Iran J Public Health, Vol. 51, No.4, Apr 2022, pp.851-859

Original Article

Body Composition Assessment by Bioelectrical Impedance Analysis in Prediction of Cardio-Metabolic Risk Factors: Tehran Lipid and Glucose Study (TLGS)

Minoo Heidari Almasi [1], Maryam Barzin [1], Sara Serahati [3], Majid Valizadeh [1], Amirabbas Momenan [4], Feridoun Azizi [2], *Farhad Hosseinpanah [1]

1. *Obesity Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
2. *Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Science, Tehran, Iran*
3. *Department of Public Health, University of Saskatchewan, Saskatoon, SK, Canada*
4. *Prevention of Metabolic Disorders Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran*

***Corresponding Author:** Email: fhospanah@endocrine.ac.ir

(Received 09 Jan 2021; accepted 19 Mar 2021)

Abstract

Background: We aimed at evaluating the best body mass index (BMI) and percent body fat (PBF) cutoffs related to cardio-metabolic risk factors and comparing the discriminative power of PBF and BMI for predicting these risk factors.

Methods: In this cross-sectional study in phase V (2012-2015), 1271 participants (age ≥ 20 yr; 54.3% women) were enrolled. Bioelectrical impedance analysis (BIA) was used to estimate PBF. Joint Interim Statement criteria were used for defining metabolic syndrome (MetS). We compared PBF with BMI through logistic regression and area under the curve of the receiver operating characteristic (ROC) curve. Percent body fat cutoff points were > 25 in men and >35 in women.

Results: Percent body fat and BMI cutoff points for predicting MetS were 25.6% and 27.2 kg/m² in men and 36.2% and 27.5 kg/m² in women, respectively. There were no significant differences between BMI and PBF area under the ROC curves for predicting MetS and its components, except for abdominal obesity in men and low high-density lipoprotein (HDL) in women in favor of BMI. Logistic regression analysis indicated that BMI in women was better for predicting MetS and its components, except for abdominal obesity. Moreover, BMI was equal or superior to PBF in men, except for low HDL and high triglyceride levels.

Conclusion: Comparison of PBF with BMI showed that the use of PBF is not significantly better than BMI in predicting cardio-metabolic risks in the general population.

Keywords: Body composition; Bioelectrical impedance analysis (BIA); Cardio-metabolic risk factor

Introduction

The universal prevalence of obesity has become a serious threat to public health as it is related to different complications, such as type 2 diabetes mellitus, metabolic syndrome (MetS), cardiovascular diseases, and several types of cancer (1).

Obesity is usually measured via body mass index (BMI), which is not able to discriminate between lean mass and body fat content. To overcome the misclassifications caused by BMI cutoff values, direct measurement of percent body fat (PBF) would be preferable for detecting obesity (2).

Although indirect methods such as dual-energy X-ray absorptiometry (DEXA) provide exact body composition data, they are inaccessible and unsafe for repeated measurements and need technical expertise. Direct methods such as MRI and CT scans are expensive and not suitable for epidemiologic and routine purposes. In contrast, bioelectrical impedance analysis (BIA) is a comparatively easy, non-invasive, and rapid method that provides accurate evaluation of body composition (3).

Despite the large number of studies performed in this area, the most appropriate PBF cutoffs reflecting cardio-metabolic disorders are not clear yet (4, 5). The first objective of this research was to determine the optimal BMI and PBF cutoffs related to cardio-metabolic abnormalities and investigate the discriminative power of PBF in comparison with BMI for predicting cardio-metabolic risk factors among the adult population in Tehran.

Materials and Methods

Data collection

The Tehran Lipid and Glucose Study (TLGS) is an incidence survey of non-communicable diseases and the related risk factors with prospective follow-up evaluation intervals of nearly three years. Additional data regarding the rationale, data collection, and sampling of the TLGS has been already published (6). In this cross-sectional study in phase V (2012-2015), we selected 1271 individuals with BMI ≥ 18.5 via simple random sampling from a total 10733 participants aged ≥ 20, and excluded those who were pregnant, had a severe chronic disease such as heart failure, cirrhosis or chronic kidney disease, drug history of using diuretics or corticosteroids, and history of limb amputation, kyphoscoliosis, and intracardiac defibrillator or using pacemakers.

