BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-014675
Article Type:	Research
Date Submitted by the Author:	13-Oct-2016
Complete List of Authors:	Li, Yanlong Wang, Hailing Wang, Ke Wang, Wenrui Dong, Fen Qian, Yonggang Gong, Haiying Xu, Guodong Li, Guoju Pan, Li Zhu, Guangjin shan, guangliang; Department of Epidemiology and Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Cardiovascular medicine
Keywords:	body composition, obesity, cardiovascular risk factors

Optimal body fat percentage cut-off values for identifying cardiovascular risk factors in Mongolian and Han adults: A Population-based Cross-Sectional Study in Inner Mongolia, China

Yanlong Li,[1] Hailing Wang,[2] Ke Wang,[1] Wenrui Wang,[2] Fen Dong,[1] Yonggang Qian,[2] Haiying Gong,[1] Guodong Xu,[3] Guoju Li,[1] Li Pan,[1] Guangjin Zhu,[1] Guangliang Shan,[1]

[1]Department of Epidemiology and Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, School of Basic Medicine, Peking Union Medical College, Beijing 100005, China

[2]Inner Mongolia Center for Disease Control and Prevention, Hohhot, Inner Mongolia Autonomous Region 010110, China

[3]Department of Epidemiology and Health Statistics, College of Public Health, Jilin University, Changchun 130021, China

Keywords: body composition, obesity, cardiovascular risk factors

Running Title: Optimal BF% cut-offs in Chinese

Corresponding Author:

Guangliang Shan

Department of Epidemiology and Health Statistics, College of Public Health, Jilin University, Changchun 130021, China

Guangliang_shan@163.com

Word Count: 2636 words

Tables: 6

Figures: 1

Supplementary Files: 0

Abstract

Objective: The present study was designed to determine the optimal cut-off values of BF% for obesity in Mongolian and Han adults.

Method: This cross-sectional study involving 3221 Chinese adults (2308 Han and 913 Mongolian) aged 20-80 years was conducted in Inner Mongolia Autonomous region, China, in 2014. Data from a standardized questionnaire, physical examination, and blood sample were obtained. The BF% was estimated using bioelectrical impedance analysis. Optimal BF% cut-offs were analyzed by receiver operating characteristic (ROC) curves to predict the risk of diabetes, hypertension, dyslipidemia. Binary logistic regression analysis was performed to evaluate the OR of each CVD risk factor according to obesity defined by BF%.

Results: Mean BF% levels were lower in men than in women (22.54±5.77 vs 32.95±6.18 in Han, 23.86±5.72 vs 33.98±6.40 in Mongolian, respectively; P<0.001). In Han adults, the optimal BF% cut-off values to detect CVD risk factors varied from 18.7% to 24.2% in men, and 32.7% to 35.4% in women. In Mongolian population, the optimal cut-off values of BF% for men and women ranged from 21.0% to 24.6% and from 35.7% to 40.0%, respectively. Subjects with high BF% (≥24% in men, ≥34% in women) had higher risk of CVD risk factors in Han (age-adjusted ORs from 1.479 to 3.680, 2.660 to 4.016, respectively). In Mongolian, adults with high BF% (≥25% in men, ≥35% in women) had higher risk of CVD risk factors (age-adjusted ORs from 2.587 to 3.772, 2.061 to 4.882, respectively).

Conclusions: The optimal BF% cut-offs for obesity for the prediction of CVD risk factors in Chinese men and women were approximately 24% and 34% for Han adults, and 25% and 35% for Mongolian population, respectively.

Strengths and limitations of this study

The present study was first designed to determine the optimal cut-off values of BF% for CVD risk factors (hypertension, diabetes, dyslipidemia) and clustering of ≥2 these risk factors in Chinese population.

This study used a large sample covering most age groups to estimate BF% cut-off values for discriminating CVD risk factors in both sexes, especially in different ethnics (Han and Mongolian) in China.

The prevention of public health problems was evaluated by PARP of BF% cut-offs in sexes and races.

The study characterizes the optimal body fat percentage cut-off values for identifying CVD risk factors in a cross-sectional setting using the occurrence of established CVD risk factors as a proxy risk estimate. Lots of epidemic studies, especially prospective cohort studies, need to be completed to improve cutoff points accuracy of BF% in China.

BF% in this study was measured using bioelectrical impendence analysis, which tends to underestimate body fat in all subjects and in men and women separately. However, considering the convenience and inexpensiveness of BIA, large-scale epidemiological investigations appropriately use this analysis.

Introduction

During the past four decades, the global prevalence of underweight and obesity has risen dramatically and is now estimated to affect over 600 million people[1]. In China, the prevalence of obesity approximately tripled from 3.75% in 1991 to 11.3% in 2011 according to diagnostic criteria of the Working Group on Obesity[2]. It is now identified that obesity essentially increases the risk of hypertension, diabetes and dyslipidemia, which has a great influence on the morbidity and mortality of Cardiovascular disease (CVD)[3].

Body mass index(BMI) closely correlated with body fatness is recommended by WHO as a population-level measure of overweight and obesity (BMI≥30 or 25 kg/m^2 is defined as obese or overweight, respectively). However, it may not consistently characterize adiposity across racial/ethnic groups[4]. Body fat percentage (BF%) as a percentage of total bodyweight has advantages over BMI in estimating fat mass[5]. The BF% cut-off points for obesity proposed by the WHO are 25% for men and 35% for women, corresponding a BMI of 30 kg/m^2 in young Caucasians[6]. It was reported that BMI and percentage of body fat differ across populations[7]. The Chinese tend to have a lower BMI but a higher fat volume. Li and colleagues[8] showed that the BF% cut-off values for Chinese adults were similar to those proposed by the WHO. However, a longitudinal epidemiological study[9] reflected that the present Chinese BMI criteria(28 kg/m^2 for obesity) was relatively inconsistent with WHO BF% criteria in determining obesity. Therefore, the appropriate BF% cut-off points for Chinese remains inconclusive and needs to be further studied. Inner Mongolia Autonomous Region located in northern China consists mainly of Han and Mongolian. Compared with Han population, the dietary pattern of Mongolians tends to be traditionally rich in whole milk, fats and oils, which might increase greater risk of obesity in Mongolia [10]. In this study, we aimed to characterize the optimal BF% cut-off points in Mongolian and Han adults according to its risk for common CVD risk factors, including diabetes, hypertension and dyslipidemia.

Methods

Study population

The present study was based on data from the China National Health Survey (CNHS) in Inner Mongolia Autonomous region in 2014, which has already been described in detail elsewhere[11]. A total of 3508 examinees aged 20-80 years were found to be eligible for the study. We excluded individuals with incomplete data for hypertension, diabetes and dyslipidemia status, sex, age and the anthropometric indices(i.e., BMI, BF%). In addition, pregnant women were excluded. This resulted in a final analytical sample of 3221 adults (2308 Han and 913 Mongolian).

Written informed consent was acquired from each participant before data collection. The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences.

Data collection

A standardized health questionnaire was completed by investigators and contained demographic information, diseases (particularly hypertension, diabetes) and the family history of diabetes, cardiovascular disease, or cancer. Body height and weight of each subject dressed in light indoor clothing without shoes were determined. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Body fat percentage was measured by bioelectrical impendence analysis (BIA), with a commercially available body analyzer (BC-420, TANITA, Japan), in subjects who wore light clothes and were barefoot. Blood pressure was taken three times using the electronic sphygmomanometer(HEM-907, OMRON, Japan) and the average was used as the mean blood pressure. All surveys were performed by trained staff.

Blood samples were collected from all participants following an overnight fast. Serum total cholesterol (TC), triglycerides (TG), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), and fasting plasma glucose (FPG) were determined by Peking Union Medical College Hospital.

Definition of CVD risk factors

Diabetes was defined as FPG ≥7.0mmol/L and/or physician-diagnosed diabetes. Hypertension was defined as mean systolic blood pressure (SBP) ≥140mmHg and/or mean diastolic blood pressure (DBP) ≥90mmHg and/or physician-diagnosed hypertension. Dyslipidemia was defined as follow: TC≥6.22mmol/L and/or LDL-C≥4.14mmol/L and/or HDL-C<1.04mmol/L and/or TG ≥2.26mmol/L. Clustering of risk factors was defined as presence of ≥2 CVD risk factors.

Statistical analysis

Statistical analysis was performed using SAS software (version 9.3; SAS Institute, Cary, NC, USA). Continuous variables were presented as mean ±SD; comparisons between two groups were used by Student's t test. Categorical variables were expressed as percentages and compared by Chi-square test. Two-tailed *P*-value less than 0.05 was considered statistically significant.

Receive operating characteristic (ROC) curve analysis was performed to using BF% as continuous variable in logistic regression models to obtain accurate estimates of area under the cure (AUC) in relation to hypertension, diabetes, and dyslipidemia, which describe the probability that a test will correctly identify subjects with disease. The optimal cut-off values were defined as the points on the ROC curve where Youden's index (sensitivity+specificity-1) was the maximal. Odd ratios (ORs) and the corresponding 95% confidence interval (CI) were calculated by binary logistic regression analysis to measure the association between obesity defined by BF% and CVD risk factors. PARP (percent of prevalence of a condition/disease in the population due to presence of risk factor or percent of prevalence of a condition/disease in the population that would be reduced if risk factor was removed) for each CVD risk factor was calculated by sex-specific cut-offs for BF%. Formulas for calculation of PARP are given below.

$$PARP(\%) = 100 * P\ (OR\text{-}1)\ /\ [\ P\ (OR\text{-}1)+1\ ]\%$$

(*P*: percent of subjects whose BF% was above the sex-specific cut-off value; *OR*: age-adjusted odds ratios for cardiovascular risk factors in subjects using sex-specific cut-offs for BF%)

Results

Base characteristics of subjects

Baseline characteristics for men and women in Han and Mongolian adults are shown in Table 1. In Han adults, men had a higher mean BMI, SBP, DBP, FG, TC, TG, meanwhile a lower BF% and HDL-C than women. LDL-C were comparable between men and women ($P>0.05$). The prevalence of hypertension, diabetes, and dyslipidemia were higher in men than in women. Similarly in Mongolian adults, men had a higher mean BMI, SBP, DBP, FG, TC, TG, LDL-C whereas a lower BF% and HDL-C than women. The prevalence of CVD risk factors were higher in men than in women.

