Preventive Medicine Reports 6 (2017) 191–196

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: http://ees.elsevier.com/pmedr

Association of body composition assessed by bioelectrical impedance analysis with metabolic risk factor clustering among middle-aged Chinese

Linfeng Zhang, Zengwu Wang *, Zuo Chen, Xin Wang, Manlu Zhu

Division of Prevention and Community Health, National Center for Cardiovascular Disease, Fuwai Hospital, Peking Union Medical College, Chinese Academy of Medical Science, Beijing, China

ARTICLE INFO

Article history:
Received 14 December 2016
Received in revised form 25 February 2017
Accepted 20 March 2017
Available online 23 March 2017

Keywords:
Obesity
Bioelectrical impedance analysis
Epidemiology

ABSTRACT

Body composition monitor (BCM) based on the bioelectric impedance analysis is very convenient to use. However, whether percentage body fat (PBF) and visceral fat index (VFI) that acquired by BCM are superior to anthropometric measures is unknown. The study explored whether PBF and VFI are better than anthropometric indexes [body mass index (BMI), waist circumference (WC) and waist circumference to height ratio(WHtR)] in predicating metabolic risk factor clustering in a representive sample across China which included 9574 Chinese men and women that were investigated in 2009–2010. PBF and VFI were compared with the BMI, WC, and WHtR through the area under the curve (AUC) of the receiver operating characteristic (ROC) curve and logistic regression. The results showed that the AUC for VFI was higher than BMI and PBF but lower than WHtR and WC in both men and Women. The AUC for WHtR, WC, VFI, BMI and PBF was 0.710, 0.706, 0.700, 0.693, 0.656 in men and 0.705, 0.699, 0.698, 0.675, 0.657 in women, respectively. After adjusting for the potential confounding factors, the odds ratios (ORs) tended to increase with all the indexes. The curve of ORs for WHtR was steepest and the curve for PBF was flattest in both men and women; the curve for VFI was similar to WC in women, but flatter than WC in men. From the data we concluded that VFI seems better than BMI and PBF, but not superior to WC and WHtR in predicating metabolic risk factor clustering in the middle-aged Chinese.

1. Introduction

Metabolic syndrome (MS) is a condition characterized by a special clustering of reversible major risk factors for cardiovascular disease and type 2 diabetes. Having metabolic syndrome significantly increases the risk of all-cause mortality and cardiovascular disease (Galassi et al., 2006). The main diagnostic components of MS are blood pressure, fasting plasma glucose, reduced HDL-cholesterol (HDL-C), and raised triglycerides (TG), all of which are related to weight gain (Vasan et al., 2001; Hayashi et al., 2004; Chang et al., 2016; Arai et al., 1994). Although detailed mechanisms remain unclear, numerous studies have emphasized the link between obesity and the increased risk of MS (Anderson et al., 2016; Bisschop et al., 2013). It is considered that visceral fat accumulation, rather than subcutaneous fat accumulation, contributes more to the development of MS (Demerath et al., 2008).

Visceral and total body fat can be assessed with different methods. Surrogate methods based on the anthropometric measures are the most widely used methods. Body mass index (BMI) and waist circumference (WC) are the most widely used surrogate indicators, waist to height ratio (WHtR) is another surrogate indicator that is considered to be superior to BMI and WC in predicting hypertension, diabetes, dyslipidemia and other CVD risk factors in recent studies (Ashwell et al., 2012; Cai et al., 2013). Bioelectric impedance analysis or dual-energy X-ray absorptiometry (DXA) are the widely used indirect measurement methods and computed tomography (CT) and magnetic resonance imaging (MRI) are the widely used direct measurement methods (Nagai et al., 2010; Müller et al., 2016; Fosbøl & Zerahn, 2015). Although the direct methods with CT and MRI are currently considered the most accurate methods for quantifying body fat on tissue level, they are costly, time-consuming or associated with a risk of radiation, and not suitable for use in the general population. The body composition monitor (BCM) which based on the bioelectric impedance method is very convenient to use by the individuals to estimate fat composition without radiation exposure and in <5 min. Percentage body fat (PBF) and visceral fat index (VFI) are the main parameters obtained with BCM (Nagai et al., 2010; Browning et al., 2010; Ryo et al., 2005; Bosy-Westphal et al., 2008). PBF is a measure of the overall obesity degree and VFI is an indicator for evaluating visceral adiposity. However, although there are some studies explored whether the indexes measured by BCM are better than the surrogate methods for identifying the metabolic risk factor clustering (Kang et al., 2015; Unno et al., 2012), the knowledge is very limited.