The institutional ethics committee of the Research Institute for Endocrine Sciences affiliated to Shahid Beheshti University of Medical Sciences (IR.SBMU.MSP.REC.1397.628) approved the research. All the tenets of Declaration of Helsinki were followed while performing this study. The participants signed a written informed consent.

Measurements

An interviewer collected the data, including demographic information and drug and medical history. All the anthropometric measurements were performed based on the standard protocol. The participant's weight was evaluated with minimal clothing and no shoes using digital scales (to the nearest 100 g). The participants' height was assessed while standing with no shoes using a tape measure when the shoulders were in a normal position. Body mass index was measured as weight divided by the square of height (kg/m^2). The patients were categorized with respect to the international cutoff points for BMI as normal (BMI < 25), overweight (25 ≤ BMI < 30), and obese (BMI ≥ 30). Waist circumference (WC) was evaluated at the umbilicus level using a tape meter with no pressure toward the body surface (to the nearest 0.1 cm). Body composition was evaluated using a transferable bioelectrical impedance analyzer (Model: GAIA 359 Plus, Co. Cosmed, Italy). Excess PBF was expressed as PBF >25 in men and PBF >35 in women (7).

Following wiping the case's palm and sole using an electrolyte tissue, the participants stood with their soles touching the foot electrodes and their hands grabbing the hand-held paddles electrodes. Other information such as sex, height, weight, and age were also recorded. The bioelectrical impedance analysis with eight electrodes assessed different segmental impedances (i.e., trunk, right and left arms, and right and left legs) at the frequencies of 5, 50, and 250 kHz from tetra-polar electrodes. Participants removed their shoes and socks changing to light clothing. The resistance against the alternating current (500- μA, 50/60 kHz) was assessed while standing on the analyz-

er's platform. The resulted data were interpreted by the "standard" option while standing with no motion and arms at the sides. Lean body mass (LBM, kg) and PBF were calculated by BIA via standard equations (8). The evaluations were done by one of the researchers. Systolic and diastolic blood pressure (SBP and DBP) were measured based on the standard protocol (9).

Following overnight fasting, blood sampling was performed, and the tests were conducted at the TLGS laboratory on the day on which blood sampling was done. We measured fasting plasma glucose (FPG), total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) (10). Details of all the measurement methods are available elsewhere (9).

Definitions

Through the Joint Interim Statement (JIS) criteria, we defined the metabolic health components as follows: 1) FPG ≥100 mg/dl or drug therapy, 2) TG ≥ 150 mg/dl/ drug therapy, 3) HDL<50 mg/dl in females and <40 mg/dl in males/drug therapy, 4) SBP ≥130 mmHg, DBP ≥85 mmHg/using antihypertensives, and 5) abdominal obesity (WC cutoff points ≥89 cm in males and ≥91 cm in females) (6). Those with three or more JIS components were categorized as metabolically unhealthy (presence of MetS) (10).

Statistical analysis

Values are presented as mean ±SD, and categorical variables are reported as number (%). Mean values and the corresponding standard deviations of the continuous variables were considered based on normal distribution. The inter-quintile for median was reported due to the highly positive skewed distribution of TG. Mann-Whitney and Kruskal-Wallis tests were run for TG as a non-normal variable. Mean comparisons of the normally distributed covariates were conducted using *t*-test and ANOVA. Chi-square test was performed for testing the univariate baseline statistical association of the categorical variables. We performed the trend test for prevalence with ANOVA for continuous and Cochran-Armitage test for categorical variables. The correlations between PBF and BMI were analyzed using Pearson's correlation test; regression analysis was used for age-adjusted correlations. Kappa was used to detect the agreements between BMI and PBF. We used AUC for comparing the predictive capacity of adiposity measurements for metabolic risk factors. The DeLong technique was applied for testing the significance of the difference between the areas under the ROC curves. We used a backward, stepwise binary logistic regression model adjusted for smoking status, height, and age for detecting the relationship between each cardio-metabolic risk (set as a dependent variable) and PBF and BMI (set as the independent variables). A *P*-value of less than 0.05 was regarded as statistically significant. Data analysis was performed by SPSS version 26 (IBM Corp., Armonk, NY, USA) and R-3.6.3 statistical software program.