Table 1 Baseline Characteristics by sex in Han and Mongolian adults

Variables	Han(n=2308)			Mongolian(n=913)		
	Men(n=898)	Women(n=1410)	All cases	Men(n=355)	Women(n=558)	All cases
Age(years)	46.20±14.05***	44.24±13.29	45.00±13.62	45.91±13.69**	43.34±13.03	44.34±13.34
Height(cm)	170.12±5.94***	158.28±5.51	162.89±8.10	170.54±6.35***	158.53±5.46	163.21±8.26
Weight(kg)	72.92±12.18***	60.20±9.70	65.15±12.39	75.11±12.96***	61.54±10.08	66.82±13.08
BMI(kg/m2)	25.17±3.82***	24.04±3.72	24.48±3.80	25.78±3.96***	24.52±4.07	25.01±4.07
BF(%)	22.54±5.77***	32.95±6.18	28.90±7.88	23.86±5.72***	33.98±6.40	30.05±7.88
SBP(mmHg)	127.40±14.96***	119.07±17.14	122.31±16.82	129.4±16.05***	118.22±17.65	122.57±17.89
DBP(mmHg)	80.21±10.52***	75.42±10.66	77.28±10.86	82.2±11.89***	75.67±11.96	78.21±12.34
FPG(mmol/L)	5.53±1.49***	5.22±1.08	5.34±1.27	5.56±1.48***	5.14±1.09	5.30±1.27
TC(mmol/L)	4.86±1.00*	4.76±1.04	4.80±1.03	5.10±0.97***	4.89±1.03	4.98±1.02
TG(mmol/L)	2.18±1.89***	1.55±1.13	1.80±1.50	2.00±1.46***	1.46±1.18	1.67±1.32
LDL-C(mmol/L)	2.86±0.86	2.83±0.85	2.84±0.86	3.13±0.87***	2.93±0.86	3.01±0.87

HDL-C(mmol/L)	1.19±0.32***	1.39±0.34	1.31±0.34	1.27±0.34***	1.45±0.37	1.38±0.37
Hypertension(%)	33.74***	23.48	27.47	40.28***	25.63	31.33
Diabetes(%)	9.58***	5.53	7.11	9.86***	3.23	5.81
Dyslipidemia(%)	51.11***	27.73	36.83	47.32***	26.34	34.5
Risk factors⩾2(%)	24.16***	12.2	16.85	27.32***	13.8	19.06

Values are means±SD or %.

**P*<0.05, ***P*<0.01, ****P*<0.001 compared with women within Han or Mongolian adults(Student's t-tests for continuous variables; Chi-square tests for categorical variables).

BF(%), body fat percentage; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;

TC, total cholesterol; TG, triglycerides; LDL-C, low-density lipoprotein-cholesterol; HDL-C, high-density lipoprotein-cholesterol.

Area under ROC and optimal cut-offs for predicting CVD risk factors

Figure 1 shows ROC curves of BF% for identifying CVD risk factors in men and women among Han and Mongolian adults. Area under ROC curves of BF% stratified by age groups are summarized in Table 2. In Han population, the AUC of BF% ranged from 0.589 to 0.699 for men and from 0.711 to 0.763 for women. Compared with men, AUCs for diabetes and clustering of ≥2 risk factors in women were significantly higher(*P*<0.05). In addition, the AUC for CVD risk factors were larger in the younger age group than that in the older in women (*P*<0.05). However, AUCs for cardiovascular risk factors were all comparable between men and women in Mongolian adults (*P*>0.05). Among these, the AUCs of BF% ranged from 0.686 to 0.736 for men and from 0.685 to 0.783 for women. Although BF% performed differently for CVD risk factors in age groups of both sexes, there were no significant difference in the AUCs (*P*>0.05).

Figure 1 ROC curves for BF% screening CVD risk factors.

Table 2 Area under receiver operating characteristic (ROC) curves of BF% screening CVD risk factors

	Hypertension	Diabetes	Dyslipidemia	Risk factors≥2
Han				
Men				
All ages	0.696(0.661,0.732)	0.589(0.531,0.648)	0.682(0.647,0.717)	0.699(0.662,0.736)
20-49 years	0.734(0.686,0.782)	0.532(0.417,0.646)	0.700(0.655,0.745)	0.731(0.681,0.780)
50-80	0.666(0.611,0.720)	0.606(0.536,0.676)	0.661(0.607,0.716)	0.670(0.613,0.726)

years				
Women				
All ages	0.737(0.707,0.767)	0.728(0.676,0.780)*	0.711(0.683,0.740)	0.763(0.729,0.797)*
20-49 years	0.761(0.718,0.805)	0.787(0.700,0.874)	0.735(0.698,0.773)	0.836(0.788,0.885)
50-80 years	0.645(0.595,0.695)#	0.617(0.544,0.689)#	0.596(0.545,0.646)#	0.644(0.590,0.698)#
Mongolian				
Men				
All ages	0.702(0.648,0.757)	0.686(0.609,0.764)	0.690(0.636,0.745)	0.736(0.683,0.789)
20-49 years	0.714(0.636,0.793)	0.765(0.646,0.884)	0.681(0.608,0.753)	0.764(0.688,0.839)
50-80 years	0.665(0.577,0.754)	0.609(0.498,0.720)	0.689(0.604,0.775)	0.689(0.606,0.772)
Women				
All ages	0.733(0.685,0.780)	0.733(0.601,0.865)	0.685(0.637,0.733)	0.783(0.730,0.835)
20-49 years	0.643(0.557,0.729)	0.729(0.616,0.842)	0.670(0.604,0.735)	0.764(0.666,0.863)
50-80 years	0.683(0.604,0.763)	0.664(0.481,0.848)	0.586(0.502,0.671)	0.690(0.607,0.773)

*$P<0.05$, Compared to men.

#$P<0.05$, Compared to 20-49 years.

Optimal cut-off points of BF% for CVD risk factors in both ethnic groups were given in Table 3, which were identified according to the highest Youden's index on ROC curves. In Han adults, the BF% cut-off values were found to optimally predict the risk of hypertension, diabetes and dyslipidemia varied from 18.7% to 24.2% in men, and 32.7% to 35.4% in women. In addition, the optimal cut-off points of BF% were all higher for women than for men in each CVD risk factor. In Mongolian, the optimal BF% cut-off values for men and women ranged from 21.0% to 24.6% and from 35.7% to 40.0%, respectively. The optimal BF% cut-offs between men and women in Mongolian adults were significantly different. Basically, the optimal cut-off values of BF% in women were mostly higher for older age group than for the younger in Han and Mongolian adults. However, the optimal BF% cut-off points varied greatly by age and CVD risk factors.

Table 3 Optimal cut-off values of BF% and their sensitivities, specificities, and Youden's index for CVD risk factors by age groups and sex

	Hypertension				Diabetes				Dyslipidemia				Risk factors≥2			
	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI
Han																
Men																
All ages	24.2	62.7	70.3	33.0	18.7	94.2	23.5	17.7	21.6	77.3	52.4	29.7	24.2	64.5	66.7	31.2
20-49 years	24.2	69.3	71.1	40.4	18.8	92.3	24.6	17.0	21.6	75.8	56.0	31.9	24.2	68.4	67.8	36.3
50-80 years	24.2	58.0	68.7	26.6	22.5	75.0	45.1	20.1	20.5	87.1	41.9	29.0	25.0	54.9	71.8	26.7
Women																
All ages	34.2	71.9	64.8	36.7	35.4	69.2	67.5	36.7	32.7	77.2	55.8	33.1	33.7	83.1	58.1	41.2
20-49 years	33.6	73.7	67.2	40.9	32.0	94.4	52.6	47.1	33.9	66.1	70.3	36.5	33.9	90.5	65.6	56.1
50-80 years	36.8	52.6	70.7	23.2	35.4	70.0	51.2	21.2	34.8	66.8	50.6	17.4	36.7	56.9	65.5	22.4
Mongolian																
Men																
All ages	23.0	84.6	48.1	32.7	21.9	97.1	33.4	30.6	21.0	89.3	41.7	31.0	24.6	77.3	60.1	37.4
20-49 years	23.0	87.3	51.3	38.6	26.8	75.0	75.1	50.1	18.5	94.5	35.1	29.6	25.7	72.2	71.6	43.8
50-80 years	21.9	88.6	40.3	29.0	22.0	95.7	28.3	24.0	21.0	94.8	38.4	33.2	21.9	96.7	37.1	33.8
Women																
All ages	35.7	71.3	66.3	37.6	40.0	55.6	84.6	40.2	36.4	62.6	68.6	31.2	36.4	80.5	66.9	47.5
20-49 years	35.7	55.6	70.7	26.3	34.8	100.0	61.8	61.8	31.1	82.9	43.5	26.3	36.4	70.0	74.1	44.1
50-80 years	36.7	73.5	54.5	28.0	41.0	60.0	81.3	41.3	36.5	77.9	46.9	24.9	36.6	84.2	46.6	30.8

Sen, sensitivity; Spe, specificity; YI, Youden's index.

The optimal cut-offs of BF% for identifying CVD risk factors in Han and Mongolian adults were also assessed. Table 4 and Table 5 show the sensitivity, specificity and Youden's index for the various cut-off values for BF% in men and women. Clearly, specificity gradually increased but sensitivity conversely decreased with the increase cut-off values of BF% in men and women. BF% cut-off points of preferable sensitivity and specificity to detect each CVD risk factor and clustering of ≥2 risk factors were selected as optimal values. In Han population, 24% and 34 % were the optimal BF% cut-off values in terms of the Youden's index, sensitivity and specificity for men and women, respectively. In Mongolian, the optimal cut-off points of BF% were 25% for men and 35% for women.

