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Optimal Cut-off Point of Waist to Height Ratio in Beijing and Its Association with Clusters of Metabolic Risk Factors*

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Summary: A host of studies found waist-to-height ratio (WHtR) having higher diagnostic value than other abdominal obesity anthropometric indicators for metabolic disorders. But the cut-off points are still not consistent. This study was aimed to explore the optimal cut-off point of WHtR in Chinese population and identify the association between WHtR and cluster of metabolic risk factors. In total, 13379 Han adults (7553 men and 5726 women) from over 40 institutions who took physical examination in Xuanwu Hospital of Capital Medical University between January 2014 and January 2015 were involved in this cross-sectional study. Subjects with two or more components of metabolic syndrome (MetS) were considered to have multiple risk factors. Optimal cut-off points of WHtR for cluster of metabolic risk factors were analyzed by receiver operating characteristic (ROC) curve analysis. The optimal cut-off points of WHtR were 0.51 for men and 0.49 for women. People with elevated WHtR had higher levels of metabolic risk factors. And the prevalence of individual and clusters of 5 risk factors were all higher among WHtR-defined abdominal obesity people than in normal subjects. The optimal cut-off points of WHtR were 0.51 for men and 0.49 for women. In conclusion, people with elevated WHtR are susceptible to cluster of metabolic risk factors.
Key words: waist-to-height ratio; abdominal obesity; metabolism; metabolic syndrome

Metabolic syndrome (MetS) is a cluster of multiple metabolic risk factors, including obesity, hypertension, impaired glucose tolerance and dyslipidemia[1–2]. MetS patients are more susceptible to type 2 diabetes mellitus (T2DM), coronary heart disease (CHD) and stroke[3–8].

Waist circumference (WC), body mass index (BMI), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) are common anthropometric indicators to distinguish abdominal obesity. Studies in South Asia, China, America, German, Australia, Japan and Korea consistently concluded that WHtR had highest diagnostic value of MetS[9–24].

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This study was aimed to get the optimal cut-off point of WHtR for MetS in Chinese population and identify the association between WHtR and cluster of metabolic risk factors.

1 SUBJECTS AND METHODS

1.1 Study Population

This study analyzed data from a large-scale cross sectional study between January 2014 and January 2015 in Xuanwu Hospital of Capital Medical University. Totally, 20 000 staffs and retirees, aged from 18 to 95 years, who took physical examinations were invited to participate at the outset. They were from over 40 institutions, including banks, schools, courts and companies. The people satisfying one of the following conditions were excluded from this study: polycystic ovarian syndrome, hypercortisolism, hypothyroidism, or other diseases known to cause secondary obesity, severe liver, kidney or heart diseases, those who were taking glucocorticoid or diuretic, those who were minority. The last data of those who took multiple physical examinations were chosen. Totally, 13 379 records (7553 males and 5726 females) were remained to analyze eventually.

Both Research Ethical Committees from Xuanwu Hospital and Capital Medical University approved this study, and written informed consents were obtained from all participants.

1.2 Data Collection

Data on socio-demographic information such as age, gender, occupation and nationality were collected by standard questionnaires.

Anthropometric data were obtained with subjects in light clothing and barefoot, using standard methods. Height and body weight were measured in the upright position to the nearest 0.5 cm and 0.1 kg, respectively. BMI was calculated by dividing weight in kilograms by the square of the height in meters (kg/m^2). WC was taken at the middle point between the inferior margin of the last rib and the iliac crest in a horizontal plane with the subject standing and at the maximum point of normal expiration. WC was measured to the nearest 0.1 cm. WHtR was calculated as the WC divided by height.

Blood pressure was measured three times consecutively after 5-min rest in a sitting position using a standard mercury sphygmomanometer with the cuff on the right upper arm. The average of the second and third measurements was used in the analysis.

Blood was sampled in the morning after a 12-h overnight fast for laboratory measurements. Fasting plasma glucose (FPG) was determined by the glucose oxidase method. Levels of triglyceride (TG), total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) were all measured using standard laboratory methods (Hitachi autoanalyzer 7060, Japan). Low-density lipoprotein cholesterol (LDL-C) was calculated by the Friedewald method.