* Corresponding author at: Division of Prevention and Community Health, National Center for Cardiovascular Disease, Fuwai Hospital, Peking Union Medical College, Chinese Academy of Medical Science, 167 Beilishi Road, Xicheng District, Beijing 100037, China.

E-mail address: wangzengwu@foxmail.com (Z. Wang).

http://dx.doi.org/10.1016/j.pmedr.2017.03.011

Table 1
Characteristics of study subjects in 12 subpopulations across China in 2009–2010.

	Total (n = 9574)	Men (n = 4461)	Women (n = 5113)	P value
Age, years	49.8 ± 8.0[a]	49.8 ± 8.2	49.7 ± 7.9	0.625
Body height, cm	160.7 ± 8.2	166.3 ± 6.8	155.8 ± 5.9	<0.001
Body weight, kg	63.6 ± 11.4	67.7 ± 11.7	60.0 ± 9.9	<0.001
BMI, kg/m^2	24.6 ± 3.6	24.4 ± 3.5	24.7 ± 3.7	<0.001
WC, cm	82.4 ± 10.6	84.6 ± 10.6	80.5 ± 10.3	<0.001
PBF, %	29.3 ± 6.7	24.7 ± 5.5	33.3 ± 5.0	<0.001
VFI	9.2 ± 4.7	10.9 ± 4.8	7.7 ± 4.0	<0.001
WHtR	0.51 ± 0.06	0.51 ± 0.06	0.52 ± 0.07	<0.001
SBP, mm Hg	128.7 ± 20.0	129.8 ± 19.3	127.7 ± 20.6	<0.001
DBP, mm Hg	82.3 ± 11.4	83.9 ± 11.6	80.9 ± 11.0	<0.001
TC, mmol/L	4.86 ± 0.93	4.82 ± 0.93	4.89 ± 0.94	<0.001
HDL-C, mmol/L	1.37 ± 0.31	1.32 ± 0.30	1.42 ± 0.30	<0.001
LDL-C, mmol/L	2.79 ± 0.79	2.78 ± 0.79	2.80 ± 0.79	0.178
TG, mmol/L	1.27(0.90, 1.89)[b]	1.32(0.93, 2.02)	1.23(0.88, 1.80)	<0.001
Glu, mg/dL	5.75 ± 1.46	5.80 ± 1.52	5.70 ± 1.40	<0.001
Clustering of metabolic risk factors, n(%)	1500(15.7)	849(19.0)	651(12.7)	<0.001
Current smokers, n(%)	2864(29.9)	2554(57.3)	310(6.1)	<0.001
Current drinkers, n(%)	1808(18.9)	1626(36.4)	182(3.6)	<0.001
High school education or higher, n(%)	1937(20.2)	1038(23.3)	899(17.6)	<0.001
North regions, n (%)	5421(56.6)	2508(56.2)	2913(57.0)	0.459
Urban areas, n (%)	2993(31.3)	1408(31.6)	1585(31.0)	0.553
With relevant family history, n (%)	5502(57.5)	2487(55.7)	3015(59.0)	0.001

BMI, Body mass index; WC, Waist Circumference; PBF, Percentage Body fat; VFI, Visceral fat index; WHtR, Waist to Height Ratio; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; TC, Total cholesterol; HDL-C, HDL cholesterol; LDL-C, LDL cholesterol; TG, Triglyceride; Glu, Fasting blood glucose; CVD, cardiovascular disease.
[a] Means ± standard deviation.
[b] Median and interquartile range.

In this study we explored the relative effects of PBF and VFI to anthropometric obesity indexes BMI, WC and WHtR in predicating metabolic risk factor clustering in a middle aged Chinese population.