Results

Table 1 presents the participant's baseline data. Their mean age was 43.2 ± 13.7 yr, and 54.3% of the participants were women. A significant difference was found in the mean PBF between men and women ($P<0.001$). Men were found with a higher prevalence of MetS and most of its components such as high TG, low HDL, impaired fasting glucose (IFG), and abdominal obesity compared with women ($P<0.05$).

The results of the age-adjusted correlation analysis indicated that BMI had a higher correlation with PBF in women (r=0.892, $P<0.001$) than in men (r =0.736, $P<0.001$). According to the ROC curves for BMI, to detect excess PBF (>25 in males and >35 in females), AUC was 0.87 in men and 0.96 in women. The best BMI cutoff points to identify PBF was 26.4 in men (83% sensitivity and 77% specificity) and 27.3 in women (90% sensitivity and specificity) (Fig. 1).

Table 1: Baseline characteristics of participants by sex groups

Variable	*Total (n=1271)*	*Men (n=580)*	*Women (n=691)*	*P-value*
Age, year	43.2 ± 13.7	43.4 ± 14.9	43.1 ±12.7	0.658
BMI, kg/m²	27.7 ± 4.8	27.3 ± 4.5	28.4 ± 5.1	<0.001
BMI groups				
Normal weight (BMI < 25)	351 (27.7)	173 (29.9)	178 (25.9)	<0.001
Overweight (25 ≤ BMI < 30)	542 (42.8)	278 (48.1)	264 (38.4)	
Obese (BMI ≥ 30)	373 (29.5)	127 (22.0)	246 (35.8)	
LBM, Kg	51.7 ± 10.6	60.4± 8.7	44.5 ±5.4	<0.001
PBF%	30.7 ± 7.5	25.1 ± 5.4	35.6 ± 5.5	<0.001
PBF ≤ 25% or 35%	572 (45.0)	268 (46.2)	304 (44.0)	0.430
PBF > 25% or 35%	699 (55.0)	312 (53.8)	387 (56.0)	
WC, cm	95.90 ± 10.59	91.07 ± 12.36	93.2 ± 11.8	<0.001
Abdominal obesity, n (%)	796 (62.8)	444 (76.9)	352 (51.0)	<0.001
SBP, mmHg	115.1 ± 17.2	118.1 ± 15.4	112.7 ± 18.3	<0.001
DBP, mmHg	77.1 ± 10.3	79.31 ± 9.8	75.3 ± 10.4	<0.001
HTN, n (%)	290 (22.8)	139 (24)	151 (21.9)	0.362
Cholesterol, mg/dL	187.6 ± 38.2	188.3 ± 38.0	187.0 ± 38.5	0.534
High cholesterol, n (%)	427 (33.6)	201 (34.7)	226 (32.7)	0.450
HDL, mg/dL	48.3 ± 12.2	43.2 ± 9.71	52.7 ± 12.4	<0.001
Low HDL, n (%)	590 (46.8)	251 (43.6)	339 (49.4)	0.038
TG, mg/dL	126 (88- 182)	149 (104- 209)	109 (78- 161)	<0.001
High TG, n (%)	544 (43.1)	304 (52.7)	240 (35.0)	<0.001
FPG, mg/dL	100.2 ± 27.8	102.4 ± 28.5	98.5 ± 27.2	0.038
IFG, n (%)	400 (31.5)	204 (35.2)	196 (28.4)	0.010
Diabetes, n (%)	11.7	60 (11.0)	78 (12.3)	0.490
Family history of Diabetes, n (%)	118 (9.3)	41 (7.1)	77 (11.2)	0.013
MetS, n (%)	349 (39)	277 (48.2)	216 (31.3)	<0.001
Smoker, n (%)	172 (13.5)	153 (26.4)	19 (2.7)	<0.001
High education, n (%)	430 (34.4)	216 (37.6)	214 (31.7)	0.028

BMI, body mass index; LBM, lean body mass; PBF, percent body fat; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; IFG, impaired fasting glucose; FPG, fasting plasma glucose; HDL, high density lipoprotein; MetS, metabolic syndrome; High education, higher than 12 class

Continuous data are shown as mean ± SD and compared using two-sample t-tests. Categorical data are shown as number (%) and compared using the Chi-square test.