1.3 Diagnostic Criteria for Metabolic Risk Factors

Diagnostic criteria for metabolic risk factors was based on the definition of MetS from a previous joint interim statement of the International Diabetes Federation (IDF), American Heart Association (AHA), National Heart, Lung and Blood Institute (NHLBI), World Heart Federation, International Atherosclerosis Society and International Association for the Study of Obesity[25]: (1) WC: ≥90 cm in males, ≥80 cm in females; (2) Elevated TG: ≥150 mg/dL (1.7 mmol/L) in both genders (whereas drug treatment for elevated triglycerides is an alternate indicator); (3) Reduced HDL-C: <40 mg/dL (1.0 mmol/L) in males, <50 mg/dL (1.3 mmol/L) in females (whereas drug treatment for reduced HDL-C is an alternate indicator); (4) Elevated blood pressure: systolic blood pressure (SBP) ≥130 mmHg or diastolic blood pressure (DBP) ≥85 mmHg in both genders (whereas antihypertensive drug treatment in a patient with a history of hypertension is an alternate indicator); (5) Elevated FPG: ≥100 mg/dL (5.6 mmol/L) in both gender (whereas drug treatment of elevated glucose is an alternate indicator). In summary, the presence of any 3 of the 5 risk factors constitutes a diagnosis of MetS.

1.4 Statistical Analysis

SPSS software, version 19.0 was employed to perform all statistical analyses in this study. Forestplots were drawn using R software 3.4.0. Data of the study participants were presented as mean±SD and the difference in genders was tested using *t* text. WHtR values were categorized by 0.03, with <0.47 as reference for both men and women. Then multiple logistic regression analysis was performed to calculate the odds ratios (OR) of each category for individual metabolic risk factors and clusters. To detect the optimal cut-off points of WHtR value, receiver operating characteristic (ROC) curve analysis was performed using WHtR as continuous variable and cluster of metabolic disorders as categorical variable. Then, based on the results, the participants were divided into two groups: people with abdominal obesity and people in normal shape. We compared the differences of metabolic indexes and prevalence of MetS as well as its individual components between the two groups using *t*-test and Chi-test, respectively. The reported *P* values were all 2-sided, and *P*<0.05 was considered to indicate statistical significance.

2 RESULTS

2.1 Basic Data of Study Participants

Totally, 13 379 participants (7653 men and 5726 women) aged from 18 to 95 years shared the same nation, Han. The mean age±SD of all was 50.10±15.89 years and 50.59±16.48 of men, 49.45±15.04 of women respectively.

Basic characteristics of study participants are listed in table 1. Men had higher mean value of WC, BMI, WHtR, SBP, DBP, FPG, TC and LDL-C. While the levels of TC and HDL-C were higher in females than in males. Among 5 metabolic risk factors, the prevalence of reduced HDL-C was higher in women (33.1% *vs.* 24.3%) but the others were all higher in men. In total, 4261 (31.85%) participants were classified as having metabolism syndrome according to the definition of the joint statement. And it was more prevalent in men (35.93%) than in women (26.39%), increasing with age in the rough. Differences aforementioned were all statistically significant (*P*<0.001).

2.2 Prevalence and Odds Ratios of Metabolic Risk Factors Categorized by WHtR

With 0.47 as reference, the prevalence and OR of four metabolic risk factors (elevated TG, blood pressure, FPG and reduced HDL-C) according to WHtR values categorized by 0.03 are listed in table 2.

Table 1 Basic characteristics of study participants by gender

Characteristics	Total (*n*=13379)	Male (*n*=7653)	Female (*n*=5726)	t/χ^2	*P* value
Age (years)	50.10±15.89	50.59±16.48	49.45±15.04	4.09	0.000
BMI (kg/m^2)	24.63±3.50	25.36±3.32	23.63±3.49	29.11	0.000
WC (cm)	83.37±11.04	88.07±9.50	77.10±9.77	65.32	0.000
WHtR	0.50±0.06	0.51±0.05	0.48±0.07	27.48	0.000
SBP (mmHg)	126.58±18.40	129.93±17.53	122.10±18.59	24.90	0.000
DBP (mmHg)	76.41±10.95	78.80±10.91	73.22±10.17	30.12	0.000
FPG (mmol/L)	5.72±1.34	5.85±1.43	5.54±1.19	13.59	0.000
TC (mmol/L)	4.89±0.94	4.86±0.93	4.94±0.96	–5.087	0.000
TG (mmol/L)	1.64±1.46	1.86±1.70	1.33±0.98	21.00	0.000
LDL-C (mmol/L)	2.47±0.66	2.48±0.63	2.45±0.69	2.82	0.005
HDL-C (mmol/L)	1.31±0.31	1.21±0.27	1.44±0.31	–45.50	0.000
Elevated WC	5478 (40.94%)	3322 (43.41%)	2156 (37.65%)	44.864[a]	0.000
Elevated TG	4297 (32.12%)	2991 (39.08%)	1306 (22.80%)	397.900[a]	0.000
Reduced HDL-C	3755 (28.07%)	1861 (24.32%)	1894 (33.08%)	1244.492[a]	0.000
Elevated BP	5810 (43.43%)	3855 (50.37%)	1955 (34.14%)	351.175[a]	0.000
Elevated FPG	4974 (37.18%)	3268 (42.70%)	1706 (29.79%)	233.669[a]	0.000
≥2 risk factors	7286 (54.46%)	4695 (61.35%)	2591 (45.25%)	342.272[a]	0.000
≥3 risk factors	4261 (31.85%)	2750 (35.93%)	1511 (26.39%)	137.489[a]	0.000

BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; FPG: fasting plasma glucose; SBP: systolic blood pressure; DBP: diastolic blood pressure; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol

[a]: χ^2 value

Table 2 Prevalence and odds ratios of metabolic risk factors[*] according to WHtR

WHtR	Case (*n*)	Elevated TG		Reduced HDL-C		Elevated BP		Elevated FPG	
		n	OR (95%CI)	*n*	OR (95%CI)	*n*	OR (95%CI)	*n*	OR (95%CI)
Men									
<0.47	1407	199	1.00	133	1.00	429	1.00	330	1.00
0.47–0.50	1418	1418	2.943 (2.442–3.547)	295	2.516 (2.020–3.135)	604	1.692 (1.449–1.975)	493	1.739 (1.475–2.051)
0.50–0.53	1740	721	4.295 (3.596–5.130)	445	3.292 (2.672–4.055)	888	2.376 (2.050–2.753)	776	2.627 (2.249–3.069)
0.53–0.56	1504	741	5.895 (4.920–7.064)	440	3.961 (3.210–4.888)	869	3.120 (2.678–3.635)	745	3.203 (2.731–3.757)
≥0.56	1584	867	7.340 (6.133–8.785)	548	5.067 (4.122–6.229)	1065	4.678 (4.008–5.460)	924	4.569 (3.899–5.355)
Women									
<0.47	2402	167	1.00	504	1.00	340	1.00	336	1.00
0.47–0.50	1038	232	3.852 (3.108–4.774)	374	2.121 (1.807–2.490)	322	2.727 (2.291–3.247)	284	2.316 (1.937–2.769)
0.50–0.53	816	262	6.329 (5.104–7.849)	340	2.690 (2.269–3.189)	364	4.884 (4.082–5.884)	307	3.709 (3.090–4.452)
0.53–0.56	640	279	10.343 (8.287–12.910)	288	3.081 (2.563–3.704)	362	7.897 (6.505–9.598)	304	5.563 (4.585–6.749)
≥0.56	830	366	10.557 (8.569–13.005)	388	3.306 (2.794–3.911)	567	13.075 (10.857–15.745)	475	8.227 (6.876–9.844)

[*]Elevated TG, reduced HDL-C, elevated blood pressure and elevated FPG were defined according to the joint statement.

OR increased with increasing of WHtR values. And the prevalence and OR of cluster of metabolic risk factors also showed a rising trend with the increasing of WHtR values in both genders (table 3).

2.3 Cut-off Points of WHtR for Predicting Cluster of Metabolic Risk Factors Analyzed by ROC Curve

The optimal cut-off points of WHtR for the cluster of metabolic risk factors were analyzed by ROC curve. 0.50798 for men and 0.48773 for women turned out to have the largest Youden index values (0.5082 and 0.6165) based on the subjects who fulfilled at least 2 risk factors (fig. 1). And for at least 3 risk factors, 0.51489 (Youden index: 0.5005) for men and 0.49379 (Youden index: 0.6100) for women were the optimal cut-offs (fig. 2). Consequently, 0.51 for men and 0.49 for women might be the optimal cut-off points for predicting cluster of metabolic risk factors. As age may be an important influence factor, we further separated all subjects based on ages (<60 and ≥60 years old) and performed ROC curve analysis, respectively. Cut-off values of different groups are all listed in table 4. The results showed cut-off values were similar in different age groups. 0.51 for men and 0.49 for women held high values for predicting cluster of metabolic risk factors.