2. Methods

2.1. Study design and participants

A cross-sectional survey on cardiovascular (CVD) disease and related risk factors was conducted in 2009–2010 among the free-living individuals across China. The details of this survey have been described previously (Hao et al., 2015; Wang et al., 2015). The participants came from 12 subpopulations, which were selected in consideration of economic and social development and located in different parts of China (Hao et al., 2015). Each subpopulations consisted of about 1000 residents aged 35–64 years. Written informed consent was obtained from all participants and Institutional review board approval was obtained from the Fuwai Hospital and each participating center.

For this analysis, we excluded those participants with history of cardiovascular disease (angina pectoris, myocardial infarction, auricular fibrillation, rheumatic heart disease, cardiomyopathy, heart failure, stroke), chronic obstructive pulmonary disease, chronic liver and renal disease, cancer and those participants with missing data for the variables analyzed from analysis.

2.2. Data collection and measurements

The demographic, personal habits such as smoking and alcohol consumption, personal and family history of cardiovascular disease, and physical examination data were collected by the trained research staffs per the study protocol. Smoking status was classified into two categories: current smokers and non-smokers. Alcohol consumption was classified into two categories: current drinkers and non-drinkers. Family history was defined as one or more of the subjects' parents or siblings had the history of hypertension, dyslipidemia, diabetes, coronary heart disease or stroke. Height was measured in the standing position without shoes, using a standard stadiometer. Waist circumference was measured midway between the bottom edge of the last rib and iliac crest in the mid-axillary plane using a cloth tape directly touching the participant's skin. Blood pressure was measured three times with the participant in the sitting position using a mercury sphygmomanometer. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded corresponding to the appearance of the first and fifth Korotkoff phase sounds, respectively. The average of the three measurements was used for analysis. Body weight, PBF and VFI were obtained using Omron body fat and weight measurement device (V-body HBF-359; Omron, Kyoto, Japan), which uses eight electrodes in a tetrapolar arrangement that requires the subject standing on metal footpads in bare feet and grasping a pair of electrodes fixed on a handle with arms extended in front of the chest. Subjects were measured barefoot with light clothing following manufacturer's instructions. BMI was calculated using the formula weight/height^2 (kg/m^2).

All blood samples were obtained in the morning after at least 8-h overnight fast, and biochemical assays were performed at a central laboratory. The serum glucose was determined using enzymatic method. The serum total cholesterol, high-density lipoprotein cholesterol, and triglyceride were determined using enzymatic methods with an autoanalyzer (Japan).

Subjects with two or more of the four risk factors (hypertension, diabetes mellitus, high TG and low HDL-C) were defined as having metabolic risk factors clustering. Hypertension was defined as SBP of at least 140 mm Hg and/or DBP of at least 90 mm Hg, and/or taking antihypertensive drugs within the latest two weeks; Diabetes mellitus was defined as a fasting glucose level of at least 7.0 mmol/l or self-reported current treatment with antidiabetic medication (insulin or oral hypoglycemic agents); high TG was defined as serum triglyceride ≥2.3 mmol/l and low HDL-C was defined as HDL cholesterol <1.0 mmol/l (Joint committee for China guideline for prevention and treatment of adult dyslipidemia amendment, 2016).

2.3. Statistical analyses

Normally distributed continuous variables were presented as mean ± standard deviation and compared with t-test; non-normally distributed continuous variables were presented as median and interquartile range and compared with Wilcoxon Test. Data for categorical variables

Table 2
Pearson correlation coefficients between the obesity indexes.

	Men					Women				
	PBF	BMI	VFI	WC	WHtR	PBF	BMI	VFI	WC	WHtR
PBF	1	0.642*	0.698*	0.671*	0.670*	1	0.668*	0.736*	0.633*	0.650*
BMI		1	0.886*	0.812*	0.817*		1	0.855*	0.758*	0.776*
VFI			1	0.809*	0.824*			1	0.782*	0.806*
WC				1	0.944*				1	0.956*

PBF, percentage body fat; BMI, body mass index; VFI, visceral fat index; WC, waist circumference; WHtR, waist to height ratio.
* $p < 0.001$.