Abdominal obesity, WC cut off points as ≥ 89 cm for men and ≥ 91cm for women; high cholesterol, cholesterol ≥ 200 (mg/dl); HTN, SBP ≥ 130 or DBP ≥ 85 (mmhg) or drug treatment; Diabetes, FBS ≥ 126 or BS2hr ≥ 200 (mg/dl) or drug treatment; IFG, FBS ≥ 100 (mg/dl); low HDL, Male, HDL < 40 or drug treatment Female, HDL < 50 (mg/dl) or drug; High TG, TG ≥ 150 (mg/dl) or drug treatment

Body mass index and PBF agreements were calculated separately in both sexes; we applied sex-specific cutoffs to create PBF and BMI categories (PBF cutoffs 25% in men and 35% in women, BMI cutoff 30). Kappa values were 0.288 in men and 0.571 in women.

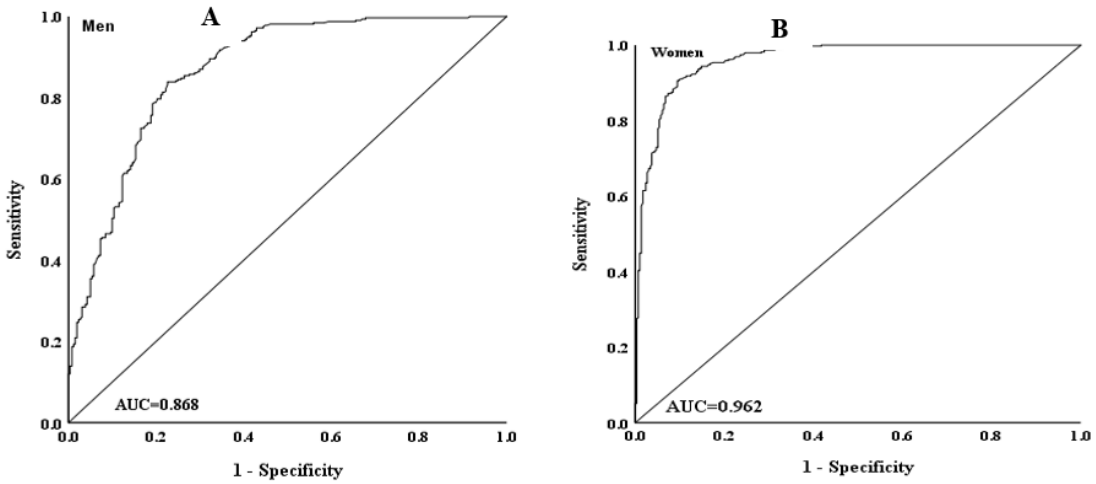

Fig.1: ROC curves for BMI to detect an excess PBF in men (A) and women (B)

Metabolic characteristics of the participants are stratified by sex across PBF tertiles (Fig. 2). MetS and all of its components were significantly higher in subjects in the third PBF tertile in both sexes (*P*-value for trend for all comparisons <0.05).

