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Association of Visceral Fat Index and Percentage Body Fat and Anthropometric Measures with Myocardial Infarction and Stroke

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Abstract

Purpose: This study aimed to evaluate the effect of bioelectrical obesity indices (percentage body fat, PBF; visceral fat index, VFI) on cardiovascular disease (CVD) and evaluate the optimal cut-off values for myocardial infarction (MI) and stroke.

Method: A community-based cross-sectional study including 6027 males and 8874 females aged ≥ 35 years was conducted in 66 sample sites by multistage random sampling method from Henan Province, China.

Result: The area under receiver operating characteristic curves (AUCs) of PBF was highest in males for MI (0.651) and stroke (0.623) and in females for MI (0.618) and stroke (0.611). VFI and PBF had better discriminatory power in males of 35~54 age groups for MI (AUC=0.667) and stroke (AUC=0.702), respectively. Optimal cut-off values for VFI and PBF in males/females were approximately 15 /10 and 25% /36%, respectively. Combined two high levels of waist-to-height ratio (WHtR), VFI and PBF could increase higher adjusted OR for MI (1.41-2.81) and stroke (1.49-2.08).

Conclusion: High level of PBF and VFI could increase the risk of CVD. PBF may be a more sensitive indicator of CVD. The combination of WHtR, PBF and VFI was found to be associated with greater OR of CVD than them alone.

Keywords: Cardiovascular disease; Stroke; Obesity; Percentage body fat; Visceral fat index

Abbreviations

CVD: Cardiovascular disease; MI: Myocardial infarction; BMI: Body mass index; WC: Waist circumference; WHtR: Waist-to-height ratio; VFI: Visceral fat index; PBF: Percentage of body fat; SD: Standard deviations; ORs: Odds ratio; CI: Confidence interval; ROC: Receiver operating characteristic; AUC: the Area under ROC curve; SBP: Systolic blood pressure; DBP: Diastolic blood pressure

Introduction

In recent years, cardiovascular disease (CVD) has been recognized as the leading cause of death world-wide causing 28.2% of all-cause mortality [1]. Of these deaths, an estimated 7.3 million were due to coronary heart disease and 6.2 million were due to stroke [2]. Moreover, the age-standardized cardiovascular and cerebrovascular disease incidence have been rising, which includes heart diseases (coronary heart disease, heart failure, rheumatic heart disease, congenital heart disease and cardiomyopathies), cerebrovascular diseases (ischemic stroke and cerebral hemorrhage), hypertension [3,4].

Obesity is widely known as a potential risk factor for cardiovascular and cerebrovascular diseases, hypertension, type-2 diabetes, and dyslipidemia [5-7]. Finding out which measurements of overweight and obesity can efficiently and exactly discriminate the individuals with increased cardiovascular and cerebrovascular diseases risk is essential.

A number of traditional anthropometric indicators including body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR) have been verified effective to screen high risk group of CVD at some degree [8]. However, the above anthropometric indicators could not discriminate the visceral fat and the subcutaneous fat. Visceral adipose tissue is a metabolically active organ and intra-abdominal obesity is an independent risk factor for metabolic alterations present in metabolic syndrome [9]. Furthermore, compared with other adiposity measurements likely micro-magnetic resonance imaging and micro-computed tomography, the multi-frequency bioelectrical impedance analysis method is less accurate but economical and more applicable in population and clinical studies [10]. Visceral fat index (VFI) is also an accurate and reliable indicator for evaluating visceral adipose [11]. Prior studies have shown PBF is a better predictor of cardiovascular disease than BMI [12].

However, few studies have directly shown the association of VFI and PBF with MI and stroke and which obesity indicators had the best discriminability in distinguishing persons with higher risk of MI and stroke. Therefore, this study aimed to evaluate the optimal cut-off values of PBF and VFI for MI and stroke in Chinese adults based on a cross-sectional study and investigate the value of VFI and PBF in predicting CVD in different gender and age groups.

Materials and Methods

Study population and database

The objects in the cross-sectional study were recruited and investigated in 2013-2015 in Henan Province and the research was part of a national survey on prevalence of hypertension covering 31 provinces and 262 counties supported by the National Key R&B program in the Twelfth Five-year Plan in China (No. 2011BAI11B01). The design scheme and implementary plan of this survey were introduced in details by Wang, et al. [13]. The samples were permanent residents selected by the stratified multistage random sampling method. Initially, the sample size in the present study was 14901 aged ≥ 35 years old after excluding the objects with missing values. The data were collected by professionals after training with face-to-face questionnaire interviews, including the information on demographic, educational status, cigarette smoking and alcohol consumption habits, labor intensity, personal and family history of CVD. Each participant was provided a written informed consent. The protocol was approved by the Ethical Committee of the Chinese Ministry of Science and Technology.

Anthropometric and bioelectrical variables

All of the anthropometric indices in this study were measured by trained and certified research staff with standard instruments. In order to ensure accuracy and reproducibility at each site, we also regularly examined the apparatuses.