Table 3
Results for different obesity indexes in the diagnosis of metabolic risk factor clustering and each individual component in 12 subpopulations across China in 2009–2010.

	AUC(95%CI)[a]				
	Hypertension	Diabetes	High TG	Low HDL-C	Metabolic risk factor clustering
Men					
PBF	0.624(0.608–0.640)**	0.641(0.615–0.667)	0.634(0.615–0.654)**	0.561(0.536–0.586)	0.655(0.637–0.674)**
BMI	0.636(0.619–0.652)**	0.636(0.609–0.663)**	0.673(0.654–0.693)	0.619(0.595–0.644)**	0.691(0.672–0.710)**
VFI	0.655(0.639–0.671)	0.642(0.615–0.669)*	0.670(0.651–0.689)*	0.616(0.591–0.640)	0.700(0.682–0.719)
WC	0.648(0.632–0.664)*	0.658(0.632–0.684)	0.680(0.662–0.699)	0.620(0.596–0.644)	0.707(0.689–0.725)
WHtR	0.655(0.639–0.671)	0.660(0.635–0.686)	0.682(0.664–0.700)	0.612(0.588–0.636)	0.710(0.692–0.728)
Women					
PBF	0.648(0.632–0.663)**	0.643(0.614–0.673)**	0.645(0.624–0.666)*	0.519(0.485–0.554)**	0.661(0.639–0.683)**
BMI	0.648(0.632–0.664)**	0.628(0.600–0.656)**	0.644(0.624–0.665)*	0.593(0.559–0.626)	0.673(0.652–0.694)**
VFI	0.678(0.663–0.693)	0.659(0.632–0.686)**	0.663(0.643–0.682)	0.574(0.541–0.607)**	0.697(0.677–0.717)
WC	0.668(0.653–0.683)	0.688(0.663–0.714)	0.658(0.638–0.678)	0.610(0.578–0.642)	0.701(0.681–0.721)
WHtR	0.671(0.656–0.686)	0.689(0.664–0.715)	0.665(0.645–0.684)	0.604(0.571–0.636)	0.707(0.687–0.726)

[a] AUC, area under the curve; CI, confidence interval. PBF, percentage body fat; BMI, body mass index; VFI, visceral fat index; WC, waist circumference; WHtR, waist to height ratio. Symbols denote significant differences in AUC compared the WHtR(*$P < 0.05$,**$P < 0.01$).

were presented as count and proportions and compared with x^2 test. Pearson's correlation coefficient was calculated for relationships between variables.

A receiver operating characteristic (ROC) curve analysis was used to assess the accuracy of the predictions for metabolic risk factor clustering. The accuracy was measured using the area under the ROC curve (AUC) with the 95% confidence interval (CI).

To explore the association between obesity indexes and the risk of having metabolic risk factor clustering the subjects were divided into quintiles(Q1 to Q5) according to each obesity indexes and the prevalence and odds ratio(OR) of metabolic risk factor clustering were calculated for each quintiles, the trend test for the prevalence was performed with Cochran-Armitage trend test and the ORs were calculated using a multivariate logistic regression analysis adjusted for age, smoking, alcohol consumption, education status, regions, areas and family history, with Q1 as the reference.

All the analyses were carried out using SAS version 9.2 (SAS institute, Cary, NC, USA). All p values were 2 sided and values <0.05 were considered significant.

3. Results

3.1. Characteristics and anthropometric indexes of the subjects analyzed

Table 1 summarized the characteristics and anthropometric indexes of the subjects analyzed. Of the 14,046 individuals invited, 11,623 participated in the survey and the data of 9574 participants were analyzed. Of the 9574 participants, 4461 were men and 5113 were women. The mean age was 49.8 ± 8.0 years. Men had a higher mean body height, body weight, WC, VFI, SBP, DBP, TG, Glu, and a lower mean of BMI, PBF, WHtR, TC, HDL-C. The proportion of subjects with smoking, alcohol consumption, education status above high school, and metabolic risk factors clustering was higher in men than in women. The proportion of subjects with relevant family history was lower in men than in women.