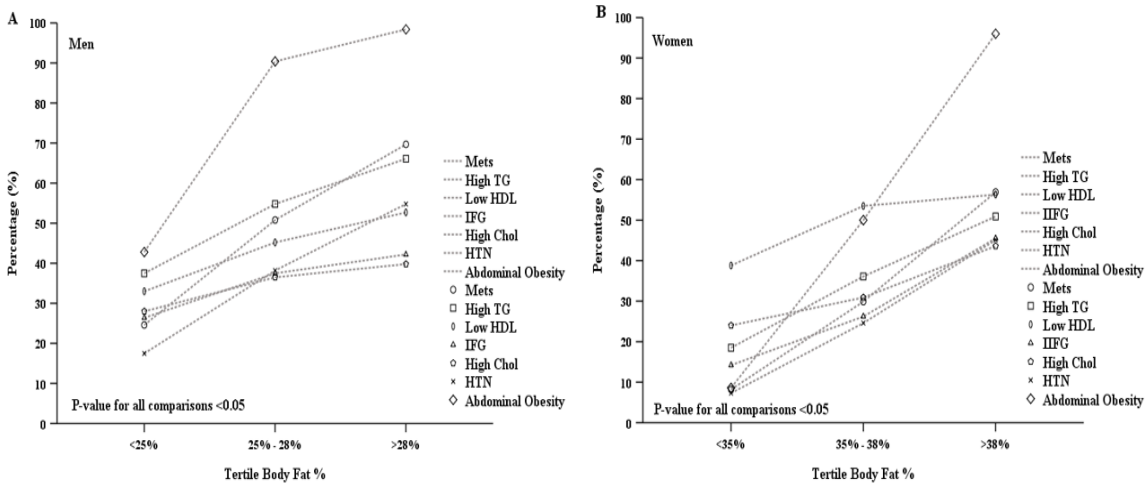

Fig. 2: The relation between PBF and prevalence of cardio-metabolic abnormalities in men (A) and women (B). Metabolic syndrome defined as three or more of five criteria (1) FPG ≥100 mg/dl (IFG) or drug treatment; (2) TG ≥150mg/dl or drug treatment; (3) HDL< 50 mg/dl in women and < 40 mg/dl in men or drug treatment; (4) hypertension defined as SBP ≥ 130 mmHg, DBP ≥ 85 mmHg or antihypertensive drug treatment (5) Abdominal obesity, WC cut off points as ≥ 89 cm for men and ≥ 91cm for women. High cholesterol, cholesterol ≥ 200 (mg/dl)

Tables 2 and 3 display the details of the diagnostic performance of PBF, LBM, and BMI for detecting MetS and its components by sex. To predict MetS, the PBF cut points were 25.6 in men (68% sensitivity and 66% specificity) and 36.2 in women (80% sensitivity and 65% specificity). The BMI cutoff points for predicting MetS were 27.2 (83% sensitivity and 77% specificity) and 27.5 (90% sensitivity and specificity), respectively. There were no significant differences between BMI and PBF under the ROC curves for predicting MetS and its components except for abdominal obesity in men and low HDL in women in favor of BMI (*P*<0.001).

Table 2: Sensitivity, specificity, PPV, NPV, AUC of PBF, LBM and BMI, predicting cardio-metabolic abnormalities in men

	AUC (95%CI)	*P-value*	*Cut Point*	*Sensitivity (95%CI)*	*Specificity (95%CI)*	*PPV*	*NPV*
Abdominal obesity							
PBF	0.901 (0.873-0.929)	<0.001	23.5	0.824(0.785-0.858)	0.834(0.760-0.893)	0.943(0.913-0.955)	0.587(0.526-0.702)
LMB	0.803 (0.761-0.844)	<0.001	56.5	0.757(0.714-0.796)	0.737(0.653-0.809)	0.906(0.866-0.923)	0.476(0.421-0.579)
BMI	0.951 (0.933-0.969)	<0.001	24.7	0.901(0.869-0.927)	0.857(0.786-0.912)	0.955(0.928-0.967)	0.722(0.654-0.817)
HTN							
PBF	0.697(0.654-0.741)	<0.001	25.5	0.693 (0.626-0.755)	0.605 (0.553-0.655)	0.503(0.450-0.579)	0.774(0.717-0.809)
LMB	0.535(0.484-0.585)	0.175	69.2	0.240(0.185-0.304)	0.888(0.852-0.919)	0.554(0.473-0.632)	0.669(0.591-0.742)
BMI	0.677 (0.631-0.722)	<0.001	27.5	0.627 (0.558-0.692)	0.678(0.628-0.726)	0.532(0.476-0.603)	0.758(0.701-0.797)
Low HDL							
PBF	0.603 (0.557-0.649)	<0.001	25.6	0.598(0.534-0.659)	0.572(0.516-0.627)	0.519(0.463-0.584)	0.648 (0.587-0.698)
LMB	0.526 (0.478-0.574)	0.336	70.9	0.175 (0.130-0.228)	0.898 (0.860-0.929)	0.571 (0.481-0.649)	0.585(0.499-0.676)
BMI	0.600 (0.554-0.646)	<0.001	25.5	0.744(0.685-0.797)	0.427(0.373-0.483)	0.501(0.445-0.576)	0.683(0.617-0.729)
High TG							
PBF	0.649(0.604-0.694)	<0.001	25.0	0.664(0.608-0.717)	0.575(0.514-0.634)	0.635(0.576-0.690)	0.606(0.547-0.664)
LMB	0.570 (0.523-0.616)	0.006	58.5	0.615(0.558-0.670)	0.538(0.477-0.599)	0.597(0.537-0.653)	0.577(0.498-0.616)
BMI	0.638(0.592-0.683)	<0.001	25.5	0.749(0.696-0.797)	0.469(0.408-0.529)	0.612(0.552-0.674)	0.625(0.562-0.681)
IFG							
PBF	0.594 (0.546-0.642)	<0.001	24.9	0.662 (0.592-0.726)	0.497 (0.445-0.549)	0.418(0.368-0.493)	0.729(0.667-0.768)
LMB	0.527 (0.477-0.577)	0.248	61.8	0.436(0.367-0.507)	0.636(0.585-0.685)	0.395(0.345-0.465)	0.674(0.608-0.720)
BMI	0.587 (0.539-0.635)	0.001	28.7	0.414 (0.345-0.485)	0.728(0.680-0.773)	0.454(0.397-0.526)	0.695(0.629-0.743)
MetS							
PBF	0.730 (0.689-0.770)	<0.001	25.6	0.682 (0.624-0.737)	0.668(0.611-0.721)	0.656 (0.599-0.713)	0.693 (0.636-0.744)
LMB	0.619(0.574-0.665)	<0.001	58.6	0.643 (0.683-0.699)	0.567(0.509-0.624)	0.579 (0.522-0.641)	0.630(0.570-0.684)
BMI	0.732 (0.691-0.773)	<0.001	27.2	0.661(0.602-0.716)	0.699 (0.644-0.751)	0.673(0.615-0.727)	0.688(0.631-0.741)