Height was measured to the nearest 0.5 cm with the participants in a sanding position without shoes, erecting, arms resting along the body, raised head and looking at a fixed point at eye level. Weight (0.1 kg precision), VFI and PBF were measured with multi-frequency bioelectrical impedance methods using Omron body fat and weight measurement tetrapolar device (V-BODY HBF-359; OMRON, Kyoto, Japan). WC was measured to the nearest 0.5 cm at umbilical level of the participants over light clothing and in a standing position. WHtR was calculated by the formula: waist/height (both measured in centimeters). BMI was calculated by the formula: weight/height^2 (kilograms/meters^2).

The subjects were required to refrain from alcohol intake for at least 48 hours, from vigorous exercise for at least 12 hours, from taking a meal or drink for at least 3 hours, and urinated and defecated within 30 minutes before take any of these measurements. According the OMRON HBF-359 measurements illustration, the subject stood in a standing position with the bare feet on the analyzer footpads and held the analyzer handgrips with the upper limbs extended forward. The systemic impedance (Z1) and impedance between the 2 hands (Z2) were measured with signal frequency (50 kHz and 500 mA) passed through the body. Z1 was determined by measuring the voltage induced by applying a current to the electrodes fixed on the bilateral palms and soles while shorting each of the current and voltage electrodes fixed on each of the bilateral palms and soles. Z2 was determined by measuring the voltage induced by applying a current to the current electrodes fixed on the bilateral palms, respectively. PBF were computed with Z1, and VFI with Z1 and Z2.

Blood pressure (BP) was measured three times with the OMRON HBO-1300 Professional Portable Blood Pressure Monitor (OMRON, Kyoto, Japan) on the right arm at the heart level and the participants in the sitting position after having a 5-minutes rest. In order to calibration, every 50 person were measured by the OMRON device and a mercury sphygmomanometer (Yutu, Shanghai Medical Instruments Co., Ltd., Shanghai, China). Finally, we calculated the mean value of the three measurements for analysis.

Definitions

WC ≥ 90 cm in men and WC ≥ 80cm in women were defined as high WC group [14]. The participants were classified into three groups: under/normal weight (<23 kg/m^2), overweight (23~27.4 kg/m^2) and obesity (≥ 27.5 kg/m^2) [14]. WHtR ≥ 0.5 was defined as high WHtR group [15]. The definition of hypertension groups were based on the medical certificate of hypertension or defined as systolic blood pressure (SBP) ≥ 140 mmHg and/or diastolic blood pressure (DBP) ≥ 90 mmHg. [16] The participants suffering from MI and stroke were diagnosed based on the medical certificate of MI and stroke issued by the hospital. Participants were categorized as non-CVD, MI, stroke and M-S (participants with MI and stroke both) four groups.

Statistical analysis

The data were analyzed by Statistical Package for the Social Sciences version 21.0 (SPSS Inc., Shanghai, co., LTD, 6761805c6989326cbf14). The variables in the study were expressed as mean and standard deviations (SD) when normally distributed and median and range when not normally distributed. The categorical variables are expressed as numbers and percentages. T test was used to compare continuous variables between two groups. The comparison of categorical data was performed using χ^2 test. The binary logistic regression was used to perform the association between obesity indicators and prevalence of CVD incident rates with odds ratio (ORs) and 95% confidence interval (CI). Pearson correlation coefficient was used to evaluate the existence of significantly bivariate correlations among different anthropometric indices depends on sex. Receiver operating characteristic (ROC) were conducted and the area under the curve (AUC) was performed with a 95% CI to determine optimal cut-off values of each bioelectrical index for CVD. The statistical significance of the difference of AUC among the different anthropometric indices was tested with Z values: with Z>1.96, P<0.05 and Z>2.58, P<0.01. All significant tests were 2-tailed, and P<0.05 was considered as statistically significant.

Result

Demographic characteristic of the participants

Totally 14901 subjects aged 35 years and older were included in this study. Table 1 shows the demographic and metabolic characteristics of the study population. The study contained 6027 males (90.66% with non-CVD, 1.84% with MI, 6.95% with stroke and 0.55% with MI and stroke both) and 8874 females (93.39% with non-CVD, 1.33% with MI, 4.97% with stroke and 0.37% with MI and stroke both). The average age in males of non-CVD groups was56.91 years old and the average age in females of non-CVD groups was 57.64 years old. The age tended to increase in the groups of MI and stroke both in males and females (all P<0.001).