3.2. Correlation coefficients between different obesity indexes

All indexes correlated with each other significantly (r values between 0.633 and 0.956, $p < 0.001$). WHtR were highly related to WC in both men and women ($r = 0.944$ for men, $r = 0.956$ for women). The correlation coefficient between VFI and WHtR was smaller than that between WC and WHtR but larger than that between BMI and WHtR in both men and women. The correlation coefficients between PBF and other indexes were smaller than all other correlation coefficients in both men and women (Table 2).

3.3. Accuracy of the indexes for predicting metabolic risk factor clustering and each individual component

All indexes were positively correlated to metabolic risk factor clustering and the individual components (Table 3). In both men and

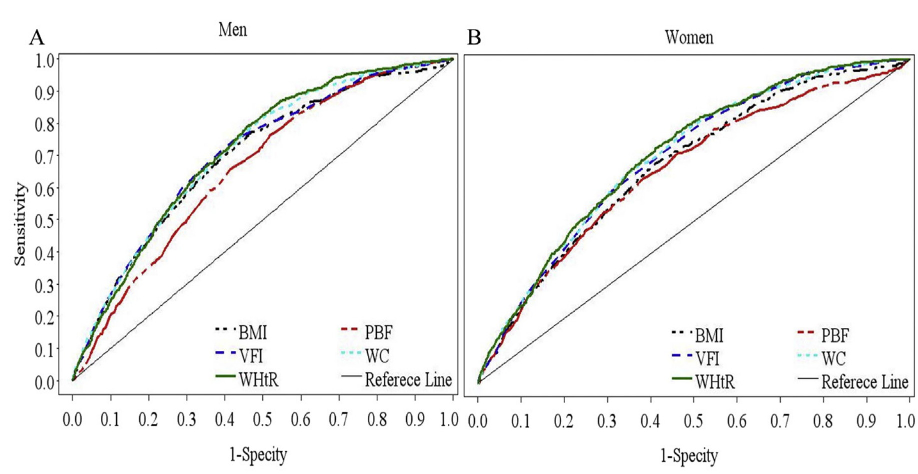

Fig. 1. Receive operating characteritic curves for metabolic risk factor clustering in men and women in 12 subpopulations across China in 2009–2010. Compared are the relative abilities of body mass index (BMI), percentage body fat (PBF), viceral fat index (VFI), waist circumference (WC), and waist –to-height ratio (WHtR) to correctly identify the subjects with metabolic risk factor clustering.

Table 4
Prevalence of metabolic risk factors clustering for the quintiles of the obesity indexes by sex in 12 subpopulations across China in 2009–2010.

	Quintile I	Quintile II	Quintile III	Quintile IV	Quintile V	*P* for trend
Men						
PBF	5.8(51/882)	13.8(124/896)	19.5(172/882)	25.3(228/902)	30.5(274/899)	<0.001
BMI	5.9(53/892)	11.2(100/892)	17.6(157/892)	24.3(217/892)	36.1(322/893)	<0.001
VFI	5.1(44/869)	13.1(91/694)	13.5(141/1043)	25.9(226/874)	35.4(347/981)	<0.001
WC	4.6(39/855)	10.1(94/929)	18.5(147/794)	25.1(248/990)	35.9(321/893)	<0.001
WHtR	3.9(35/891)	9.3(83/893)	19.8(178/897)	27.5(244/887)	34.6(309/893)	<0.001
Women						
PBF	5.7(58/1014)	7.3(75/1026)	11.6(118/1018)	16.2(167/1029)	22.7(233/1026)	<0.001
BMI	3.6(37/1022)	9.5(97/1024)	11.1(113/1021)	16.3(167/1024)	23.2(237/1022)	<0.001
VFI	2.6(14/545)	5.3(57/1071)	10.6(129/1212)	16.5(207/1256)	23.7(244/1029)	<0.001
WC	2.9(28/956)	6.9(75/1086)	11.6(118/1020)	16.6(171/1028)	25.3(259/1023)	<0.001
WHtR	2.5(26/1022)	7.2(74/1024)	11.4(113/995)	17.1(179/1049)	25.3(259/1023)	<0.001