AUC, area under curve; PPV, positive predictive value; NPV, negative predictive value; PBF, percent body fat; LBM, lean body mass; BMI, body mass index; MetS, metabolic syndrome; HTN, hypertension; IFG, impaired fasting glucose; HDL, high density lipoprotein; TG, triglyceride

Table 3: Sensitivity, specificity, PPV, NPV, AUC of PBF, LBM and BMI, predicting cardio-metabolic abnormalities in women

	AUC (95%CI)	*P-value*	*Cut Point*	*Sensitivity (95%CI)*	*Specificity (95%CI)*	*PPV*	*NPV*
				Abdominal obesity			
PBF	0.921(0.901-0.941)	<0.001	36.2	0.835(0.792-0.872)	0.873(0.832-0.906)	0.872(0.832-0.902)	0.836(0.793-0.878)
LMB	0.776(0.742-0.810)	<0.001	44.1	0.702(0.651-0.749)	0.716(0.665-0.763)	0.720(0.669-0.765)	0.697(0.646-0.767)
BMI	0.933(0.915-0.950)	<0.001	27.8	0.863(0.823-0.897)	0.843(0.799-0.880)	0.851(0.809-0.888)	0.856(0.814-0.890)
				HTN			
PBF	0.754(0.713-0.794)	<0.001	37.7	0.691(0.617-0.759)	0.712(0.671-0.751)	0.449(0.402-0.535)	0.871(0.829-0.892)
LMB	0.596 (0.546-0.647)	<0.001	44.7	0.588(0.512-0.662)	0.609(0.565-0.651)	0.339(0.299-0.413)	0.813(0.761-0.839)
BMI	0.754(0.714-0.794)	<0.001	29.7	0.655(0.579-0.725)	0.733(0.692-0.771)	0.454(0.406-0.536)	0.862(0.819-0.885)
				Low HDL			
PBF	0.597 (0.555-0.639)	<0.001	30.6	0.906(0.869-0.934)	0.268(0.222-0.318)	0.547(0.485-0.643)	0.744(0.668-0.787)
LMB	0.607(0.565-0.649)	<0.001	44.3	0.572(0.518-0.625)	0.617(0.563-0.668)	0.593(0.539-0.645)	0.596(0.542-0.648)
BMI	0.620(0.578-0.662)	<0.001	23.9	0.903(0.866-0.932)	0.301(0.253-0.353)	0.559(0.499-0.652)	0.759(0.687-0.799)
				High TG			
PBF	0.664(0.623-0.705)	<0.001	36.6	0.633(0.569-0.694)	0.623(0.576-0.668)	0.475(0.427-0.543)	0.759(0.707-0.794)
LMB	0.525(0.478-0.571)	0.253	49.0	0.242(0.189-0.301)	0.843(0.806-0.875)	0.453(0.390-0.528)	0.674(0.602-0.730)
BMI	0.663(0.622-0.704)	<0.001	26.8	0.762(0.703-0.815)	0.495(0.448-0.543)	0.449(0.403-0.528)	0.794(0.740-0.824)
				IFG			
PBF	0.683 (0.639-0.727)	<0.001	38.2	0.561(0.489-0.632)	0.735(0.694-0.773)	0.456(0.407-0.529)	0.808(0.759-0.838)
LMB	0.595(0.549-0.642)	<0.001	45.1	0.526(0.453-0.597)	0.639(0.595-0.682)	0.366(0.324-0.436)	0.773(0.718-0.804)
BMI	0.673(0.629-0.718)	<0.001	28.9	0.638(0.566-0.705)	0.650(0.606-0.692)	0.421(0.376-0.497)	0.818(0.769-0.845)
				MetS			
PBF	0.777(0.741-0.813)	<0.001	36.2	0.805(0.746-0.856)	0.658(0.613-0.700)	0.518(0.469-0.607)	0.881(0.840-0.900)
LMB	0.646(0.599-0.692)	<0.001	44.7	0.611(0.543-0.676)	0.634(0.589-0.678)	0.433(0.387-0.504)	0.781(0.729-0.812)
BMI	0.793(0.758-0.827)	<0.001	27.5	0.842(0.787-0.888)	0.603(0.557-0.674)	0.493(0.446-0.591)	0.893(0.852-0.909)