Table 4. Sensitivity, specificity and Youden's index for BF% to detect CVD risk factors by sex-specific cut-offs in Han adults

	Hypertension			Diabetes			Dyslipidemia			Risk factors≥2		
	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI
Men												
21	83.8	41.3	25.2	79.1	34.1	13.2	81.1	47.4	28.4	88.0	39.5	27.5
22	77.6	49.4	27.0	70.9	41.5	12.4	73.4	54.7	28.1	81.1	47.1	28.3
23	69.6	59.2	28.8	61.6	50.6	12.3	63.8	63.3	27.2	72.4	56.4	28.7
24	**64.0**	**67.1**	**31.1**	**53.5**	**57.6**	**11.1**	**56.0**	**69.7**	**25.7**	**66.4**	**63.9**	**30.2**
25	52.5	74.5	26.9	44.2	66.4	10.6	45.3	76.5	21.9	55.8	72.1	27.9
26	43.9	81.3	25.2	33.7	73.5	7.2	51.1	81.3	32.4	44.7	78.4	23.1
Women												
32	84.0	50.5	34.5	89.7	44.3	34.0	80.3	51.1	31.4	91.3	47.1	38.4
33	78.6	56.9	35.5	82.1	50.4	32.4	74.7	57.5	32.2	85.5	53.3	38.8
34	**72.2**	**63.2**	**35.4**	**75.6**	**56.7**	**32.3**	**68.3**	**63.8**	**32.1**	**79.7**	**59.7**	**39.3**
35	64.4	70.9	35.3	70.5	64.6	35.1	58.6	70.8	29.3	69.8	67.1	36.9
36	55.6	77.3	32.9	62.8	71.5	34.3	48.3	76.5	24.8	61.1	73.8	34.9
37	47.7	82.7	30.4	53.9	77.3	31.1	38.9	81.1	19.9	52.3	79.4	31.7

Sen, sensitivity; Spe, specificity; YI, Youden's index.

Table 5. Sensitivity, specificity and Youden's index for BF% to detect CVD risk factors by sex-specific cut-offs in Mongolian adults

	Hypertension			Diabetes			Dyslipidemia			Risk factors≥2		
	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI
Men												
21	88.1	37.3	25.4	97.1	29.7	26.8	89.3	41.7	31.0	95.9	35.7	31.5
22	86.7	43.4	30.1	94.3	34.1	28.4	82.7	43.9	26.6	93.8	40.7	34.5
23	84.6	48.1	32.7	88.6	37.5	26.1	81.0	49.2	30.2	91.8	45.0	36.7
24	72.7	54.7	27.5	82.9	46.6	29.4	69.1	55.1	24.1	79.4	52.3	31.7

25	**60.8**	**64.2**	**25.0**	**71.4**	**56.9**	**28.3**	**60.1**	**66.8**	**27.0**	**70.1**	**63.2**	**33.3**
26	53.2	72.2	25.3	60.0	64.4	24.4	49.4	72.2	21.6	60.8	70.5	31.4
Women												
32	84.6	42.9	27.5	83.3	36.5	19.8	81.6	42.1	23.7	92.2	40.3	32.5
33	79.7	48.9	28.6	83.3	42.4	25.7	76.9	48.2	25.1	88.3	46.4	34.7
34	75.5	54.7	30.2	83.3	48.0	31.3	73.5	54.3	27.7	85.7	52.2	37.9
35	**73.4**	**62.2**	**35.6**	**77.8**	**54.1**	**31.9**	**68.7**	**60.8**	**29.5**	**84.4**	**59.0**	**43.5**
36	68.5	67.0	35.5	66.7	58.7	25.4	63.3	65.5	28.7	80.5	64.0	44.6
37	58.7	73.5	32.2	61.1	66.1	27.2	55.1	72.5	27.6	70.1	70.9	41.0

Sen, sensitivity; Spe, specificity; YI, Youden's index.

The age-adjusted OR(95%CI) and PARP of each CVD risk factor using sex-specific cut-offs for BF% in Han and Mongolian adults are shown in Table 6. In Han adults, BF% corresponded to significantly higher OR for hypertension and dyslipidemia in men except diabetes, while BF% corresponded to significantly higher OR for all CVD risk factors in women. In Mongolian population, BF% corresponded to significantly higher OR for all CVD risk factors in both sexes except diabetes in women. According to PARP analysis, the proportion of Han adults whose BF% ≥24% was about 43% in men. If BF% were controlled below 24%, 53.8% of hypertension, 17.2% of diabetes, 46.1% of dyslipidemia, and 51.6% of clustering of ≥2 CVD risk factors would be prevented. Women whose BF% ≥34% was about 45% in Han women. If BF% were controlled under 24%, 57.6% of clustering of ≥2 risk factors would be prevented. In Mongolian, the proportions of subjects whose BF% above 25% for men and 35% for women were round 46% and 47%, respectively. If BF% were controlled under 25% for men and 35% for women, 56%-65% of clustering of ≥2 risk factors would be prevented.

Table 6. Age-adjusted OR(95%CI) and PARP of each CVD risk factor by sex-specific cut-offs for BF% in Han and Mongolian adults

	*OR**	*95%CI*	*PARP(%)*
Han			
Men(BF%⩾24%)			
Hypertension	3.680	2.728-4.964	53.8
Diabetes	1.479	0.940-2.328	17.2
Dyslipidemia	2.966	2.251-3.908	46.1
Risk fators⩾2	3.450	2.490-4.780	51.6

	OR	95% CI	PARP
Women(BF%⩾34%)			
Hypertension	3.382	2.544-4.494	51.8
Diabetes	2.660	1.539-4.596	42.8
Dyslipidemia	3.152	2.439-4.072	49.3
Risk fators⩾2	4.016	2.682-6.014	57.6
Mongolian			
Men(BF%⩾25%)			
Hypertension	2.587	1.635-4.094	42.2
Diabetes	2.982	1.374-6.471	47.6
Dyslipidemia	2.986	1.930-4.620	47.7
Risk fators⩾2	3.772	2.251-6.321	56.0
Women(BF%⩾35%)			
Hypertension	2.851	1.796-4.526	46.5
Diabetes	2.061	0.634-6.697	33.3
Dyslipidemia	2.599	1.704-3.964	42.9
Risk fators⩾2	4.882	2.497-9.545	64.6

*Adjusted odds ratios for cardiovascular risk factors in subjects using sex-specific cut-offs for BF%, adjusted for age.
OR, odds ratios; PARP, population attributable risk proportion.

Discussion

The present study, using data obtained from Han and Mongolian adults from Inner Mongolia, China showed that BF% performed differently for discriminating CVD risk factors in sex and ethnicity. The optimal BF% cut-off points for men and women were approximately 24.0% and 34.0% in Han adults, and 25.0% and 35.0% in Mongolian population, respectively. Compared with WHO criteria, the optimal BF% cut-offs in this study were relatively lower in Han adults, but similar in Mongolian, which were taken account of validity to detect CVD risk factors and clustering two or more CVD risk factors.

BMI is the most widely used measure to diagnose obesity. However, the accuracy of BMI in detecting excess body adiposity in the general adult population is limited, because BMI cannot measure BF% directly and poorly distinguishes among total body fat, total body lean, and bone mass[12, 13]. To overcome misclassifications, direct measurements of BF% would be a better tool for diagnosing obesity. Moreover, BF% has been found to have a stronger association with multiple CVD risk factors in several studies conducted in China[8], Korea[14], and other ethnic groups[15-17]. Our data also support the good discrimination of BF% for each CVD risk factor and clustering of ≥2 risk factors in both sexes and ethnicities. However, BF% seems performed better in women than in men to detect CVD risk factors, which might result from greater less mass and lower fat mass men had than women[18]. Besides, BF% had larger AUCs for almost CVD risk factors in women aged <50 years than in the older women, but not obviously in men. In a Korean study, women after menopause had not only higher total body fat percentage but also its different distribution, which independently correlates with cardiovascular disease risk factors[19]. In addition, a study of 402 women aged 30-75 years in Southern India also shown that menopausal status and associated obesity created a compatible atmosphere for abnormal metabolism and aggravated cardio metabolic risk factors[20]. However, the relationship between obesity in women after menopause and CVD risk factors is more vulnerable to the effect of confounding variables, such as ageing, which might affect the accuracy of prediction of BF% for CVD risk factors.

It has been demonstrated that adipose tissue distribution varies among different ethnicities[21]. As is well known, the increased risks of metabolic diseases associated with obesity occur at lower BMIs in Asians, and these population are predisposed to visceral or abdominal obesity. In a study of peri- and postmenopausal women in Thai, 34% was proposed as the optimal BF% cut-off points to identify women at risk of metabolic syndrome[22]. In addition, A cross-sectional study of the middle-aged Japanese men shown that the cut-off point of BF% for detecting participants with 1 or more CVD risk factors (diabetes mellitus, hypertension, dyslipidemia) was 20.3%[23]. Joseph, *et al*. recommended an optimal BF% cut-off values of 25.5 in men and 38.0 in women for Asian Indian individuals[24]. Furthermore, Kim, *et al* reported that a BF% of 21% for men and 37% for women may be the appropriate cut-off values in Korean adults[25]. These discrepancies mainly results from different ethnic groups, age and outcome. By now, BF% has not been recommended as an adiposity index in the Chinese population yet, and there has been little study on the cutoff point for BF%. Li, *et al* proposed 25% and 35% as optimal BF% cut-off points for Chinese men and women to predict metabolic syndrome and Type 2 diabetes using data from the Shanghai Diabetes Studies (SHDS), respectively[8]. In this study, the optimal cut-off values of BF% to detect diabetes, hypertension, and dyslipidemia for men and women in Han adults were found to be 24% and 34%, respectively. In Mongolian population, the optimal BF% cut-offs were 25% for men and 35% for women. Mongolians have a distinctive lifestyle and dietary habits characterized by a preference for high protein and fatty foods of animal origin[26], which is different from Han population. Zhang, *et al* reported the prevalence of overweight or obesity was higher in Mongolian people than Han people using WHO criteria (26.1% vs 21.3%, respectively). Moreover, a study evaluating the relationship among ethnic groups and their CVD risk factors (hypertension, obesity, diabetes, dyslipidemia, smoking) shown that clustering of ≥2 or ≥3 of these risk factors was noted in 66.9% or 36.5% of Mongolian as well as 62.0% or 28.3% of Han subjects, respectively[27]. Because of different ethnicities, the optimal BF% cut-offs of Han adults may be not the same as Mongolian.