Data are presented as percentages (count/total in each cell). PBF, percentage body fat; BMI, body mass index; VFI, visceral fat index; WC, waist circumference; WHtR, waist to height ratio.

women although WHtR had the highest AUC value for predicting metabolic risk factor clustering (0.710, 95% CI = 0.692–0.728 and 0.707, 95% CI = 0.687–0.726, respectively), the differences between WHtR and WC, WHtR and VFI were of no statistical significance. The AUC values of PBF and BMI for predicting metabolic risk factor clustering were lower than other indexes. The ROC curves for metabolic risk factor clustering were shown in Fig. 1.

3.4. Prevalence and risk of the metabolic risk factors clustering for the quintiles of the obesity indexes

For all indexes, the prevalence increased significantly with the quintiles of each obesity indexes in both men and women (Table 4). Table 5 and Fig. 2 showed the risk of metabolic risk factor clustering for the quintiles in men and women. In the multivariate model (including age, smoking, alcohol consumption, education status, regions, areas and family history) the odds ratios (ORs) tended to increase with the values of these indexes. Fig. 2 showed that, the curve for WHtR was steeper than those for other indexes and the curve for PBF and BMI were flatter than those for other indexes in both men and women; the curve for VFI was flatter than WC in men, but similar to WC in women. The prevalences of the potential confounders and each component of the metabolic risk factors clustering for the quintiles of each indexes in both men and women were shown in the supplement tables (Table A 1.1–2.4).

4. Discussion

In this study we assessed the predictive value of PBF and VFI measured with the BCM and compared them with the anthropometric indexes BMI, WC and WHtR in the middle-aged Chinese. Our study showed that WHtR was the strongest indexes in both men and women, PBF and BMI were the weakest indexes, VFI was weaker than WC in men but similar to WC in women in predicating the risk of the metabolic risk factor clustering.

It is believed that visceral fat is more metabolically active, and thus will increase the risk of insulin resistance (Fox et al., 2007; Kanaya et al., 2004; Sadashiv et al., 2012), So visceral fat accumulation rather than total body fat, contributes more to the development of MS (Matsushita et al., 2010; He et al., 2015). BMI and WC are the most widely used indexes to assess obesity, a large quantity of studies have associated BMI and WC with cardiovascular diseases (Huang et al., 2016). BMI is used as an index of the total body fat and WC is often used as a parameter for indirect evaluation of visceral fat. In recent studies WHtR has been proposed as a better screening tool than WC and BMI for adult cardiometabolic risk factors (Ashwell et al., 2012; Cai et al., 2013) as this ratio corrects the WC for the height of the individual. PBF and VFI are the two indexes measured with BCM, PBF represents the total body fat and VFI reflects visceral fat. Our study showed that WHtR, WC, and VFI had a stronger association with the metabolic risk factor clustering than BMI and PBF, which adds evidence to support the opinion that visceral fat contribute more to the development of MS.

The obesity has been widely studied and there are many methods to determine the body composition, but controversy remains with regard to the best index for making the diagnosis of obesity and MS. VFI is an estimation of visceral fat area (VFA) with multifrequency BIA method and has a strong correlation with the CT and MRI measured VFA (Bosy-Westphal et al., 2008; Nagai et al., 2010). An OMRON monitor similar to that used in this study, was shown to have excellent correlation with body magnetic resonance imaging (MRI) and dual X-ray absorptiometry (DEXA) for estimating visceral fat ($r = 0.92$) (Bosy-Westphal et al., 2008). Some studies have shown that VFA measured with BIA have been correlated to hypertension and other cardiovascular diseases (Amato et al., 2014). We have reported previously that VFI was

Table 5
Adjusted odds ratio of clustering of metabolic risk factors for the quintiles of the obesity indexes by sex in 12 subpopulations across China in 2009–2010.

