0.98) / (≧0.94)	WHtR (≧0.55) / (≧0.55)	PBF (≧25.5) / (≧36.1)

*age, sex, smoking, drinking

obesity indicators as associated indicators for CVDRF in a wide range of age, 20 to 80 years, in Han people in southwest China from a large sample based cross-sectional study. These indicators contain direct measurements (BMI, WC, HC, WHR, WHtR) and indirect measurement (PBF).

The AUCs between CVDRF and the anthropometric measurements suggested that HC is the poorest, while WHtR is the best associated indicator for CVDRF for both genders. WC and WHtR had similar performance in assessing CVDRF, except hypertension. PBF and WHtR had similar performance in assessing CVDRF, except MS. WHR and WHtR had similar performance in assessing dyslipidemia and diabetes. BMI and WHtR had similar performance in assessing diabetes only. BF and WHtR had similar performance in assessing dyslipidemia and diabetes for male (Table 2). The association between WHtR and CVDRF was the strongest among other indicators (Table 4).

Our study suggested that HC was not an appropriate indicator to assess risk factors for cardiovascular and metabolic diseases. Consistently, there were studies suggesting that the high HC could even be a protective factor for cardiovascular diseases, especially in women.[24,25] Upper thigh muscles and fat could contribute to this effect because of different fat metabolism from other parts of the body.[26]

We showed that BMI was a weaker associated indicator than some other obesity indices for hypertension, dyslipidemia, and MS in both genders. Similar results were also reported in the population studies in Peninsular Malaysia adults[27] and middle-aged Korean adults.[28] The AUCs indicated that BMI was a good associated indicator of diabetes. There were studies reporting that the higher BMI associated with glycemia.[29–31] Thus, BMI could be an accurate associated indicator for diabetes, even though it is no direct measurement of abdominal fat. However, the reasons of different performances of BMI in assessing different CVDRF need more investigation.

Our study demonstrated that the validity in assessing certain CVDRF such as of PBF by BIA was similar to convenient anthropometric indicators such as WHtR and better than BMI in female, which was consistent to previous studies.[3,32] BIA directly measures fat content. However, it could not reliably assess BF and PBF for the extreme obese individuals. Thus, we re-analyzed the assessing power of BIA after excluding subjects with extreme obesity (BMI > 34 kg/m^2) and yielded the similar results to the initial analysis (analysis not shown in this paper). This indicated that our findings were robust and not influenced by the BIA measurements from the extreme obese participants (data not shown).

Abdominal fat had higher association with cardiovascular or metabolic diseases than BMI, which merely measured overall body weight. This study showed that abdominal fat measurements (WC, WHtR, and WHR) had similarly performance in assessing dyslipidemia and diabetes for male based on estimated AUC. The abdominal visceral fat associates with higher level of metabolism and inflammation than subcutaneous fat, which could explain that these abdominal fat indicators are better associated indicator for metabolic diseases.[33]

Our study found that the WHR had lower validity than WHtR in assessing hypertension for female, and lower validity than both WHtR and WC in assessing MS. This is consistent to a previous study.[6] Besides, obese and non-obese people may have the same WHR. Our study found that WHR associated more closely with hypertension in male than female (Table 2). The hormonal difference between male and female impacts BF distribution, with higher fat deposition in the lower body part of female,[27] and it could explain the variation between male and female. Previous study showed that a larger hip circumference associated with a reduction risk in multiple metabolic abnormalities only in female, while WHR associated with hypertension less in female than male in this study.

Studies showed that WHtR was better than WC in assessing risk factors of cardiovascular disease in Asians and Caucasian.[14,34–37] Our study yielded similar findings that WHtR performed better than WC in assessing various CVDRF (Table 2) for both gender and had the most stable performance in assessing having at least 1 CVDRF based on adjusted OR values. This may be because that WHtR take height into consideration in assessing obesity. And multiple studies reported association between height and various CVDRF. A study reported the correlation between the short height and coronary heart disease.[38] Henriksson etc reported that there was a negative correlation between height and cholesterol content independent from BMI and WHR.[39] Thus, height-adjusted waist is a reasonable measurement of obesity. As both genders shared similar WHtR quartiles, we made comparisons between genders in different quartiles and found that the association between WHtR and CVDRF was more profound in male than female (Table 5). This may be because that male and female had different reasons affecting the WHtR measurements. The unhealthy lifestyles, such as limited exercise, excess alcohol consumption and excess energy intake, could be the major factors affecting WHtR measurements in males. On the contrary, the figure of postpartum is the major reason affecting WHtR measurements in females.

Table 5

The relationship between different obesity indicators and the odds ratio of having at least 1 cardiometabolic risk factor in both genders after adjustment for age, smoking and drinking.