The current definitions of obesity using BF% are based on Western populations and probably need to be modified for Chinese population. The present study showed the optimal BF% cut-off points for men and women were around 24.0% and 34.0% in Han adults, and 25.0% and 35.0% in Mongolian population, respectively.

Acknowledgments This study was supported by the National Science & Technology Pillar Program during the 12th Five-year Plan Period, Grant 2012BAI37B02 from the Ministry of Science and Technology, Beijing, People's Republic of China to Guangliang Shan, which enabled the completion of the project. We sincerely express our gratitude to all the staff of Inner Mongolia Autonomous Region Center for Disease Control and Prevention for support with the collection of demographic data.

Contributors YL participated in the data collection and drafted the manuscript. HW, WW, HG, YQ, GX, GL participated in the data collection. KW, FD, LP, GZ, GS participated in the design of the study and undertook statistical analyses. All authors were involved in writing the paper and had final approval of the submitted and published versions.

Funding This study was supported by the National Science & Technology Pillar Program during the 12th Five-year Plan Period, Grant 2012BAI37B02 from the Ministry of Science and Technology, Beijing, People's Republic of China to Guangliang Shan.

Competing interests None declared.

Ethics approval The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences(NO.028-2013).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

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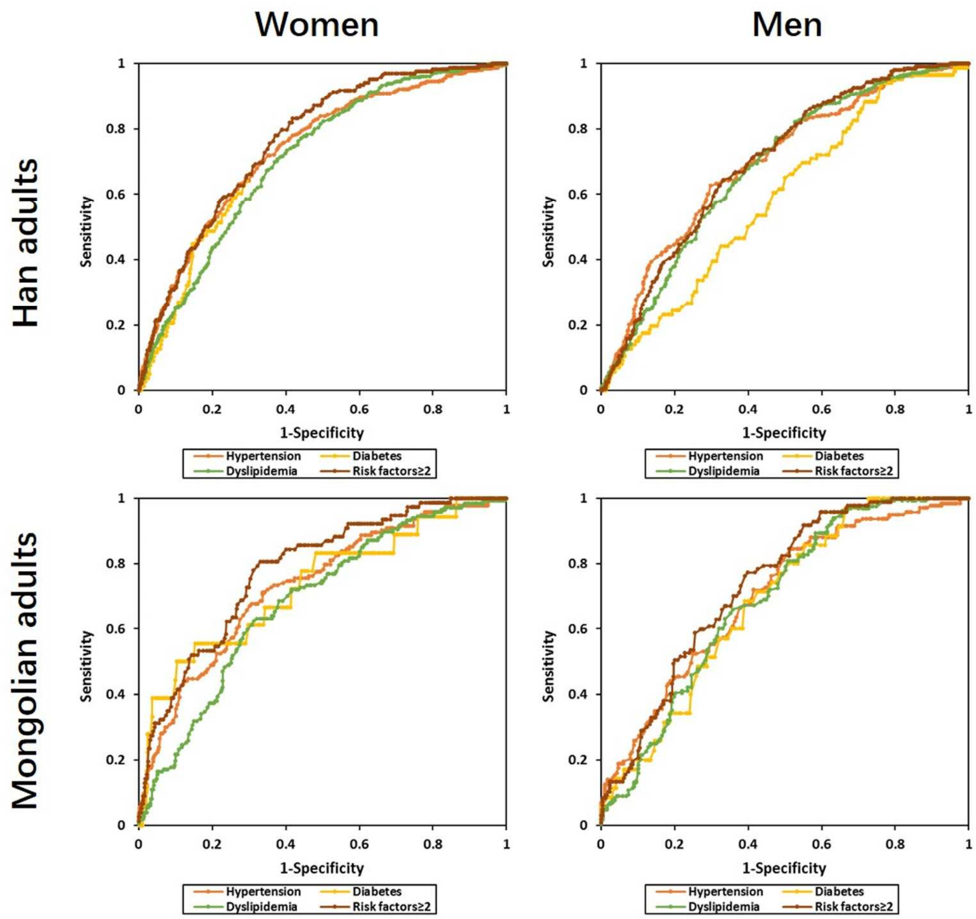

Figure 1 ROC curves for BF% screening CVD risk factors.
Optimal body fat percentage cu
283x267mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3-4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	3-4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	4-5
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Results			Page No
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	3,5
		(b) Give reasons for non-participation at each stage	3,5
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	5-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	2
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Optimal body fat percentage cut-off values for identifying cardiovascular risk factors in Mongolian and Han adults: A Population-based Cross-Sectional Study in Inner Mongolia, China

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-014675.R1
Article Type:	Research
Date Submitted by the Author:	06-Dec-2016
Complete List of Authors:	Li, Yanlong; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics Wang, Hailing; Inner Mongolia Center for Disease Control and Prevention Wang, Ke; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China, Department of Obstetrics, Key Laboratory of Birth Defects and Related Diseases of Women and Children (Sichuan University), Ministry of Education Wang, Wenrui; Inner Mongolia Center for Disease Control and Prevention Dong, Fen; China-Japan Friendship Hospital Qian, Yonggang; Inner Mongolia Center for Disease Control and Prevention Gong, Haiying; Fangshan District Center for Disease Control and Prevention Xu, Guodong; China-Japan Friendship Hospital Li, Guoju; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences,, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics Pan, Li; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics Zhu, Guangjin; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics shan, guangliang; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	body composition, obesity, cardiovascular risk factors

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Optimal body fat percentage cut-off values for identifying cardiovascular risk factors in Mongolian and Han adults: A Population-based Cross-Sectional Study in Inner Mongolia, China

Yanlong Li[1], Hailing Wang [2], Ke Wang[3], Wenrui Wang[2], Fen Dong[4], Yonggang Qian[2], Haiying Gong[5], Guodong Xu[4], Guoju Li[1], Li Pan[1], Guangjin Zhu[1], Guangliang Shan[1]

[1] Department of Epidemiology and Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, School of Basic Medicine, Peking Union Medical College, Beijing, China
[2] Inner Mongolia Center for Disease Control and Prevention, Hohhot, China
[3] National Office for Maternal and Child Health Surveillance of China, Department of Obstetrics, Key Laboratory of Birth Defects and Related Diseases of Women and Children (Sichuan University), Ministry of Education, West China Second University Hospital, Sichuan University, Chengdu, China.
[4] China-Japan Friendship Hospital, Beijing, China
[5] Fangshan District Center for Disease Control and Prevention, Beijing, China

Keywords: body composition, obesity, cardiovascular risk factors

Running Title: Optimal BF% cut-offs in Chinese

Corresponding Author:

Guangliang Shan

Department of Epidemiology and Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, School of Basic Medicine, Peking Union Medical College, Beijing 100005, China

Guangliang_shan@163.com

Word Count: 2675 words

Tables: 6

Figures: 1

Supplementary Files: 0

Abstract

Objective: The present study was designed to determine the optimal cut-off values of body fat percentage (BF%) for the detection of cardiovascular disease (CVD) risk factors in Mongolian and Han adults. **Method:** This cross-sectional study involving 3221 Chinese adults (2308 Han and 913 Mongolian) aged 20-80 years was conducted in Inner Mongolia Autonomous region, China, in 2014. Data from a standardized questionnaire, physical examination, and blood sample were obtained. The BF% was estimated using bioelectrical impedance analysis. Optimal BF% cut-offs were analyzed by receiver operating characteristic (ROC) curves to predict the risk of diabetes, hypertension, dyslipidemia. Binary logistic regression analysis was performed to evaluate the odds ratio (OR) of each CVD risk factor according to obesity defined by BF%. **Results:** Mean BF% levels were lower in men than in women (22.54±5.77 vs 32.95±6.18 in Han, 23.86±5.72 vs 33.98±6.40 in Mongolian, respectively; $P<0.001$). In Han population, the area under curve (AUC) values for BF% ranged from 0.589 to 0.699 for men and from 0.711 to 0.763 for women. Compared with men, AUCs for diabetes and clustering of ≥2 risk factors in women were significantly higher ($P<0.05$). The AUCs for BF% in women (0.685-0.783) were similar with those in men (0.686-0.736) for CVD risk factors in Mongolian. In Han adults, the optimal BF% cut-off values to detect CVD risk factors varied from 18.7% to 24.2% in men, and 32.7% to 35.4% in women. In Mongolian population, the optimal cut-off values of BF% for men and women ranged from 21.0% to 24.6% and from 35.7% to 40.0%, respectively. Subjects with high BF% (≥24% in men, ≥34% in women) had higher risk of CVD risk factors in Han (age-adjusted ORs from 1.479 to 3.680, 2.660 to 4.016, respectively). In Mongolian, adults with high BF% (≥25% in men, ≥35% in women) had higher risk of CVD risk factors (age-adjusted ORs from 2.587 to 3.772, 2.061 to 4.882, respectively). **Conclusions:** The optimal BF% cut-offs for obesity for the prediction of CVD risk factors in Chinese men and women were approximately 24% and 34% for Han adults, and 25% and 35% for Mongolian population of Inner Mongolia, China, respectively.

Strengths and limitations of this study

The present study was first designed to determine the optimal cut-off values of BF% for CVD risk factors (hypertension, diabetes, dyslipidemia) and clustering of ≥2 these risk factors in Chinese population.

This study used a large sample covering most age groups to estimate BF% cut-off values for discriminating CVD risk factors in both sexes, especially in different ethnics (Han and Mongolian) in China.

The prevention of public health problems was evaluated by PARP of BF% cut-offs in sexes and races.

The study characterizes the optimal body fat percentage cut-off values for identifying CVD risk factors in a cross-sectional setting using the occurrence of established CVD risk factors as a proxy risk estimate. Lots of epidemic studies, especially prospective cohort studies, need to be completed to improve cutoff points accuracy of BF% in China.

BF% in this study was measured using bioelectrical impedance analysis, which tends to underestimate body fat in all subjects and in men and women separately. However, considering the convenience and inexpensiveness of BIA, large-scale epidemiological investigations appropriately use this analysis.