	Quintile I	Quintile II	Quintile III	Quintile IV	Quintile V	*P* for trend
Men						
PBF	1.0	2.4(1.7–3.4)	3.5(2.5–4.9)	4.9(3.5–6.8)	6.3(4.5–8.8)	<0.001
BMI	1.0	1.9(1.3–2.7)	3.1(2.2–4.3)	4.5(3.2–6.2)	7.9(5.8–10.9)	<0.001
VFI	1.0	2.6(1.8–3.8)	2.7(1.9–3.8)	5.7(4.1–8.1)	8.8(6.3–12.4)	<0.001
WC	1.0	2.3(1.5–3.3)	4.5(3.1–6.5)	6.6(4.6–9.4)	11.0(7.7–15.8)	<0.001
WHtR	1.0	2.4(1.6–3.6)	5.7(3.9–8.3)	8.6(5.9–12.5)	11.8(8.1–17.1)	<0.001
Women						
PBF	1.0	1.1(0.8–1.6)	1.7(1.2–2.4)	2.2(1.6–3.1)	2.9(2.1–4.0)	<0.001
BMI	1.0	2.7(1.8–4.0)	2.8(1.9–4.2)	4.6(3.2–6.7)	6.2(4.3–9.0)	<0.001
VFI	1.0	1.9(1.0–3.4)	3.6(2.0–6.3)	5.3(3.0–9.3)	7.2(4.1–12.6)	<0.001
WC	1.0	2.2(1.4–3.4)	3.5(2.3–5.3)	5.0(3.3–7.6)	7.7(5.1–11.6)	<0.001
WHtR	1.0	2.6(1.6–4.1)	3.8(2.4–5.9)	5.8(3.8–8.9)	8.6(5.6–13.1)	<0.001

Data are presented as odd ratio (95% confidence interval). All models were adjusted for age, smoking, drinking, educational status, regions, areas, and family history, in addition to the independent variables listed for respective models. PBF, percentage body fat; BMI, body mass index; VFI, visceral fat index; WC, waist circumference; WHtR, waist to height ratio.

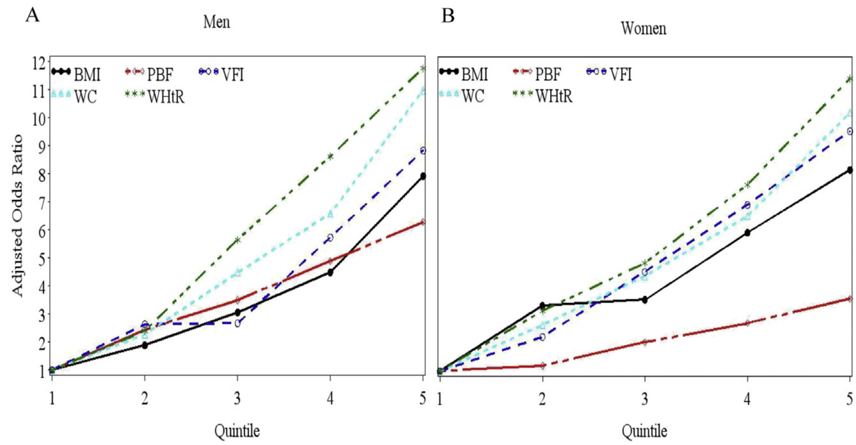

Fig. 2. ORs for the metabolic risk factors clustering according to the quintiles (Q1–Q5) of different obesity indexes in 12 subpopulations across China in 2009–2010. BMI: body mass index, PBF: percentage body fat, VFI: viceral fat index, WC: waist circumference, WHtR: waist-to-height ratio. The ORs were estimated with Q1 as the reference category by the logistic regression models adjusted for age, smoking, alcohol consumption, education status, regions, areas and family history.

strongly associated with higher risk of hypertension (Hao et al., 2015). In this study, the data showed that VFI had stronger association with metabolic risk factor clustering and its each individual component. However, the association of VFI with metabolic risk factor clustering and its components except hypertension was slightly weaker than WHtR in both genders and weaker than WC in men. Although the slopes for the curves in Fig. 2 were not compared with statistical analysis, we can deduce that VFI obtained with BCM is not superior to the WHtR and WC in predicting metabolic risk factor clustering.