AUC, area under curve; PPV, positive predictive value; NPV, negative predictive value; PBF, percent body fat; LBM, lean body mass; BMI, body mass index; MetS, metabolic syndrome; HTN, hypertension; IFG, impaired fasting glucose; HDL, high density lipoprotein; TG, triglyceride.

The logistic regression model adjusted for age, height, and smoking status was used to evaluate the relation of each cardio-metabolic risk factor with BMI and PBF (Table 4). In women, PBF

was only associated with abdominal obesity. However, BMI had an independent association with all the variables. In men, BMI was not associated with low HDL and high TG. Regarding all the other variables, both BMI and PBF remained in the model.

Table 4: Logistic regression of obesity measures associated with cardio-metabolic risk factors

Dependent Variable	*Independent Variable*	*OR (95% CI) Men*	*P-value*	*OR (95% CI) Women*	*P-value*
Abdominal obesity	BMI	2.66 (2.01 – 3.53)	<0.001	1.76 (1.49-2.06)	<0.001
	PBF	1.33 (1.16 – 1.53)	<0.001	1.16 (1.02 – 1.32)	0.024
HTN	BMI	1.13 (1.05 – 1.21)	0.001	1.17 (1.12 – 1.22)	<0.001
	PBF	1.07 (1.0 0– 1.13	0.035	-	
Low HDL	BMI	-		1.09 (1.06 – 1.13)	<0.001
	PBF	1.07 (1.03 – 1.11)	<0.001	-	
High TG	BMI	-		1.06 (1.02-1.10)	0.001
	PBF	1.12 (1.07 – 1.16)	<0.001	-	
IFG	BMI	1.07 (1.03 – 1.12)	0.001	1.09 (1.06 – 1.14)	<0.001
	PBF	-		-	
MetS	BMI	1.11 (1.03 – 1.19)	0.007	1.22 (1.17 – 1.28)	<0.001
	PBF	1.14 (1.07 – 1.21)	<0.001	-	

BMI, body mass index; PBF, percent body fat; CI, confidence interval; HTN, hypertension; HDL, high density lipoprotein; TG, triglyceride; IFG, impaired fasting glucose MetS, metabolic syndrome; Data from logistic regression analysis adjusted for age, height, and smoking; dashes mean variable removed from the equation by backward stepwise selection. Metabolic syndrome defined as three or more of five criteria (1) FPG ≥100 mg/dl (IFG) or drug treatment; (2) TG ≥150mg/dl or drug treatment; (3) HDL< 50 mg/dl in women and < 40 mg/dl in men or drug treatment; (4) hypertension defined as SBP ≥ 130 mmHg, DBP ≥ 85 mmHg or antihypertensive drug treatment (5) Abdominal obesity, WC cut off points as ≥ 89 cm for men and ≥ 91cm for women

Discussion

In this population-based cross-sectional study, we identified that PBF and BMI cutoff points for predicting MetS were 25.6% and 27.2 kg/m^2 in men and 36.2% and 27.5 kg/m^2 in women, respectively. For the prediction of MetS and its components, AUC revealed a similar accuracy of BMI and PBF, except for abdominal obesity in men and low HDL in women in favor of BMI. Moreover, according to logistic regression analysis, BMI in women was a better predictor for all the risk factors, except for abdominal obesity. In addition, in men BMI was equal or superior compared to PBF, except for low HDL and high TG.