2.4 Metabolic Indices

By the cut-off points of WHtR evaluated above, all subjects were divided into two groups, people with abdominal obesity (WHtR≥0.51 for men and WHtR≥0.49 for women) and normal subjects. Abdominal obesity population (1.23±0.27 mmol/L)

Table 3 Prevalence and odds ratios of cluster of metabolic risk factors* according to WHtR

WHtR	Case number	≥1 risk factor		≥2 risk factors		≥3 risk factors	
		n	OR (95%CI)	*n*	OR (95%CI)	*n*	OR (95%CI)
Men							
<0.47	1407	750	1.00	280	1.00	56	1.00
0.47–0.50	1418	1078	2.777 (2.365–3.262)	585	2.827 (2.389–3.345)	188	3.687 (2.709–5.019)
0.50–0.53	1740	1541	6.783 (5.660–8.130)	1084	6.651 (5.651–7.828)	540	10.856 (8.156–14.450)
0.53–0.56	1504	1479	51.824 (34.430–78.006)	1269	21.735 (17.955–26.311)	819	28.844 (21.672–38.391)
≥0.56	1584	1582	–	1477	55.560 (43.886–70.339)	1147	63.321 (47.423–84.548)
Women							
<0.47	2402	973	1.00	291	1.00	69	1.00
0.47–0.50	1038	765	4.115 (3.506–4.831)	416	4.852 (4.075–5.776)	172	6.715 (5.025–8.975)
0.50–0.53	816	758	19.194 (14.518–25.375)	551	15.083 (12.461–18.258)	317	21.480 (16.271–28.356)
0.53–0.56	640	638	468.501 (116.638–1881.830)	555	47.366 (36.555–61.376)	378	48.782 (36.626–64.972)
≥0.56	830	830	–	778	108.535 (79.898–147.436)	575	76.242 (57.554–100.997)

*Metabolic risk factors were defined according to the joint statement.

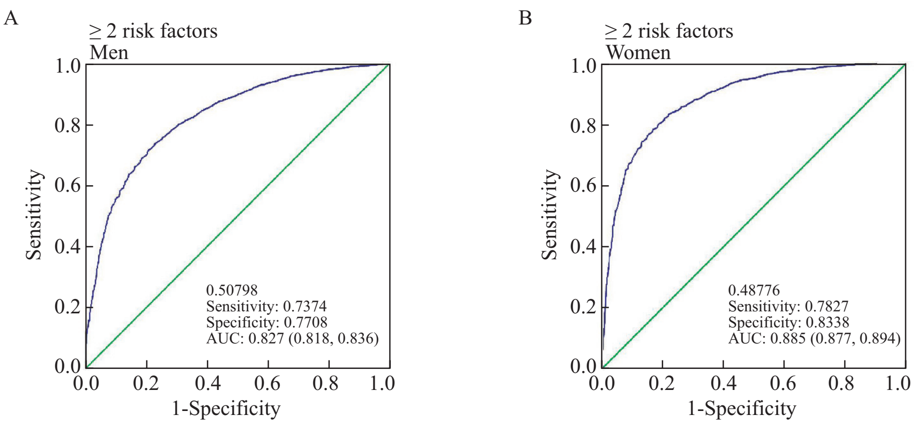

Fig. 1 ROC curve analysis of WHtR regarding the ability to identify the cluster of at least 2 metabolic risk factors in men (A) and women (B)

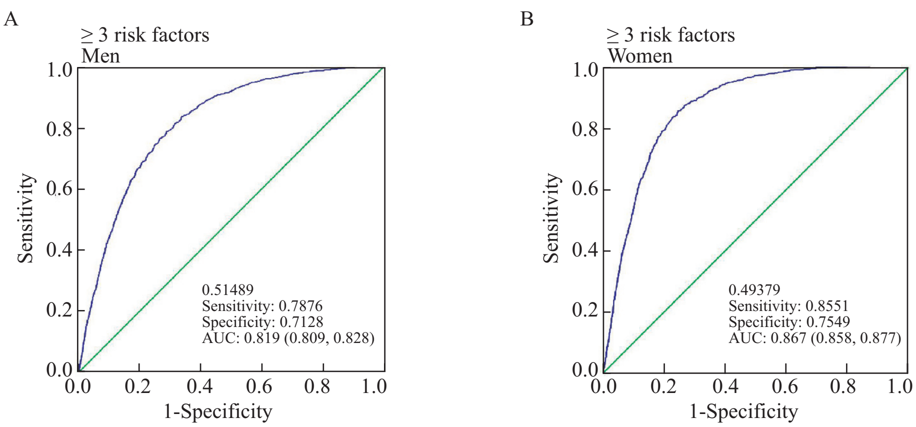

Fig. 2 ROC curve analysis of WHtR regarding the ability to identify the cluster of at least 3 metabolic risk factors in men (A) and women (B)