Majority of the participants were in 55~75 age groups both in males and females. The proportion of smoking and alcohol consumption in males were much higher than females (P ≥ 0.05). There is statistically difference between smoking status, alcohol consumption, family history and hypertension in groups of MI and stroke when compared with non-CVD group. No statistical difference was found for daily alcohol consumption is similar between Non-CVD and CVD for both sexes. The values of VFI (P<0.05) and PBF (P<0.001) in MI group were higher than non-CVD group in males and WC (P<0.05), WHtR (P<0.01), VFI (P<0.01) and PBF (P<0.001) in MI group were higher than non-CVD in females. The anthropometric indicators, including BMI, WC, WHtR, VFI and PBF in group of stroke were all higher than non-CVD group (P<0.05). The mean values of BMI, WHtR and PBF of men were lower than women (P=0.003) and the values of WC and VFI in males were higher than females in all four groups. The mean value of SBP in MI group in males was 140.15 mmHg (P<0.001) which was higher than the other groups in males and tended to increase in MI group, stroke group and M-S group in females. However, the value of DBP only in stroke group in females was higher than the non-CVD group (P<0.001).

Characteristics	Male (n=6027)				Female (n=8874)			
	Non-CVD	MI	Stroke	M-S	Non-CVD	MI	Stroke	M-S
	(5464, 0.66%)	(111, 1.84%)	(419, 6.95%)	(33, 0.55%)	(8287, 93.39%)	(117, 1.33%)	(441, 4.97)	(33, 0.37%)
Age (year)	56.91 ± 12.40	63.60 ± 10.70***	64.94 ± 9.19***	67.12 ± 8.94***	57.64 ± 11.60	65.86 ± 8.92***	64.72 ± 8.36***	66.59 ± 7.41***
35~54	2431 (44.49)	25 (22.52)	50 (11.93)	2 (6.06)	3459 (41.74)	13 (11.11)	45 (10.20)	2 (6.90)
55~74	2556 (46.78)	63 (56.76)	306 (73.03)	25 (75.76)	4158 (50.17)	84 (71.79)	349 (79.14)	22 (75.86)
≥ 75	477 (8.73)	23 (20.72)	63 (15.04)	6 (18.18)	670 (8.08)	20 (17.09)	47 (10.66)	5 (17.24)
Smoking, n (%)								
Never	1765 (32.30)	22 (19.82)	108 (25.78)	6 (18.18)	8154 (98.40)	113 (96.58)	430 (97.51)	27 (93.10)
Quit	1163 (21.28)	52 (46.85)***	166 (39.62)***	17 (51.52)***	33 (0.40)	2 (1.71)*	5 (1.13)	2 (6.90)**
Always	2536 (46.41)	37 (33.33)	145 (34.61)	10 (30.30)	100 (1.20)	2 (1.71)	6 (1.36)	0
Alcohol consumption, n (%)								
Never	2959 (54.15)	70 (63.06)	245 (58.47)	20 (60.61)	7992 (96.44)	114 (97.44)	429 (97.28)	26 (89.66)
Monthly	752 (13.76)	10 (9.01)*	36 (8.59)	2 (6.06)	111 (1.34)	0 (0)	3 (0.68)	0 (0)
Weekly	927 (16.97)	20 (18.02)***	64 (15.27)	5 (15.55)	97 (1.17)	1 (0.85)*	2 (0.45)	1 (3.45)
Daily	826 (15.12)	11 (9.91)	74 (17.66)	6 (18.88)	87 (1.05)	2 (1.71)	7 (1.59)	2 (6.90)*
Physical activity, n (%)								
Low	1203 (22.02)	34 (30.63)	104 (24.82)	6 (18.18)	1555 (18.76)	33 (28.20)	107 (24.26)	6 (20.69)
Medium	2800 (51.24)	46 (41.44)	203 (48.45)	17 (51.52)	3407 (41.11)	41 (35.04)*	170 (38.55)*	12 (41.38)
High	1461 (26.74)	31 (27.93)	112 (26.73)	10 (30.30)	3325 (40.12)	43 (36.75)*	164 (37.19)*	11 (37.93)
Family History, n (%)								
Yes	973 (17.81)	34 (30.63)***	111 (26.49)***	12 (36.36)*	1621 (19.56)	26 (22.22)	106 (24.04)*	8 (27.59)
No	4491 (82.19)	77 (69.37)	308 (73.51)	21 (63.64)	6666 (80.44)	91 (77.78)	335 (75.96)	21 (72.41)
Hypertension, n (%)								
Yes	2205 (40.36)	55 (49.55)	307 (73.27)***	23 (69.70)***	3589 (43.31)	66 (56.41)**	353 (80.05)***	22 (75.86)***
No	3259 (59.64)	56 (50.45)	112 (26.73)	10 (20.30)	4698 (56.69)	51 (43.60)	88 (19.95)	7 (24.14)
BMI (kg/m2)	25.01 ± 3.42	25.41 ± 3.30	25.40 ± 3.59*	25.96 ± 3.20	25.74 ± 3.71	26.01 ± 4.01	26.36 ± 3.85***	26.26 ± 4.48
WC (cm)	88.62 ± 9.51	90.21 ± 9.39	90.56 ± 9.66***	90.80 ± 8.85	86.47 ± 10.00	88.48 ± 10.42*	89.64 ± 10.03***	89.80 ± 11.55
WHtR	0.53 ± 0.06	0.54 ± 0.05	0.55 ± 0.05***	0.56 ± 0.06**	0.56 ± 0.07	0.58 ± 0.07**	0.59 ± 0.07***	0.60 ± 0.08**
VFI	11.94 ± 4.91	12.99 ± 5.11*	13.40 ± 5.46***	14.24 ± 5.76**	9.08 ± 4.31	10.13 ± 4.66**	10.23 ± 4.61***	10.76 ± 5.57