Introduction

During the past four decades, the global prevalence of overweight and obesity has risen dramatically and is now estimated to affect over 600 million people[1]. In China, the prevalence of obesity approximately tripled from 3.75% in 1991 to 11.3% in 2011 according to diagnostic criteria of the Working Group on Obesity[2]. It is now identified that obesity essentially increases the risk of hypertension, diabetes and dyslipidemia, which has a great influence on the morbidity and mortality of Cardiovascular disease (CVD)[3].

Body mass index(BMI) closely correlated with body fatness is recommended by WHO as a population-level measure of overweight and obesity (BMI≥30 or 25 kg/m^2 is defined as obese or overweight, respectively). However, it may not consistently characterize adiposity across racial/ethnic groups[4]. Body fat percentage (BF%) as a percentage of total bodyweight has advantages over BMI in estimating fat mass[5]. The BF% cut-off points for obesity proposed by the WHO are 25% for men and 35% for women, corresponding a BMI of 30 kg/m^2 in young Caucasians[6]. It was reported that BMI and percentage of body fat differ across populations[7]. The Chinese tend to have a lower BMI but a higher fat volume. Li and colleagues[8] showed that the BF% cut-off values for Chinese adults were similar to those proposed by the WHO. However, a longitudinal epidemiological study[9] reflected that the present Chinese BMI criteria (28 kg/m^2 for obesity) was relatively inconsistent with WHO BF% criteria in determining obesity. Therefore, the appropriate BF% cut-off points for Chinese remains inconclusive and needs to be further studied. Inner Mongolia Autonomous Region located in northern China consists mainly of Han and Mongolian. Compared with Han population, the dietary pattern of Mongolians tends to be traditionally rich in whole milk, fats and oils, which might increase greater risk of obesity in Mongolia [10]. In this study, we aimed to characterize the optimal BF% cut-off points in Mongolian and Han adults according to its risk for common CVD risk factors, including diabetes, hypertension and dyslipidemia.

Methods

Study population

The present study was based on data from the China National Health Survey (CNHS) in Inner Mongolia Autonomous region in 2014, which has already been described in detail elsewhere[11]. A total of 3508 examinees aged 20-80 years were found to be eligible for the study. We excluded individuals with incomplete data for hypertension, diabetes and dyslipidemia status, sex, age and the anthropometric indices (i.e., BMI, BF%). In addition, pregnant women were excluded. This resulted in a final analytical sample of 3221 adults (2308 Han and 913 Mongolian).

Written informed consent was acquired from each participant before data collection. The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences.

Data collection

A standardized health questionnaire was completed by investigators and contained demographic information, diseases (particularly hypertension, diabetes) and the family history of diabetes, cardiovascular disease, or cancer. Anthropometric measurements including height, weight, and body fat percentage were taken with the subjects after an overnight fast and wearing light clothes and without shoes in the morning. Height was measured to the nearest 0.1cm using a fixed stadiometer. Body weight was measured in an upright position to the nearest 0.1kg. Body weight and body fat percentage was measured by bioelectrical impedance analysis (BIA), with a commercially available body analyzer (BC-420, TANITA, Japan). BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Blood pressure was taken three times using the electronic sphygmomanometer (HEM-907, OMRON, Japan) and the average was used as the mean blood pressure. All surveys were performed by trained staff.

Blood samples were collected from all participants following an overnight fast. Serum total cholesterol (TC), triglycerides (TG), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), and fasting plasma glucose (FPG) were determined by General Hospital of Chinese PLA.

Definition

Diabetes was defined as FPG ≥7.0mmol/L and/or physician-diagnosed diabetes. Hypertension was defined as mean systolic blood pressure (SBP) ≥140mmHg and/or mean diastolic blood pressure (DBP) ≥90mmHg and/or physician-diagnosed hypertension. Dyslipidemia was defined as follow: TC≥6.22mmol/L and/or LDL-C≥4.14mmol/L and/or HDL-C<1.04mmol/L and/or TG ≥2.26mmol/L. Clustering of risk factors was defined as presence of ≥2 CVD risk factors. Overweight and obesity were defined as a subject with BMI≥25 and <30 kg/m^2, and BMI≥ 30kg/m^2 respectively,

Statistical analysis

Statistical analysis was performed using SAS software (version 9.3; SAS Institute, Cary, NC, USA). Continuous variables were presented as mean±SD; comparisons between two groups were used by Student's t test. Categorical variables were expressed as percentages and compared by Chi-square test. Two-tailed *P*-value less than 0.05 was considered statistically significant.

Receive operating characteristic (ROC) curve analysis was performed to using BF% as continuous variable in logistic regression models to obtain accurate estimates of area under the cure (AUC) in relation to hypertension, diabetes, and dyslipidemia, which describe the probability that a test will correctly identify subjects with disease. The optimal cut-off values were defined as the points on the ROC curve where Youden's index (sensitivity+specificity-1) was the maximal. Odd ratios (ORs) and the corresponding 95% confidence interval (CI) were calculated by binary logistic regression analysis to measure the association between obesity defined by BF% and CVD risk factors. PARP (percent of prevalence of a condition/disease in the population due to presence of risk factor or percent of prevalence of a condition/disease in the population that would be reduced if risk factor was removed) for each CVD risk factor was calculated by sex-specific cut-offs for BF%. Formulas for calculation of PARP are given below.

$$PARP = 100 * P\,(OR\text{-}1) \,/\, [\, P\,(OR\text{-}1) + 1]\ \%$$

(*P*: percent of subjects whose BF% was above the sex-specific cut-off value; *OR*: age-adjusted odds ratios for cardiovascular risk factors in subjects using sex-specific cut-offs for BF%)

Results

Base characteristics of subjects

Baseline characteristics for men and women in Han and Mongolian adults are shown in Table 1. In Han adults, men had a higher mean BMI, SBP, DBP, FG, TC, TG, meanwhile a lower BF% and HDL-C than women. LDL-C were comparable between men and women (P>0.05). The prevalence of hypertension, diabetes, and dyslipidemia were higher in men than in women. Similarly, in Mongolian adults, men had a higher mean BMI, SBP, DBP, FG, TC, TG, LDL-C whereas a lower BF% and HDL-C than women. The prevalence of CVD risk factors was higher in men than in women. In total, compared with Han population, Mongolian had a higher mean weight, BMI, BF%, TC, LDL-C, HDL-C but a lower TG. Moreover, the prevalence of obesity and hypertension was higher in Mongolian than in Han.

Area under ROC and optimal cut-offs for predicting CVD risk factors

Figure 1 shows ROC curves of BF% for identifying CVD risk factors in men and women among Han and Mongolian adults. Area under ROC curves of BF% stratified by age groups are summarized in Table 2. In Han population, the AUC of BF% ranged from 0.589 to 0.699 for men and from 0.711 to 0.763 for women. Compared with men, AUCs for diabetes and clustering of ≥2 risk factors in women were significantly higher(P<0.05). In addition, the AUC for CVD risk factors were larger in the younger age group than that in the older in women (P<0.05). However, AUCs for cardiovascular risk factors were all comparable between men and women in Mongolian adults (P>0.05). Among these, the AUCs of BF% ranged from 0.686 to 0.736 for men and from 0.685 to 0.783 for women. Although BF% performed differently for CVD risk factors in age groups of both sexes, there were no significant difference in the AUCs (P>0.05).

Optimal cut-off points of BF% for CVD risk factors in both ethnic groups were given in Table 3, which were identified according to the highest Youden's index on ROC curves. In Han adults, the BF% cut-off values were found to optimally predict the risk of hypertension, diabetes and dyslipidemia varied from 18.7% to 24.2% in men, and 32.7% to 35.4% in women. In addition, the optimal cut-off points of BF% were all higher for women than for men in each CVD risk factor. In Mongolian, the optimal BF% cut-off values for men and women ranged from 21.0% to 24.6% and from 35.7% to 40.0%, respectively. The optimal BF% cut-offs between men and women in Mongolian adults were remarkably different. Basically, the optimal cut-off values of BF% in women were mostly higher for older age group than for the younger in Han and Mongolian adults. However, the optimal BF% cut-off points varied greatly by age and CVD risk factors.

The optimal cut-offs of BF% for identifying CVD risk factors in Han and Mongolian adults were also assessed. Table 4 and Table 5 show the sensitivity, specificity and Youden's index for the various cut-off values for BF% in men and women. Clearly, specificity gradually increased but sensitivity conversely decreased with the increase cut-off values of BF% in men and women. BF% cut-off points of preferable sensitivity and specificity to detect each CVD risk factor and clustering of ≥2 risk factors were selected as optimal values. In Han population, 24% and 34 % were the optimal BF% cut-off values in terms of the Youden's index, sensitivity and specificity for men and women, respectively. In Mongolian, the optimal cut-off points of BF% were 25% for men and 35% for women.

The age-adjusted OR(95%CI) and PARP of each CVD risk factor using sex-specific cut-offs for BF% in Han and Mongolian adults are shown in Table 6. In Han adults, BF% corresponded to significantly higher OR for hypertension and dyslipidemia in men except diabetes, while BF%

corresponded to significantly higher OR for all CVD risk factors in women. In Mongolian population, BF% corresponded to significantly higher OR for all CVD risk factors in both sexes except diabetes in women. According to PARP analysis, the proportion of Han adults whose BF% ≥24% was about 43% in men. If BF% were controlled below 24%, 53.8% of hypertension, 17.2% of diabetes, 46.1% of dyslipidemia, and 51.6% of clustering of ≥2 CVD risk factors would be prevented. Women whose BF% ≥34% was about 45% in Han women. If BF% were controlled under 24%, 57.6% of clustering of ≥2 risk factors would be prevented. In Mongolian, the proportions of subjects whose BF% above 25% for men and 35% for women were round 46% and 47%, respectively. If BF% were controlled under 25% for men and 35% for women, 56%-65% of clustering of ≥2 risk factors would be prevented.

Discussion

The present study, using data obtained from Han and Mongolian adults from Inner Mongolia, China showed that BF% performed differently for discriminating CVD risk factors in sex and ethnicity. The optimal BF% cut-off points for men and women were approximately 24.0% and 34.0% in Han adults, and 25.0% and 35.0% in Mongolian population, respectively. Compared with WHO criteria, the optimal BF% cut-offs in this study were a little lower in Han adults, but similar in Mongolian, which were taken account of validity to detect CVD risk factors and clustering two or more CVD risk factors.