had a lower mean level of HDL-C than normal people (1.38±0.32 mmol/L). However, for other 7 indices including SBP (132.88±18.02 mmHg *vs.* 119.98±16.38 mmHg), DBP (79.32±11.15 mmHg *vs.* 73.36±9.86 mmHg), FPG (6.02±1.56 mmol/L *vs.* 5.40±0.98 mmol/L), TC (5.03±0.94 mmol/L *vs.* 4.74±0.92 mmol/L), TG (2.01±1.56 mmol/L *vs.* 1.25±1.23 mmol/L) and LDL-C (2.60±0.66 mmol/L *vs.* 2.34±0.63 mmol/L), the mean values in abdominal obesity population were all higher (P<0.001).

2.5 Prevalence of Metabolic Risk Factors among Abdominal Obesity and Normal Subjects Defined by WHtR

Table 5 showed the prevalence of individuals and

Table 4 Cut-off values of WHtR for predicting cluster of metabolic risk factors

Characteristics	≥2 risk factors	≥3 risk factors
Men		
Total	0.50798	0.51489
<60 years	0.50806	0.51070
≥60 years	0.51081	0.51537
Women		
Total	0.48773	0.49379
<60 years	0.48766	0.49074
≥60 years	0.49787	0.49429

clusters of 5 metabolic risk factors for MetS including elevated WC, TG, BP, FPG and reduced HDL-C. MetS was far more common among abdominal obesity population (56.03%) than in normal subjects (9.09%). The prevalence of all individual components was higher in abdominal obesity group. Furthermore, among normal population, 2786 subjects (40.43%) did not have any risk factors, and 31.65%, 18.84%, 7.05%, 1.92%, 0.12% of all had 1 to 5 risk factor(s), respectively. Among abdominal obesity population, it was 3.07%, 14.29%, 26.62%, 28.75%, 20.27% and 7.02% for 0 to 5 clustering factor(s), respectively. The proportion of people with 2 or more risk factors in normal and abdominal obesity population was 27.92% and 82.64%, respectively. 9.09% and 56.03% had at least 3 risk factors. There were significant differences between these two groups (P<0.001).

3 DISCUSSION

Many researches in different countries have been conducted to detect the optimal cut-off point of WHtR for detecting metabolic disorders. Study population and outcomes were diverse from each other. A study of 4485 South Asian adults reported that the cut-offs for hypertension in all subjects, males and female were 0.502, 0.484 and 0.516, respectively. The values for MetS were 0.518, 0.501 and 0.531[11]. For Brazil, a study involving 1720 adults concluded 0.50 for men and 0.49 for women[26]. Research from Japan reported the cut-off points for the identification of one or more AHA/NHLBI/IDF-defined metabolic risk factors were 0.50 for males and 0.48 for females, respectively, and those for identification of 2 or more risk factors were both 0.50[21]. Then in China, the values were not in agreement. In Taiwan, the values were reported to be 0.48 and 0.45 for male and female[11]. A study of 3006 adults in Jinan, a northern city of China, showed the cut-off point as 0.52 for both men and women[17]. One study conducted in Hong Kong including 2895 residents suggested that the optimal value was 0.48[13]. And a cross-sectional study in Beijing stated the optimal points for WHtR ranged from 0.51 to 0.53 in men and 0.48 to 0.50 in women for predicting hypertension, diabetes and dyslipidemia[12]. Our study included a total of 13 379 individuals (7553 males and 5726 females) aged from 18 to 95, working in over 40 different institutions. Compared with other research, our study population was larger and more representative based on age and vocation.

Reported values of the cut-off point for WHtR in different studies are not consistent, but they all fluctuate around 0.50. In our study, the ROC curve analysis detected that 0.51 for men and 0.49 for male were the optimal cut-off points of WHtR, which fit with the value 0.50.