PBF (%)	24.91 ± 5.90	27.95 ± 5.11***	27.21 ± 5.37***	28.02 ± 4.43**	26.36 ± 3.85	36.74 ± 4.86***	36.69 ± 4.25***	37.55 ± 5.25**
SBP (mmHg)	132.48 ± 18.79	134.94 ± 18.61	140.15 ± 20.97***	137.44 ± 23.15	131.87 ± 21.32	138.51 ± 20.50***	143.59 ± 23.96***	146.30 ± 20.92***
DBP (mmHg)	79.29 ± 11.37	78.26 ± 11.51	80.34 ± 11.70	79.00 ± 12.89	75.10 ± 11.11	75.24 ± 12.37	77.84 ± 11.59***	77.79 ± 11.04
Abbreviations: BMI=Body mass index; WC=Waist circumference; WHtR=Waist–to-height ratio; VFI=Visceral fat index; PBF=percentage body fat; SBP=Systolic blood pressure; DBP=Diastolic blood pressure								

Table 1: Demographic and metabolic characteristics of the study population.

Normally distributed variables are expressed as mean ± SD; not distributed variables as median and range; categorical variables as n and %.

Symbols denote significant differences from Non-CVD (***P<0.001, **P<0.01, *P<0.05) with t test, Wilcoxon test, or chi-square test.

AUC of various obesity indices for CVD prevalence

Table 2 shows the AUC of five obesity indices for MI and stroke prevalence. In the five obesity indicators, the PBF had the largest AUC for MI (0.651, P<0.01) and the AUC of BMI, WC, WHtR and VFI had no significantly statistical difference in males (P>0.05). In females, the AUC of PBF for MI (0.618, P<0.01) was higher than BMI only (P<0.05). When comparing the AUCs of obesity indices for stroke, the AUC of WHtR (0.591, P<0.01), VFI (0.578, P<0.05) and PBF (0.623, P<0.01) were all higher than that of BMI (0.532) and the AUC of PBF was higher than VFI and WC except WHtR in males. In females, the AUC of WC, WHtR and PBF were higher than BMI (P<0.01).

There was no significantly statistical difference of AUC for various obesity indices between different genders (all P>0.05). The AUC for these obesity indices stratified by 20-year age groups are also summarized in Table 3. In males, all indices had better discriminatory power for MI in 35~54 age groups. On the contrary, the AUC of BMI, WC, and WHtR for stroke were larger in 75~ age groups, while the VFI and PBF also had better discriminatory power for stroke in younger age groups. In females, BMI and WC had no discriminatory power for MI (P>0.05). Only in 55~74 age groups were the AUCs of VFI and PBF for MI significantly different. The AUCs of all indices for stroke were higher in 35~54 age groups in females.

	AUC (95%CI) for MI		AUC (95%CI) for Stroke	
	Male	**Female**	**Male**	**Female**
BMI				
Overall	0.531 (0.478-0.584)	0.519 (0.464-0.574)	0.532 (0.503-0.561)	0.548 (0.520-0.575)
35~54	0.656 (0.552-0.760)	0.543 (0.385-0.702)	0.563 (0.479-0.647)	0.599 (0.512-0.685)
55~74	0.509 (0.440-0.577)	0.555 (0.491-0.619)	0.537 (0.504-0.571)	0.544 (0.513-0.575)
75~	0.587 (0.480-0.695)	0.391 (0.284-0.498)	0.594 (0.515-0.674)	0.514 (0.430-0.598)
WC				
Overall	0.550 (0.499-0.602)	0.565 (0.513-0.617)*	0.558 (0.529-0.586)	0.592 (0.566-0.619)
35~54	0.683 (0.587-0.779)	0.599 (0.440-0.758)	0.560 (0.481-0.640)	0.610 (0.527-0.693)
55~74	0.514 (0.448-0.580)	0.561 (0.499-0.623)	0.550 (0.516-0.583)	0.564 (0.533-0.595)
75~	0.536 (0.422-0.650)	0.397 (0.292-0.501)	0.597 (0.522-0.671)	0.517 (0.435-0.599)
WHtR				
Overall	0.547 (0.497-0.598)	0.591 (0.540-0.643)	0.591 (0.563-0.618)	0.614 (0.588-0.640)
35~54	0.657 (0.556-0.759)	0.608 (0.443-0.773)	0.595 (0.517-0.674)	0.616 (0.533-0.700)
55~74	0.497 (0.430-0.565)	0.571 (0.509-0.634)	0.559 (0.526-0.592)	0.570 (0.540-0.601)
75~	0.512 (0.404-0.620)	0.377 (0.272-0.481)	0.616 (0.542-0.689)	0.520 (0.432-0.605)
VFI				