BMI is the most widely used measure to diagnose obesity. However, the accuracy of BMI in detecting excess body adiposity in the general adult population is limited, because BMI cannot measure BF% directly and poorly distinguishes among total body fat, total body lean, and bone mass[12, 13]. To overcome misclassifications, direct measurements of BF% would be a better tool for diagnosing obesity. Moreover, BF% has been found to have a strong association with multiple CVD risk factors in several studies conducted in China[8], Korea[14], and other ethnic groups[15-17]. Our data also support the good discrimination of BF% for each CVD risk factor and clustering of ≥2 risk factors in both sexes and ethnicities. However, BF% seems performed better in women than in men to detect CVD risk factors, which might result from greater less mass and lower fat mass men had than women[18]. Besides, BF% had larger AUCs for almost CVD risk factors in women aged <50 years than in the older women, but not obviously in men. In a Korean study, women after menopause had not only higher total body fat percentage but also its different distribution, which independently correlates with cardiovascular disease risk factors[19]. In addition, a study of 402 women aged 30-75 years in Southern India also shown that menopausal status and associated obesity created a compatible atmosphere for abnormal metabolism and aggravated cardio metabolic risk factors[20]. However, the relationship between obesity in women after menopause and CVD risk factors is more vulnerable to the effect of confounding variables, such as ageing, which might affect the accuracy of prediction of BF% for CVD risk factors.

It has been demonstrated that adipose tissue distribution varies among different ethnicities[21]. As is well known, the increased risks of metabolic diseases associated with obesity occur at lower BMIs in Asians, and these population are predisposed to visceral or abdominal obesity. In a study of peri- and postmenopausal women in Thai, 34% was proposed as the optimal BF% cut-off points to identify women at risk of metabolic syndrome[22]. In addition, A cross-sectional study of the middle-aged Japanese men shown that the cut-off point of BF% for detecting participants with 1 or more CVD risk factors (diabetes mellitus, hypertension, dyslipidemia) was 20.3%[23]. Joseph, *et al*. recommended an optimal BF% cut-off values of 25.5 in men and 38.0 in women for

Asian Indian individuals[24]. Furthermore, Kim, *et al* reported that a BF% of 21% for men and 37% for women may be the appropriate cut-off values in Korean adults[25]. These discrepancies mainly result from different ethnic groups, age and outcome. By now, BF% has not been recommended as an adiposity index in the Chinese population yet, and there has been little study on the cutoff point for BF%. Li, *et al* proposed 25% and 35% as optimal BF% cut-off points for Chinese men and women to predict metabolic syndrome and Type 2 diabetes using data from the Shanghai Diabetes Studies (SHDS), respectively[8]. In this study, the optimal cut-off values of BF% to detect diabetes, hypertension, and dyslipidemia for men and women in Han adults were found to be 24% and 34%, respectively. In Mongolian population, the optimal BF% cut-offs were 25% for men and 35% for women. Mongolians have a distinctive lifestyle and dietary habits characterized by a preference for high protein and fatty foods of animal origin[26], which is different from Han population. Zhang, *et al* reported the prevalence of overweight or obesity was higher in Mongolian people than Han people using WHO criteria (26.1% vs 21.3%, respectively)[27]. Moreover, a study evaluating the relationship among ethnic groups and their CVD risk factors (hypertension, obesity, diabetes, dyslipidemia, smoking) shown that clustering of ≥2 or ≥3 of these risk factors was noted in 66.9% or 36.5% of Mongolian as well as 62.0% or 28.3% of Han subjects, respectively[28]. Because of different genetic backgrounds, lifestyles and dietary patterns, the optimal BF% cut-offs of Han adults may be not the same as Mongolian.

There are some limitations to our study. A major limitation of the present study is cross-sectional design, which cannot be used to establish temporal relationship and causality. Lots of epidemic studies, especially prospective cohort studies, need to be completed to improve cutoff points accuracy of BF% in China. Second, BF% in this study was measured using bioelectrical impedance analysis, which tends to underestimate body fat in all subjects and in men and women separately[29]. However, considering the convenience and inexpensiveness of BIA, large-scale epidemiological investigations appropriately use this analysis. Finally, the subjects were from Inner Mongolia, so the study's findings cannot necessarily be representative of all Chinese adults, especially Han people.

The current definitions of obesity using BF% are based on Western populations and probably need to be modified for Chinese population. The present study showed the optimal BF% cut-off points for men and women were around 24.0% and 34.0% in Han adults, and 25.0% and 35.0% in Mongolian population of Inner Mongolia, China, respectively. Considering the rapid growth of obesity in China[2], these optimal body fat percentage cut-offs will contribute to public health prevention and intervention.

Acknowledgments This study was supported by the National Science & Technology Pillar Program during the 12th Five-year Plan Period, Grant 2012BAI37B02 from the Ministry of Science and Technology, Beijing, People's Republic of China to Guangliang Shan, which enabled the completion of the project. We sincerely express our gratitude to all the staff of Inner Mongolia Autonomous Region Center for Disease Control and Prevention for support with the collection of demographic data.

Contributors YL participated in the data collection and drafted the manuscript. HW, WW, HG, YQ, GX, GL participated in the data collection. KW, FD, LP, GZ, GS participated in the design of the study and undertook statistical analyses. All authors were involved in writing the paper and had final approval of the submitted and published versions.

Funding This study was supported by the National Science & Technology Pillar Program during the 12th Five-year Plan Period, Grant 2012BAI37B02 from the Ministry of Science and Technology, Beijing, People's Republic of China to Guangliang Shan.

Competing interests None declared.

Ethics approval The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences(NO.028-2013).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

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Table 1. Baseline Characteristics by sex in Han and Mongolian adults

Variables	Han(n=2308)			Mongolian(n=913)		
	Men(n=898)	Women(n=1410)	All cases	Men(n=355)	Women(n=558)	All cases
Age(years)	46.20±14.05***	44.24±13.29	45.00±13.62	45.91±13.69**	43.34±13.03	44.34±13.34
Age groups (%)	***			***		
20-49	58.02	66.52	63.21	57.75	68.64	64.4
50-80	41.98	33.48	36.79	42.25	31.36	35.6
Height(cm)	170.12±5.94***	158.28±5.51	162.89±8.10	170.54±6.35***	158.53±5.46	163.21±8.26
Weight(kg)	72.92±12.18***	60.20±9.70	65.15±12.39###	75.11±12.96***	61.54±10.08	66.82±13.08
BMI(kg/m2)	25.17±3.82***	24.04±3.72	24.48±3.80###	25.78±3.96***	24.52±4.07	25.01±4.07
BMI groups (%)	***		###	***		
overweight	40.42	34.04	36.53	41.41	37.28	38.88
obesity	21.71	14.04	17.03	28.45	17.92	22.02
BF (%)	22.54±5.77***	32.95±6.18	28.90±7.88###	23.86±5.72***	33.98±6.40	30.05±7.88
SBP(mmHg)	127.40±14.96***	119.07±17.14	122.31±16.82	129.4±16.05***	118.22±17.65	122.57±17.89
DBP(mmHg)	80.21±10.52***	75.42±10.66	77.28±10.86	82.2±11.89***	75.67±11.96	78.21±12.34
FPG(mmol/L)	5.53±1.49***	5.22±1.08	5.34±1.27	5.56±1.48***	5.14±1.09	5.30±1.27
TC(mmol/L)	4.86±1.00*	4.76±1.04	4.80±1.03###	5.10±0.97***	4.89±1.03	4.98±1.02
TG(mmol/L)	2.18±1.89***	1.55±1.13	1.80±1.50##	2.00±1.46***	1.46±1.18	1.67±1.32
LDL-C(mmol/L)	2.86±0.86	2.83±0.85	2.84±0.86###	3.13±0.87***	2.93±0.86	3.01±0.87
HDL-C(mmol/L)	1.19±0.32***	1.39±0.34	1.31±0.34###	1.27±0.34***	1.45±0.37	1.38±0.37
Hypertension (%)	33.74***	23.48	27.47#	40.28***	25.63	31.33
Diabetes (%)	9.58***	5.53	7.11	9.86***	3.23	5.81
Dyslipidemia (%)	51.11***	27.73	36.83	47.32***	26.34	34.5
Risk factors≥ 2(%)	24.16***	12.2	16.85	27.32***	13.8	19.06

Values are means ± SD or %.

**P*<0.05, ***P*<0.01, ****P*<0.001 compared with women within Han or Mongolian adults; #P<0.05, ##P<0.01, ###P<0.001 compared with Mongolian adults (Student's t-tests for continuous variables; Chi-square tests for categorical variables).

BF (%), body fat percentage; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;

TC, total cholesterol; TG, triglycerides; LDL-C, low-density lipoprotein-cholesterol; HDL-C, high-density lipoprotein-cholesterol.

Table 2. Area under receiver operating characteristic (ROC) curves of BF% screening CVD risk factors

	Hypertension	Diabetes	Dyslipidemia	Risk factors≥2
Han				
Men				
All ages	0.696(0.661,0.732)	0.589(0.531,0.648)	0.682(0.647,0.717)	0.699(0.662,0.736)
20-49 years	0.734(0.686,0.782)	0.532(0.417,0.646)	0.700(0.655,0.745)	0.731(0.681,0.780)
50-80 years	0.666(0.611,0.720)	0.606(0.536,0.676)	0.661(0.607,0.716)	0.670(0.613,0.726)
Women				
All ages	0.737(0.707,0.767)	0.728(0.676,0.780) *	0.711(0.683,0.740)	0.763(0.729,0.797) *
20-49 years	0.761(0.718,0.805)	0.787(0.700,0.874)	0.735(0.698,0.773)	0.836(0.788,0.885)
50-80 years	0.645(0.595,0.695) #	0.617(0.544,0.689) #	0.596(0.545,0.646) #	0.644(0.590,0.698) #
Mongolian				
Men				
All ages	0.702(0.648,0.757)	0.686(0.609,0.764)	0.690(0.636,0.745)	0.736(0.683,0.789)
20-49 years	0.714(0.636,0.793)	0.765(0.646,0.884)	0.681(0.608,0.753)	0.764(0.688,0.839)
50-80 years	0.665(0.577,0.754)	0.609(0.498,0.720)	0.689(0.604,0.775)	0.689(0.606,0.772)
Women				
All ages	0.733(0.685,0.780)	0.733(0.601,0.865)	0.685(0.637,0.733)	0.783(0.730,0.835)
20-49 years	0.643(0.557,0.729)	0.729(0.616,0.842)	0.670(0.604,0.735)	0.764(0.666,0.863)
50-80 years	0.683(0.604,0.763)	0.664(0.481,0.848)	0.586(0.502,0.671)	0.690(0.607,0.773)

*P<0.05, Compared to men.