Many attempts have been made to identify the BMI and PBF cutoff points for detecting cardio-metabolic abnormalities. Our data about PBF and BMI cutoff points for predicting MetS (25.6% and 27.2 kg/m^2 in men and 36.2% and 27.5 kg/m^2 in women, respectively) differ from the previous results (4, 11). The optimal PBF cutoff values for predicting cardio-metabolic risk factors were 24% and 33% using a foot-to-foot BIA and JIS criteria for defining MetS in Chinese men and women, respectively, which were both lower than our proposed cutoffs. The reasons behind this difference may be the applied methodologies, race, and end points (4). Further studies are needed to estimate PBF cutoff points for predicting cardio-metabolic risk factors in different populations.

There are conflicting results regarding the capability of BMI and PBF for predicting cardio-metabolic risk factors. Although BMI is potentially restricted by its inefficiency to assess fat mass and lean body mass (12) as reported in previous studies (13, 14), its measures of body fat had no superiority over BMI in predicting metabolic abnormalities. The results of the former studies are discrepant as to whether the use of adiposity estimation devices can be improved via BMI for identifying subjects at risk for cardio-metabolic disorders (15). These controversies may be explained by the differences in adiposity

measurement tools, applying different definitions of MetS and its individual elements instead of MetS as a whole concept, or even divergent sample characteristics.

Using logistic regression analysis, our results revealed that BMI in women was a better predictor of MetS and most of its components, except for abdominal obesity; however, both BMI and PBF were related to cardio-metabolic risk factors in men, while PBF was a better predictor for low HDL and high TG. This supports the results that reported BMI was a better predictor of HTN, insulin resistance, hypertriglyceridemia, hyperleptinemia, and hyperglycemia in Thai women than PBF, while it was not the case in men (16). This may be explained by the differences in the fatty acid mobilization, storage, oxidation, and distribution of fat in men and women.

In contrast to our results, in a study of 12,287 Japanese men and 6657 women aged 30–69 y (17), PBF (using BIA) was more significantly associated with serum lipids as compared with BMI. Our results do not support the findings of the previous investigation among 2,483 Japanese suggesting that except for HDL, measuring PBF by BIA may be better than BMI for anticipating serum lipids (15), although they did not present the data on waist circumference and MetS as a whole concept. Therefore, the associations between measures of body composition and cardio-metabolic risk in the general population are not clear and require future consideration to determine the predictive values of PBF and BMI.

Although PBF measurement via BIA is regarded as one of the most reliable methods for detecting adiposity and some studies have shown a good correlation between body fat measurements using BIA compared with DEXA (11), this method has certain limitations including the incapability to detect body fat distribution. Moreover, we did not use imaging studies to detect regional fat distribution because of their expenses. Some known risk factors such as physical activity and dietary intake were not taken into account in this study as well. In addition, we did not assess insulin resistance as a cardio-metabolic risk factor. What's more, considering the age-specific changes in body composition in our subjects, the cutoff points may differ among various age groups which needs further tests to be performed. Among the strengths of our study were its population-based design and analysis of the data for men and women separately.

Conclusion

Although BMI has its limitations, comparison of PBF with BMI showed that the use of PBF is not significantly superior to BMI in determining cardio-metabolic risks. Percent body fat does not seem to be useful in clinical practice, and BMI remains a simple, relatively inexpensive, and easily obtainable method to assess the cardio-metabolic risk factors in both sexes. Further research should be performed to compare the diagnostic accuracy of PBF with other anthropometric indices. Moreover, future cohort studies be conducted on the prognostic values of BMI and PBF for cardiovascular diseases and all-cause mortality.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

The authors are grateful to the staff and participants in the TLGS study for their important contribution.

Conflict of interest

The authors declare that there is no conflict of interests.

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