Overall	0.562 (0.508-0.616)	0.572 (0.519-0.625)	0.578 (0.548-0.607)	0.581 (0.553-0.608)
35~54	0.667 (0.558-0.776)	0.556 (0.390-0.722)	0.605 (0.525-0.685)	0.595 (0.509-0.681)
55~74	0.515 (0.444-0.586)	0.566 (0.503-0.629)	0.540 (0.506-0.574)*	0.543 (0.512-0.574)
75~	0.536 (0.421-0.651)	0.411 (0.301-0.521)	0.595 (0.516-0.673)*	0.505 (0.418-0.592)
PBF				
Overall	0.651 (0.604-0.698)	0.618 (0.566-0.670)	0.623 (0.596-0.651)	0.611 (0.585-0.637)
35~54	0.702 (0.617-0.786)	0.570 (0.403-0.736)	0.613 (0.540-0.687)	0.596 (0.512-0.680)
55~74	0.598 (0.528-0.667)	0.568 (0.504-0.632)	0.571 (0.537-0.604)	0.550 (0.519-0.581)
75~	0.569 (0.456-0.683)	0.488 (0.353-0.622)	0.586 (0.510-0.662)	0.513 (0.426-0.599)
Abbreviations: BMI=Body mass index; WC=Waist circumference; WHtR=Waist –to-height ratio; VFI=Visceral fat index; PBF=Percentage body fat; CI=Confidence interval				

Table 2: AUC of various anthropometric indices for MI and stroke by gender and age group.

Optimal cut-off values of VFI and PBF for CVD incident

The optimal cut-off values of anthropometric indices were determined using the ROC analyses in both sexes are summarized in Table 3. In men, the VFI cut-off values that were found to optimally predict the risk of MI and the stroke ranged from 10.50 to 16.50 and the optimal PBF cut-off values ranged from 22.25 to 26.95. In women, the VFI cut-off values that were found to optimally predict the risk of MI and the stroke ranged from 9.45 to 14.50 and the optimal PBF cut-off values ranged from 33.45 to 40.25. In addition, the optimal cut-off values of VFI were all higher for men than for women in each age group. On the contrary, the optimal cut-off values of PBF were all higher for women than for men in each age group.

Both in men and women, the optimal cut-off values of VFI for MI and stroke were higher in the 35~54 age group and in 75~ age group, respectively. The optimal cut-off values of PBF were higher in 75~age groups except for MI in males which was higher in 55~74 age groups.

MI							**Stroke**					
	Cut-off value		**Sensitive (%)**		**Specificity (%)**		**Cut-off value**		**Sensitive (%)**		**Specificity (%)**	
	male	**female**	**male**	**female**	**male**	**female**	**male**	**female**	**male**	**female**	**male**	**female**
VFI												
Overall	14.55	10.7	36.94	31.98	72.99	68.02	15.55	9.95	34.37	53.74	78.46	59.5
35~54	14.55	14.5	48	23.08	81.04	93.58	10.5	9.5	72	48.89	44.71	69.07
55~74	11.55	10.7	55.63	53.57	32.01	61.57	12.55	9.45	56.54	54.73	51.02	52.36
75~	12.5	10.5	69.57	46.83	44.03	46.27	16.5	10.5	36.51	46.81	82.6	62.69
PBF												
Overall	23.25	36.65	86.49	58.97	36.58	62.34	26.85	36.05	58.23	60.54	62.32	56.85
35~54	25.05	38.15	76	30.77	61.42	88.41	22.25	33.45	80	68.89	39.82	50.48
55~74	28.15	36.65	52.38	61.9	65.02	52.16	26.95	37.55	58.5	46.7	55.52	61.5
75~	23.35	40.25	100	40	20.55	68.66	31.1	38.15	39.68	57.45	77.36	50.6
Abbreviations: VFI=Visceral fat index; PBF= Percentage body fat; Sens= Sensitive; Spec= Specificity												

Table 3: Cut-off values of VFI and PBF for predicting MI and stroke by age group and gender.

Association of five anthropometric indicators with CVD

The adjusted ORs and the 95% CI of MI and stroke associated with different measurements determined by age and gender specific from the binary logistic regression are shown in Table 4. After adjusted, only PBF corresponded to significantly higher OR for MI in males (OR=1.05, 1.02-1.08) and none of them shown significantly association with MI in females. Compared with different anthropometric indicators, the WHtR had a strong statistical association with stroke both in males (OR=1.68, 1.30-2.17) and in females (OR=1.75, 1.27-2.42). The BMI, WC, VFI, and PBF all shown significantly higher OR for stroke both in males and females when expressed per 1SD increment in these obesity indices. For further analysis, BMI (OR=1.08, 1.00-1.17) and WC (OR=1.03, 1.00-1.06) showed the significantly association with stroke only in 75~ age groups for males. VFI and PBF showed no significantly association with MI and stroke, excluding 75~age group for MI in males.