#P<0.05, Compared to 20-49 years.

Table 3. Optimal cut-off values of BF% and their sensitivities, specificities, and Youden's index for CVD risk factors by age groups and sex

	Hypertension				Diabetes				Dyslipidemia				Risk factors≥2			
	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI
Han																
Men																
All ages	24.2	62.7	70.3	33.0	18.7	94.2	23.5	17.7	21.6	77.3	52.4	29.7	24.2	64.5	66.7	31.2
20-49 years	24.2	69.3	71.1	40.4	18.8	92.3	24.6	17.0	21.6	75.8	56.0	31.9	24.2	68.4	67.8	36.3
50-80 years	24.2	58.0	68.7	26.6	22.5	75.0	45.1	20.1	20.5	87.1	41.9	29.0	25.0	54.9	71.8	26.7
Women																
All ages	34.2	71.9	64.8	36.7	35.4	69.2	67.5	36.7	32.7	77.2	55.8	33.1	33.7	83.1	58.1	41.2
20-49 years	33.6	73.7	67.2	40.9	32.0	94.4	52.6	47.1	33.9	66.1	70.3	36.5	33.9	90.5	65.6	56.1
50-80 years	36.8	52.6	70.7	23.2	35.4	70.0	51.2	21.2	34.8	66.8	50.6	17.4	36.7	56.9	65.5	22.4
Mongolian																
Men																
All ages	23.0	84.6	48.1	32.7	21.9	97.1	33.4	30.6	21.0	89.3	41.7	31.0	24.6	77.3	60.1	37.4
20-49 years	23.0	87.3	51.3	38.6	26.8	75.0	75.1	50.1	18.5	94.5	35.1	29.6	25.7	72.2	71.6	43.8
50-80 years	21.9	88.6	40.3	29.0	22.0	95.7	28.3	24.0	21.0	94.8	38.4	33.2	21.9	96.7	37.1	33.8
Women																
All ages	35.7	71.3	66.3	37.6	40.0	55.6	84.6	40.2	36.4	62.6	68.6	31.2	36.4	80.5	66.9	47.5
20-49 years	35.7	55.6	70.7	26.3	34.8	100.0	61.8	61.8	31.1	82.9	43.5	26.3	36.4	70.0	74.1	44.1
50-80 years	36.7	73.5	54.5	28.0	41.0	60.0	81.3	41.3	36.5	77.9	46.9	24.9	36.6	84.2	46.6	30.8

Sen, sensitivity; Spe, specificity; YI, Youden's index.

Table 4. Sensitivity, specificity and Youden's index for BF% to detect CVD risk factors by sex-specific cut-offs in Han adults

	Hypertension			Diabetes			Dyslipidemia			Risk factors≥2		
	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI
Men												
21	83.8	41.3	25.2	79.1	34.1	13.2	81.1	47.4	28.4	88.0	39.5	27.5
22	77.6	49.4	27.0	70.9	41.5	12.4	73.4	54.7	28.1	81.1	47.1	28.3
23	69.6	59.2	28.8	61.6	50.6	12.3	63.8	63.3	27.2	72.4	56.4	28.7
24	64.0	67.1	31.1	53.5	57.6	11.1	56.0	69.7	25.7	66.4	63.9	30.2
25	52.5	74.5	26.9	44.2	66.4	10.6	45.3	76.5	21.9	55.8	72.1	27.9
26	43.9	81.3	25.2	33.7	73.5	7.2	51.1	81.3	32.4	44.7	78.4	23.1
Women												
32	84.0	50.5	34.5	89.7	44.3	34.0	80.3	51.1	31.4	91.3	47.1	38.4
33	78.6	56.9	35.5	82.1	50.4	32.4	74.7	57.5	32.2	85.5	53.3	38.8
34	72.2	63.2	35.4	75.6	56.7	32.3	68.3	63.8	32.1	79.7	59.7	39.3
35	64.4	70.9	35.3	70.5	64.6	35.1	58.6	70.8	29.3	69.8	67.1	36.9
36	55.6	77.3	32.9	62.8	71.5	34.3	48.3	76.5	24.8	61.1	73.8	34.9
37	47.7	82.7	30.4	53.9	77.3	31.1	38.9	81.1	19.9	52.3	79.4	31.7

Sen, sensitivity; Spe, specificity; YI, Youden's index.

Table 5. Sensitivity, specificity and Youden's index for BF% to detect CVD risk factors by sex-specific cut-offs in Mongolian adults

	Hypertension			Diabetes			Dyslipidemia			Risk factors≥2		
	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI
Men												
21	88.1	37.3	25.4	97.1	29.7	26.8	89.3	41.7	31.0	95.9	35.7	31.5
22	86.7	43.4	30.1	94.3	34.1	28.4	82.7	43.9	26.6	93.8	40.7	34.5
23	84.6	48.1	32.7	88.6	37.5	26.1	81.0	49.2	30.2	91.8	45.0	36.7
24	72.7	54.7	27.5	82.9	46.6	29.4	69.1	55.1	24.1	79.4	52.3	31.7
25	60.8	64.2	25.0	71.4	56.9	28.3	60.1	66.8	27.0	70.1	63.2	33.3
26	53.2	72.2	25.3	60.0	64.4	24.4	49.4	72.2	21.6	60.8	70.5	31.4
Women												
32	84.6	42.9	27.5	83.3	36.5	19.8	81.6	42.1	23.7	92.2	40.3	32.5
33	79.7	48.9	28.6	83.3	42.4	25.7	76.9	48.2	25.1	88.3	46.4	34.7
34	75.5	54.7	30.2	83.3	48.0	31.3	73.5	54.3	27.7	85.7	52.2	37.9
35	73.4	62.2	35.6	77.8	54.1	31.9	68.7	60.8	29.5	84.4	59.0	43.5
36	68.5	67.0	35.5	66.7	58.7	25.4	63.3	65.5	28.7	80.5	64.0	44.6
37	58.7	73.5	32.2	61.1	66.1	27.2	55.1	72.5	27.6	70.1	70.9	41.0

Sen, sensitivity; Spe, specificity; YI, Youden's index.

Table 6. Age-adjusted OR(95%CI) and PARP of each CVD risk factor by sex-specific cut-offs for BF% in Han and Mongolian adults

	*OR**	*95%CI*	*PARP(%)*
Han			
Men(BF%⩾24%)			
Hypertension	3.680	2.728-4.964	53.8
Diabetes	1.479	0.940-2.328	17.2
Dyslipidemia	2.966	2.251-3.908	46.1
Risk factors⩾2	3.450	2.490-4.780	51.6
Women(BF%⩾34%)			
Hypertension	3.382	2.544-4.494	51.8
Diabetes	2.660	1.539-4.596	42.8
Dyslipidemia	3.152	2.439-4.072	49.3
Risk factors⩾2	4.016	2.682-6.014	57.6
Mongolian			
Men(BF%⩾25%)			
Hypertension	2.587	1.635-4.094	42.2
Diabetes	2.982	1.374-6.471	47.6
Dyslipidemia	2.986	1.930-4.620	47.7
Risk factors⩾2	3.772	2.251-6.321	56.0
Women(BF%⩾35%)			
Hypertension	2.851	1.796-4.526	46.5
Diabetes	2.061	0.634-6.697	33.3
Dyslipidemia	2.599	1.704-3.964	42.9
Risk factors⩾2	4.882	2.497-9.545	64.6

*Adjusted odds ratios for cardiovascular risk factors in subjects using sex-specific cut-offs for BF%, adjusted for age.
OR, odds ratios; PARP, population attributable risk proportion.

Figure 1. ROC curves for BF% screening CVD risk factors in men and women among Han and Mongolian adults.

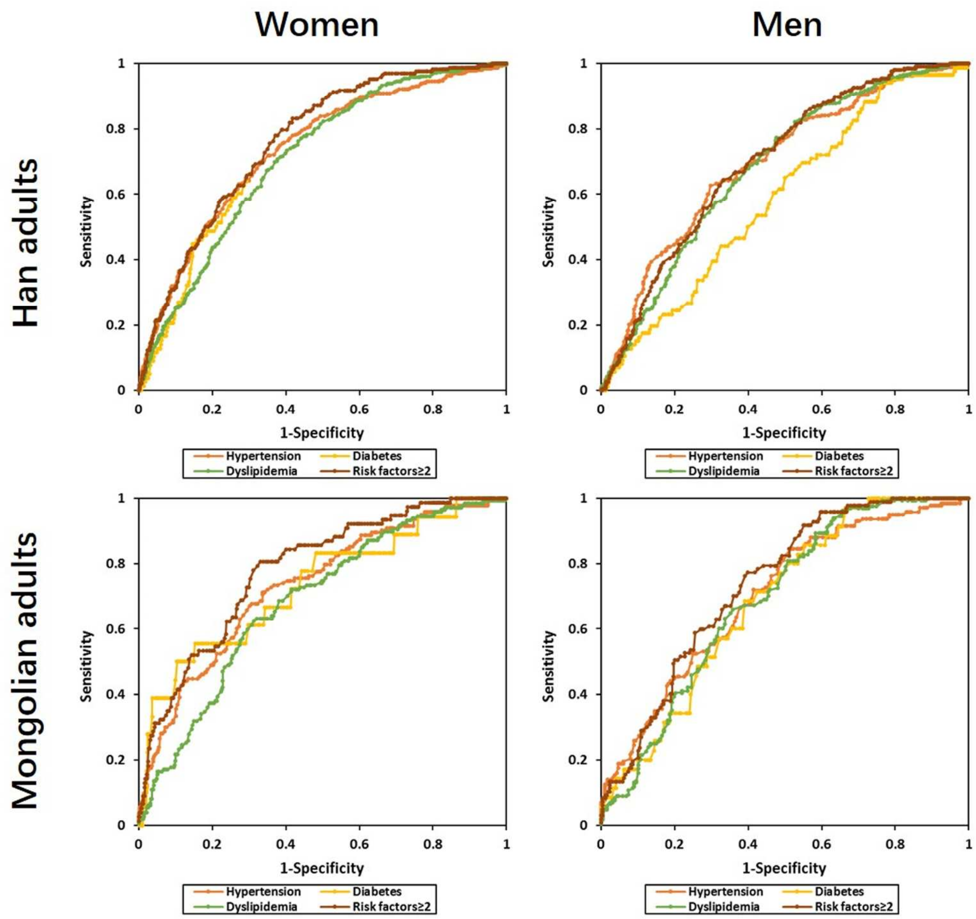

Figure 1 ROC curves for BF% screening CVD risk factors.
Optimal body fat percentage cu
283x267mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3-4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	3-4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	4-5
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Results			**Page No**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	3,5
		(b) Give reasons for non-participation at each stage	3,5
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	5-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	2
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Optimal body fat percentage cut-off values for identifying cardiovascular risk factors in Mongolian and Han adults: A Population-based Cross-Sectional Study in Inner Mongolia, China