When all participants were categorized according to WHtR values and the prevalence and OR of single and clusters of risk factors (elevated TG, blood pressure, FPG and reduced HDL-C) compared among groups, the association between WHtR and metabolic risk factors was clearly revealed. For four individual risk factors, including elevated TG, blood pressure, FPG and reduced HDL-C, the prevalence and OR were both higher in higher-WHtR-value groups. And for clusters, they also showed a rising trend with the increasing of WHtR value. With the increase of WHtR, prevalence of more than 3 metabolic risk factors rose

Table 5 Comparison of metabolic risk factors between abdominal obesity people and normal people

Factors	Total (%) (n=13 379)	Normal people (%) (n=6891)	Abdominal obesity people (%) (n=6488)	χ^2	P value
Increased WC	5478 (40.94)	291 (4.22)	5187 (79.90)	7924.789	0.000
Increased TG	4297 (32.12)	1326 (19.24)	2971 (45.79)	1080.415	0.000
Reduced HDL-C (%)	2501 (18.69)	1427 (20.71)	2328 (35.88)	381.084	0.000
Increased BP (%)	5810 (43.43)	2033 (29.50)	3777 (58.22)	1212.390	0.000
Increased FPG	4974 (37.18)	1726 (25.05)	3248 (50.06)	895.275	0.000
0 risk factor (%)	2985 (22.31)	2786 (40.43)	199 (3.07)		
1 risk factor (%)	3108 (23.23)	2181 (31.65)	927 (14.29)		
2 risk factors (%)	3025 (23.12)	1298 (18.84)	1727 (26.62)		
3 risk factors (%)	2351 (17.59)	486 (7.05)	1865 (28.75)	5008.853	0.000
4 risk factors (%)	1447 (9.39)	132 (1.92)	1315 (20.27)		
5 risk factors (%)	463 (2.27)	8 (0.12)	455 (7.01)		
<60 years	0.48766	0.49074			
≥60 years	0.49787	0.49429			

from 3.98% to 72.41% in men and from 2.87% to 69.28% in women. It could be concluded that people in categories of increasing WHtR values were much more susceptible to metabolic disorders and more likely to have clustering metabolic risk factors.

Since WHtR has been recommended as a better anthropometric indicator of abdominal obesity and predictor of metabolic diseases[9-24], we divided all subjects into two groups based on the optimal cut-off points for WHtR. The difference of relative metabolic indices and prevalence of risk factors between them was calculated and compared. Compared with normal population, people with WHtR-defined abdominal obesity had lower mean level of HDL-C and higher levels of blood pressure (both SBP and DBP), FPG, TC, TG, LDL-C. While MetS was evident in 56.03% of those with abdominal obesity, the prevalence in normal population was only 9.09%. MetS was much more prevalent in abdominal obesity population defined by WHtR. In addition, the prevalence of every single metabolic risk factor and clusters were all higher in abdominal obesity category. As it was shown, people with abdominal obesity were at higher risk to develop MetS, diabetes, hypertension, dyslipidemia and other relative diseases. Furthermore, a cross-sectional study including 38 406 Taiwan adults found that people with normal BMI or WC but elevated WHtR had higher levels of metabolic risk factors than their counterparts with normal BMI or WC but low WHtR[10]. Research in America[27] and Spain[28] also drew the similar conclusion. As an anthropometric parameter of abdominal obesity, WHtR is closely related with metabolic disorders and has higher diagnostic value than WC and BMI.

In this study, our results demonstrated that 48.49% (51.89% of men and 43.96% of women) Chinese middle-aged population had abdominal obesity. Only about a half of our subjects did not have abdominal obesity. In European population, the prevalence of abdominal obesity diagnosed as WHtR≥0.5 was 89% and 77% in men and women respectively[28]. Along with the process of industrialization and change of life style, people now tend to consume high-calorie dietary pattern but do insufficient exercise, which are likely to increase the possibility of obesity[29]. It is widely accepted that obesity is a risk factor of cardiovascular diseases[30], hypertension[30], diabetes[27] and all-course mortality[31]. Furthermore, abdominal obesity is closely related with visceral adipose accumulation and insulin resistance. It has been demonstrated to have stronger ability to predict the risk of morbidity[32–35] and all-cause mortality[36] contrast with overall obesity. Such a high rate of central obesity may lead to increasing prevalence of multiple chronic metabolic diseases.

There are several limitations in this study. First, this study was conducted in single ethnic group. Extrapolating or generalizing these results to other ethnic groups should be performed with caution. Second, all study samples were from the same hospital and they were not representative enough when detecting the prevalence. Nevertheless, it was a large-scale study and the range of age and vocation were wide. We believe our results are informative.

In conclusion, our analysis suggest that 0.51 for men and 0.49 for women are the optimal WHtR cut-off points to predict cluster of metabolic risk factors. Subjects with higher WHtR have higher levels of blood pressure, WC, FPG, TG and lower level of HDL-C. The prevalence of individual and clusters of 5 metabolic risk factors were all higher among WHtR-defined abdominal obesity people than in normal subjects.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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