Obesity indicators	MI [ORs (95%CI)]		Stroke [ORs (95%CI)]	
	Male	Female	Male	Female
BMI	1.05 (0.99-1.11)	1.03 (0.98-1.08)	1.06 (1.03-1.09)***	1.05 (1.03-1.08)***
35~54	1.10 (0.97-1.24)	1.02 (0.89-1.18)	0.98 (0.89-1.07)	1.01 (0.93-1.09)
55~74	1.03 (0.96-1.10)	1.03 (0.98-1.09)	1.00 (0.97-1.04)	1.01 (0.98-1.04)
75~	1.08 (0.97-1.21)	0.99 (0.88-1.11)	1.08 (1.00-1.17)*	1.02 (0.94-1.10)
WC	1.02 (1.00-1.04)	1.01 (0.99-1.03)	1.02 (1.01-1.03)***	1.02 (1.01-1.03)***
35~54	1.04 (1.00-1.09)	1.01 (0.95-1.06)	0.99 (0.96-1.02)	1.00 (0.97-1.03)
55~74	1.01 (0.98-1.03)	1.01 (0.99-1.03)	1.00 (0.99-1.02)	1.01 (1.00-1.02)
75~	1.01 (0.97-1.05)	1.00 (0.96-1.05)	1.03 (1.00-1.06)*	1.00 (0.98-1.03)
WHtR	1.33 (0.85-2.09)	1.13 (0.66-1.91)	1.68 (1.30-2.17)***	1.75 (1.27-2.42)***
35~54	1.70 (0.62-4.67)	1.08 (0.29-4.08)	0.96 (0.49-1.89)	0.89 (0.40-1.99)
55~74	1.49 (0.86-2.58)	1.07 (0.60-1.92)	1.43 (1.05-1.94)*	1.41 (0.97-2.04)
75~	1.01 (0.97-1.05)	1.00 (0.96-1.05)	1.03 (1.00-1.06)*	1.00 (0.98-1.03)
VFI	1.02 (0.99-1.06)	1.03 (0.99-1.07)	1.04 (1.02-1.06)***	1.03 (1.01-1.06)**
35~54	1.06 (0.97-1.16)	1.03 (0.91-1.18)	1.02 (0.95-1.08)	0.99 (0.92-1.07)
55~74	1.01 (0.97-1.06)	1.03 (0.99-1.07)	1.00 (0.98-1.02)	1.00 (0.97-1.02)
75~	1.04 (0.97-1.11)	1.00 (0.91-1.09)	1.05 (1.00-1.10)*	1.00 (0.95-1.07)
PBF	1.05 (1.02-1.08)***	1.02 (0.98-1.06)	1.04 (1.02-1.05)***	1.03 (1.01-1.05)*
35~54	1.06 (1.00-1.12)	1.02 (0.89-1.16)	1.00 (0.96-1.05)	1.00 (0.93-1.08)
55~74	1.05 (1.01-1.09)*	1.02 (0.97-1.06)	1.02 (1.00-1.04)	1.00 (0.98-1.03)
75~	1.07 (1.01-1.15)*	1.04 (0.95-1.13)	1.04 (0.99-1.09)	0.99 (0.93-1.06)

Abbreviations: BMI=Body mass index; WC=waist circumference; WHtR=Waist –to-height ratio; VFI=Visceral fat index; PBF=Percentage body fat; CI=Confidence interval; OR=Odds ratio. All models were adjusted for age, race, smoking, alcohol consumption, education status, family history, systolic blood pressure and diastolic blood pressure. ***P<0.001, **P<0.01, *P<0.05

Table 4: Adjusted odds ratios (ORs) for MI and stroke associated with different measurements.

Associations of combined anthropometric indices with CVD

As were shown in Table 5, we combined the effects of WHtR, VFI and PBF. Men and women with a PBF ≥ 25% and VFI ≥ 15 (in male) or PBF ≥ 36% and VFI ≥ 10 (in female) had a significantly increased risk than those with a PBF<25% (in male) or <36% (in female) and VFI<15 (in male) or < 10 (in female). Similar results were obtained for participants with a WHtR ≥ 0.5 and PBF ≥ 25% (in male)or ≥ 36% (in female) and with a WHtR ≥ 0.5 and VFI ≥15 (in male) or ≥10 (in female), which could suggest that simultaneous use two indices could much improve the predictive power.