To our knowledge, this is the first large scale study to compare association of the PBF and VFI with clustering of the metabolic risk factors to the traditional used surrogate indexes in China. Our study had several strengths, including a standardized protocol, its large sample size, and the adjustment for known and potential confounders. A constant hydration of lean mass is an underlying assumption of the bioelectric impedance body composition analysis, this assumption is violated under some clinical conditions, so in this study we excluded those with known chronic disease from the analysis. Of course, there are some limitations of our study. First, The study design is cross-sectional and can not establish the causality between the anthropometric indexes and the metabolic risk factor clustering. Second, the visceral body fat in this study was measured through a commercially available BIA instrument specifically designed for body composition analysis and some studies have shown that validity of BIA method is highly dependent on selecting a regression equation suitable for the subject category in question (Fosbøl & Zerahn, 2015). Although an OMRON monitor similar to that used in this study has been proven to have excellent validity (Bosy-Westphal et al., 2008). That data is from a Caucasian population, the validity of the OMRON monitor in the Chinese population should be proved to explain the results. Third, there is no universal definition of metabolic risk factor clustering. The definition of metabolic risk factor clustering in this study was based on the serum lipids criteria of the Chinese population, which may be more suitable for Chinese population but may limit the generalization of the study results. We tried to use the cut-off points recommended by the National Cholesterol Education Program's Adult Treatment Panel III guideline in 2005 (Grundy et al., 2005), the results were similar (See supplement Table A.3).

5. Conclusion

In conclusion, our data indicate that VFI seems better than BMI and PBF, but not superior to WC and WHtR in predicting the metabolic risk factor clustering in the middle-aged Chinese.

Funding

This work was supported by the National health and Family Planning Commission of the Peoples' Republic of China (200902001, 201402002). The authors have also received support from Omron Corporation, Kyoto, Japan, for body fat and weight measurement (V-body HBF-359); Changsha Aican Electronic Co., Ltd., China, for collecting digital information of ECG (AIKD-B12 V3.0); and HealthSTATS, Singapore, for central BP measurement (Bpro device with A-Pulse CASP software).

Disclosure

The authors declared no conflict of interest.

Author contributions

Zengwu Wang, Linfeng Zhang, Zuo Chen, Xin Wang and Manlu Zhu designed the study. Linfeng Zhang analyzed the data and drafted the manuscript. All authors contributed to discussion of manuscript.

Acknowledgments

The authors acknowledge the contributions of the principal investigators and subcenters. The principal investigators and subcenters are as follows: Cardiovascular Institute and Fu Wai Hospital: Zengwu Wang, Linfeng Zhang, Zuo Chen, Xin Wang, Min Guo, Lan Shao, Manlu Zhu, Wen Wang and Weiwei Chen; Deyang institute of Hygiene, Sichuan: Guogang Zhang, Anbing Wang, and Xiaoyang Liao; Guangdong Provincial Hospital: Xiaoqing Liu, Jinzhuang Mai, Jiyan Chen, and Meiling Shi; Hanzhong Hospital, Shaanxi: Ruihai Yang and Jun Yang; Jintan Institute of Hygiene, Jiangsu: Jiantao Guo, Xin Zhou, and Xiaoping Yang; Yuxian Hospital, Shanxi: Dongshuang Guo and Shengying Liang; Zhoushan Cardiovascular Institute, Zhejiang: Liansheng Ruan and Chengguo Liu; First Affiliated Hospital of Harbin Medical University, Heilongjiang: Weimin Li, Yujuan Zhao, and Lihang Dong; Beijing Chaoyang District Center for Disease Control and Prevention, Beijing: Xiaoyan Han; Yunnan Center for Disease Control and Prevention, Yunan: Yize Xiao; Baotou Medical College, Inner Mongolia Autonomous Region: Ying Wang and Chengyi Li; Tibet Autonomous Region Center for Disease Control and Prevention, Tibet: Hui Xiong, Cangjue Gama, Ruodeng Xirao, and Guoxia Bai; and Yining Center for Disease Control and Prevention, Xinjiang Uygur Autonomous Region: Dongsheng Wang.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.pmedr.2017.03.011.

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