Male		Female	
Subgroup	Odds ratio (95% CI)	Subgroup*	Odds ratio (95% CI)
BMI			
Group1 (<21.0)	1 (reference)	Group1 (<20.4)	1 (reference)
Group2 (21.0–23.3)	2.24 (1.50, 3.35)	Group2 (20.4–22.3)	1.57 (1.05, 2.34)
Group3 (23.4–25.9)	3.26 (2.17, 4.90)	Group3 (22.4–25.1)	2.72 (1.85, 4.02)
Group4 (≥25.9)	10.43 (6.52, 16.68)	Group4 (≥25.2)	5.06 (3.41, 7.51)
WC			
Group1 (<73.3)	1 (reference)	Group1 (<69.4)	1 (reference)
Group2 (73.3–81.6)	1.87 (1.25, 2.80)	Group2 (69.4–75.3)	2.00 (1.34, 2.96)
Group3 (81.7–88.8)	4.65 (3.05, 7.09)	Group3 (75.4–83.0)	2.74 (1.85, 4.05)
Group4 (≥88.9)	11.47 (7.17, 18.37)	Group4 (≥83.1)	5.20 (3.51, 7.72)
WHR			
Group1 (<0.88)	1 (reference)	Group1 (<0.83)	1 (reference)
Group2 (0.88–0.92)	2.99 (1.98, 4.53)	Group2 (0.83–0.87)	1.36 (0.93, 2.01)
Group3 (0.93–0.98)	5.12 (3.36, 7.80)	Group3 (0.88–0.93)	2.02 (1.39, 2.94)
Group4 (≥0.98)	10.33 (6.52, 16.38)	Group4 (≥0.94)	4.15 (2.79, 6.16)
WHtR			
Group1 (<0.45)	1 (reference)	Group1 (<0.45)	1 (reference)
Group2 (0.45–0.49)	2.88 (1.92, 4.30)	Group2 (0.45–0.49)	1.61 (1.08,2.39)
Group3 (0.50–0.54)	6.39 (4.24, 9.65)	Group3 (0.50–0.54)	2.71 (1.80, 4.07)
Group4 (≥0.55)	11.30 (6.84,18.68)	Group4 (≥0.55)	5.29 (3.49,8.00)
PBF			
Group1 (<17.8)	1 (reference)	Group1 (<28.2)	1 (reference)
Group2 (17.8–22.0)	1.91 (1.28, 2.86)	Group2 (28.2–31.8)	1.78 (1.18, 2.67)
Group3 (22.1–25.4)	3.41 (2.27, 5.12)	Group3 (31.9–36.0)	2.98 (2.00, 4.43)
Group4 (≥25.5)	9.60 (6.03, 15.28)	Group4 (≥36.1)	5.56 (3.73, 8.31)

CI = confidence interval.

* The obesity indicators were classified to 4 subgroups according to quartiles in different gender.

It should be noted that the mean WHtR cut-off value for four types of CVDRF in this study was 0.51 for male and 0.50 for female, similar to the established the global WHtR cut-off value of 0.5.[40] The similar WHtR cut-off points between our study and existing standard may further justify that it is better than other obesity indices in assessing the CVDRF in our studied population. Even though Han Chinese in the southwest were shorter in height than those in the north and national average, the cut-off value of WHtR proposed in our study was similar to other studies in China.[13,41] The other studies reported that WHtR could assess CVDRF at cut-offs ranged from 0.48 to 0.52 for Asian populations.[42–44] Besides, WHtR is easy to calculate and the cutoff at 0.5 is also easy to memorize. Meanwhile, a number of meta-analysis on CVDRF outcomes suggested that WHtR cut-off at 0.5 could be appropriate for both genders, different age groups, and ethnicities.[7,45,46] This is of the clinical and public health importance as a unified index with same cutoff could be applied to diverse population.

Even though the BMI mean cut-off point of 25 kg/m^2 in male and 24 kg/m^2 in female found in this study was similar to the threshold (24 kg/m^2) for overweight definition by the WGOC (Working Group on Obesity in China). Moreover, our study yielded similar cut-off value for WC to measure central obesity as WGOC definition (85.0 cm for male and 80.0 cm for female).[47]

Finally, the results from this study may not be generalized to other populations. Therefore, further studies are needed to examine whether the same results will be found in other populations. Besides, other lifestyle factors are needed to include in the future analysis (eg, diet, reproductive factors among women etc).

5. Conclusion

In conclusion, our results indicated that WHtR was the best associated indicator for the CVDRF among other convenient obesity measures. As WHtR can be easily measured and determined, it has the potential to become a versatile discriminating associated indicator to identify CVDRF in southwest Han Chinese population. The obesity indices and optimal cut-off values were BMI (24 kg/m^2), WC (male: 85 cm; female: 80 cm), WHtR (0.50) and WHR (male: 0.96; female: 0.90). Moreover, we reported that the cutoff value of PBF is 22.8% for male and 33.1% for female. Further investigation with follow-up study is needed to explore whether the same results will be found in other populations.

Acknowledgments

We thank all the participants, staffs, and research fellows in the CNHS Study for their long-term commitment to the study. Special thanks are for Qin Yang, Limin Zhang, Jianfang Ye, Xiaolong Gong from Guiyang Medical College and for Baoshen Qi and Ying Sun from Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences. We also thank Zhenning CDC and Nanming district CDC for their assistant.

Author contributions

KW participated in the data collection, statistical analysis and drafting the manuscript; GG, LP, DW, FD, YY, LW, LL, TL, LS, GZ, KF, KX, XP, TC, HP, JM, YZ, and BP participated in the data collection and checked the data; GS led the study, supervised the staff and edited the manuscript. All authors approved the final manuscript.

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