	MI[ORs (95%CI)		Stroke[ORs (95%CI)]	
	Male	Female	Male	Female

PBF<25% (male) or <36% (female)				
VFI<15 (male) or < 10 (female)	1	1	1	1
VFI≥15 (male) or ≥ 10 (female)	1.22 (0.16-9.13)	1.35 (0.56-3.22)	1.35 (0.53-3.46)	1.33 (0.86-2.06)
PBF ≥ 25% (male) or ≥ 36% (female)				
VFI<15 (male) or < 10 (female)	1.77 (1.08-2.89)	1.22 (0.67-2.22)	1.47 (1.13-1.92)**	1.09 (0.79-1.52)
VFI ≥ 15 (male) or ≥ 10 (female)	1.89 (1.15-3.09)**	1.42 (1.02-2.19)*	1.69 (1.32-2.18)***	1.49 (1.19-1.86)***
PBF<25% (male)or <36% female)				
WHtR<0.5	1	1	1	1
WHtR ≥ 0.5	1.27 (0.62-2.59)	1.20 (0.62-2.30)	1.69 (1.18-2.43)**	1.57 (1.10-2.26)*
PBF ≥ 25% (male)or ≥ 36% (female)				
WHtR<0.5	1.97 (1.11-3.49)*	1.46 (0.79-2.07)	1.87 (1.14-3.04)*	1.02 (0.35-2.92)
WHtR ≥ 0.5	2.65 (1.18-5.97)*	2.81 (1.38-3.92)*	2.08 (1.53-2.83)***	1.90 (1.34-2.69)***
VFI<15 (male) or <10 (female)				
WHtR<0.5	1	1	1	1
WHtR ≥ 0.5	1.20 (0.73-1.97)	1.13 (0.62-2.07)	1.54 (1.17-2.04)**	1.50 (1.06-2.11)*
VFI ≥ 15 (male) or ≥ 10 (female)				
WHtR<0.5	1.18 (0.79-3.65)	1.08 (0.77-2.56)	1.70 (0.21-13.98)	1.40 (0.66-3.15)
WHtR ≥ 0.5	1.42 (1.12-2.36)***	1.41 (1.10-2.52)***	1.84 (1.39-2.45)***	1.95 (1.40-2.72)***
Abbreviations: WHtR=Waist –to-height ratio; VFI=Visceral fat index; PBF=Percentage body fat; CI=Confidence interval; OR=Odds ratio. All models were adjusted for age, race, smoking, alcohol consumption, education status, family history, systolic blood pressure and diastolic blood pressure. ***P<0.001, **P<0.01, *P<0.05				

Table 5: Adjusted odds ratios (ORs) for MI and stroke associated with combined anthropometric indices.

Discussion

The present community-based cross-sectional study demonstrated that WHtR, VFI and PBF performed better than BMI and WC as obesity indices in discriminating MI and stroke. The optimal cut-off values of VFI were approximately 15 for males and 10 for females in evaluating CVD. The optimal cut-off values of PBF were approximately 25% for males and 36% for females in evaluating CVD, respectively. Notably, the combination of WHtR and bioelectrical indices (VFI and PBF), based on the optimal cut-off values, could much improve the predictive power and more sensitively identifies the risk of CVD in both sexes.

It was clear that obesity could increase the risk of CVD, hypertension, type-2 diabetes, and dyslipidemia [17]. The traditional anthropometric indicators including BMI, WC and WHtR have been widely used to investigate the obesity groups [18]. Combined with the measurements of PBF and VFI, we can clearly know more about the distribution of adipose tissue and accurately differentiate which obesity phenotypes could gain the risk of CVD [11,19].

The result revealed that PBF and VFI could increase the risk of CVD after adjusted the confounding factors both in males and females. The indicators including BMI, WC, WhtR had been widely used and the normal values had been universally accepted [15], while the normal value of PBF and VFI in different groups were still unknown [20]. Few studies had shown the association between PBF and VFI with the prevalence of CVD.As was shown in previous study, the age, alcohol consumption, SBP, DBP, BMI, WC, WHtR, and prevalence of CVD and hypertension were all increasing along with VFI quintiles [21].

The AUC of the five adiposity indices with MI and stroke stratified by age and gender were analyzed in present study. By comparison, PBF proved to perform better than the other obesity indices in discriminating MI and stroke in present study. Jiang J et al. [22] analyzed the association of PBF and VFI with hypertension and shown that VFI and PBF could be better candidates for identifying hypertension both in males and females. However, Xinyan Bi et al. [23] suggested that PBF does not outperform the simple anthropometric measurements of obesity in the prediction of CVD risk factors in healthy Asian adults based on a cross-section study in Singapore. In addition, we found that the obesity indices for MI in males and for stroke in females had better discriminating power in younger adults participating in this study. The difference between men and women may be due to confounding factors of age, lifestyle, estrogen and other effects [24]. While lower predictive power in females for MI may be confounded by the insufficient of sample size. These findings need to be verified and explored in more different populations.

Furthermore, we used the AUC for the relationship of VFI and PBF for CVD to acquire the optimal cut-off value to find out the accurately critical value to diagnose obesity. In order to identify which anthropometric indicators could be better to investigate the risk groups of CVD and whether age and sex influences the AUC of obesity indicators for CVD.

BMI has been known as the most commonly anthropometric indicators used to assessing obesity [25] and the diagnostic accuracy of BMI to diagnose obesity has limitation [26]. This study clearly demonstrated that, the AUC for the relationship of PBF and CVD was the highest in these obesity indicators. The cut-off values of VFI that were found to optimally predict the risk of MI and the stroke ranged from 10.50 to 16.50 and the optimal PBF cut-off values ranged from 22.25 to 26.95 in males. In women, the VFI cut-off values that were found to optimally predict the risk of MI and the stroke ranged from 9.45 to 14.50 and the optimal PBF cut-off values ranged from 33.45 to 40.25.

The present study used a very large sample covering 35~year age groups to estimate optimal cut-off values to predict CVD. The optimal cut-off values of VFI were approximately 15 for males and 10 for females in evaluating CVD. The optimal cut-off values of PBF were approximately 25% for males and 36% for females in evaluating CVD, respectively. World Health Organization defined obesity based on a PBF > 25% in men and PBF >35% in women which was almost the same to this present study [27,28].

WC has been recognized as the important indicator to make out abdominal obesity type [28]. Previous studies showed that the risk of CVD among participants increased with increasing WC [29]. However, the WC reflects the adipose tissue of abdominal wall and internal organs which could not distinguish the two kinds of adipose tissues and the adipose tissues located in different parts body have different biological characteristics and functions [30].

WhtR was found to have a stronger association with MI and stroke after adjusted the confounding factors. Previous studies have shown WHtR had a stronger association with risk factors of CVD and effective to assess overall or central obesity [31]. When we combined the obesity indices WHtR, PBF and VFI, the result clearly showed the combination of the three indices had a better predictive power for CVD. The present study supported that the individuals with higher WHtR, PBF and VFI values higher than the cut-off values could gain greater risk of CVD in both sexes. The visceral adipose secretes more pro-inflammatory adipokines [32]. In recent years, some studies have demonstrated that individuals with normal weight obesity" or "normal weight central obesity" have an increased risk of CVD, whose PBF or WC is high but with normal BMI level [2,33-35].

PBF is also an anthropometric indicator reflecting level of the totally body fat and could understand more intuitively the fat level of individuals [31]. Considering the level of PBF and VFI based on the optimal cut-off value in this study could effective for identifying individuals at higher risk of CVD.

The data of VFI and PBF collected by Omron body composition monitor. Correlations for visceral fat by BIA and MRI were better (r=0.92) in the previous study [36]. Some studies had shown bioelectrical impedance analysis (BIA), as compared to DXA, accurately assessed body fat both cross-sectionally and longitudinally [37]. Savastano et al. [38] also observed a good agreement between fat mass from conventional tetrapolar BIA and DXA. On the other hand, Thomson et al. [39] found an underestimation of fat mass (-3.8 kg) by leg to leg-BIA, but not by multi-frequency BIA, before weight loss when compared with DXA. Linares et al. [40] found that in a large population including 5740 subjects, the BIA significantly overestimated fat mass in comparison with DXA (1.1 kg). As men have more visceral fat relative to subcutaneous fat in the abdominal region than females, this may also introduce a sex-specific bias. Bioelectrical impedance as the major investigation has been used in various studies with reasonable accuracy [41,42]. The multi-frequency bioelectric impedance method verified as an improvement compared with traditional bioelectrical impedance method to assess visceral fat.

The strengths of the present study lie in its strict and scientific design and implement and well-trained researchers. The data were parallel inputted by two keyboarders in different computers. Almost 10% of all the participants were randomly selected to be interviewed by telephone in order to assess the veracity which could reduce the potential biases and measurements errors. The present study investigated the associations between obesity indices and MI and stroke in a large community population of China. We estimated the optimal cut-off values of PBF and VFI based on the large sample to predict directly.

Meanwhile, there are still some limitations in the present study need to be noted. This study was based on a large-population cross-sectional study which could not be used to establish temporal relationship and causality and the order of suffering from hypertension or diabetes or obesity or the same CVD were not known. The effect of therapies, diet and physical activity on the risk of CVD may have been underestimated or overestimated. In the stratified analysis, the population size in some group was small, which might reduce the statistical power. The measurement of visceral fat and body fat percent based on Omron body fat and weight measurement device may be overestimated compared with MRI and CT. The population included in the study is exclusively Chinese and the results need to be validated in other ethnic groups.

Conclusion

The present study demonstrated that high level of WhtR, PBF and VFI could increase the risk of developing CVD. The obesity indicators VFI and PBF could perform better than BMI and WC for discriminating MI and stroke. We managed to determine the optimal cut-off values of VFI and PBF based on Chinese population by gender, which could be used to better assess the relationship between the adiposity accumulation and the risk of CVD.

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