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-014675.R2
Article Type:	Research
Date Submitted by the Author:	09-Mar-2017

Complete List of Authors:	Li, Yanlong; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics Wang, Hailing; Inner Mongolia Center for Disease Control and Prevention Wang, Ke; Sichuan University West China Second University Hospital, National Office for Maternal and Child Health Surveillance of China, Department of Obstetrics, Key Laboratory of Birth Defects and Related Diseases of Women and Children (Sichuan University), Ministry of Education Wang, Wenrui; Inner Mongolia Center for Disease Control and Prevention Dong, Fen; China-Japan Friendship Hospital Qian, Yonggang; Inner Mongolia Center for Disease Control and Prevention Gong, Haiying; Fangshan District Center for Disease Control and Prevention Xu, Guodong; China-Japan Friendship Hospital Li, Guoju; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences,, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics Pan, Li; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics Zhu, Guangjin; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics shan, guangliang; Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, Department of Epidemiology and Statistics; School of Basic Medicine, Peking Union Medical College, Department of Epidemiology and Statistics

Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	body composition, obesity, cardiovascular risk factors

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Optimal body fat percentage cut-off values for identifying cardiovascular risk factors in Mongolian and Han adults: A Population-based Cross-Sectional Study in Inner Mongolia, China

Yanlong Li[1], Hailing Wang [2], Ke Wang[3], Wenrui Wang[2], Fen Dong[4], Yonggang Qian[2], Haiying Gong[5], Guodong Xu[4], Guoju Li[1], Li Pan[1], Guangjin Zhu[1], Guangliang Shan[1]

[1] Department of Epidemiology and Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, School of Basic Medicine, Peking Union Medical College, Beijing, China

[2] Inner Mongolia Center for Disease Control and Prevention, Hohhot, China

[3] National Office for Maternal and Child Health Surveillance of China, Department of Obstetrics, Key Laboratory of Birth Defects and Related Diseases of Women and Children (Sichuan University), Ministry of Education, West China Second University Hospital, Sichuan University, Chengdu, China.

[4] China-Japan Friendship Hospital, Beijing, China

[5] Fangshan District Center for Disease Control and Prevention, Beijing, China

Keywords: body composition, obesity, cardiovascular risk factors

Running Title: Optimal BF% cut-offs in Chinese

Corresponding Author:

Guangliang Shan

Department of Epidemiology and Statistics, Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences, School of Basic Medicine, Peking Union Medical College, Beijing 100005, China

Guangliang_shan@163.com

Word Count: 2675 words

Tables: 6

Figures: 1

Supplementary Files: 0

Abstract

Objective: The present study was designed to determine the optimal cut-off values of body fat percentage (BF%) for the detection of cardiovascular disease (CVD) risk factors in Mongolian and Han adults. **Method:** This cross-sectional study involving 3221 Chinese adults (2308 Han and 913 Mongolian) aged 20-80 years was conducted in Inner Mongolia Autonomous region, China, in 2014. Data from a standardized questionnaire, physical examination, and blood sample were obtained. The BF% was estimated using bioelectrical impedance analysis. Optimal BF% cut-offs were analyzed by receiver operating characteristic (ROC) curves to predict the risk of diabetes, hypertension, dyslipidemia. Binary logistic regression analysis was performed to evaluate the odds ratio (OR) of each CVD risk factor according to obesity defined by BF%. **Results:** Mean BF% levels were lower in men than in women (22.54±5.77 vs 32.95±6.18 in Han, 23.86±5.72 vs 33.98±6.40 in Mongolian, respectively; $P<0.001$). In Han population, the area under curve (AUC) values for BF% ranged from 0.589 to 0.699 for men and from 0.711 to 0.763 for women. Compared with men, AUCs for diabetes and clustering of ≥2 risk factors in women were significantly higher (P<0.05). The AUCs for BF% in women (0.685-0.783) were similar with those in men (0.686-0.736) for CVD risk factors in Mongolian. In Han adults, the optimal BF% cut-off values to detect CVD risk factors varied from 18.7% to 24.2% in men, and 32.7% to 35.4% in women. In Mongolian population, the optimal cut-off values of BF% for men and women ranged from 21.0% to 24.6% and from 35.7% to 40.0%, respectively. Subjects with high BF% (≥24% in men, ≥34% in women) had higher risk of CVD risk factors in Han (age-adjusted ORs from 1.479 to 3.680, 2.660 to 4.016, respectively). In Mongolian, adults with high BF% (≥25% in men, ≥35% in women) had higher risk of CVD risk factors (age-adjusted ORs from 2.587 to 3.772, 2.061 to 4.882, respectively). **Conclusions:** The optimal BF% cut-offs for obesity for the prediction of CVD risk factors in Chinese men and women were approximately 24% and 34% for Han adults, and 25% and 35% for Mongolian population of Inner Mongolia, China, respectively.

Strengths and limitations of this study

The present study was first designed to determine the optimal cut-off values of BF% for CVD risk factors (hypertension, diabetes, dyslipidemia) and clustering of ≥2 these risk factors in Chinese population.

This study used a large sample covering most age groups to estimate BF% cut-off values for discriminating CVD risk factors in both sexes, especially in different ethnics (Han and Mongolian) in China.

The prevention of public health problems was evaluated by PARP of BF% cut-offs in sexes and races.

The study characterizes the optimal body fat percentage cut-off values for identifying CVD risk factors in a cross-sectional setting using the occurrence of established CVD risk factors as a proxy risk estimate. Lots of epidemic studies, especially prospective cohort studies, need to be completed to improve cutoff points accuracy of BF% in China.

BF% in this study was measured using bioelectrical impedance analysis, which tends to underestimate body fat in all subjects and in men and women separately. However, considering the convenience and inexpensiveness of BIA, large-scale epidemiological investigations appropriately use this analysis.

Introduction

During the past four decades, the global prevalence of overweight and obesity has risen dramatically and is now estimated to affect over 600 million people[1]. In China, the prevalence of obesity approximately tripled from 3.75% in 1991 to 11.3% in 2011 according to diagnostic criteria of the Working Group on Obesity[2]. It is now identified that obesity essentially increases the risk of hypertension, diabetes and dyslipidemia, which has a great influence on the morbidity and mortality of Cardiovascular disease (CVD)[3].

Body mass index(BMI) closely correlated with body fatness is recommended by WHO as a population-level measure of overweight and obesity (BMI≥30 or 25 kg/m^2 is defined as obese or overweight, respectively). However, it may not consistently characterize adiposity across racial/ethnic groups[4]. Body fat percentage (BF%) as a percentage of total bodyweight has advantages over BMI in estimating fat mass[5]. The BF% cut-off points for obesity proposed by the WHO are 25% for men and 35% for women, corresponding a BMI of 30 kg/m^2 in young Caucasians[6]. It was reported that BMI and percentage of body fat differ across populations[7]. The Chinese tend to have a lower BMI but a higher fat volume. Li and colleagues[8] showed that the BF% cut-off values for Chinese adults were similar to those proposed by the WHO. However, a longitudinal epidemiological study[9] reflected that the present Chinese BMI criteria (28 kg/m^2 for obesity) was relatively inconsistent with WHO BF% criteria in determining obesity. Therefore, the appropriate BF% cut-off points for Chinese remains inconclusive and needs to be further studied. Inner Mongolia Autonomous Region located in northern China consists mainly of Han and Mongolian. Compared with Han population, the dietary pattern of Mongolians tends to be traditionally rich in whole milk, fats and oils, which might increase greater risk of obesity in Mongolia [10]. In this study, we aimed to characterize the optimal BF% cut-off points in Mongolian and Han adults according to its risk for common CVD risk factors, including diabetes, hypertension and dyslipidemia.

Methods

Study population

The present study was based on data from the China National Health Survey (CNHS) in Inner Mongolia Autonomous region in 2014, which has already been described in detail elsewhere[11]. A total of 3508 examinees aged 20-80 years were found to be eligible for the study. We excluded individuals with incomplete data for hypertension, diabetes and dyslipidemia status, sex, age and the anthropometric indices (i.e., BMI, BF%). In addition, pregnant women were excluded. This resulted in a final analytical sample of 3221 adults (2308 Han and 913 Mongolian).

Written informed consent was acquired from each participant before data collection. The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences.

Data collection

A standardized health questionnaire was completed by investigators and contained demographic information, diseases (particularly hypertension, diabetes) and the family history of diabetes, cardiovascular disease, or cancer. Anthropometric measurements including height, weight, and body fat percentage were taken with the subjects after an overnight fast and wearing light clothes and without shoes in the morning. Height was measured to the nearest 0.1cm using a fixed stadiometer. Body weight was measured in an upright position to the nearest 0.1kg. Body weight and body fat percentage was measured by bioelectrical impedance analysis (BIA), with a commercially available body analyzer (BC-420, TANITA, Japan). BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Blood pressure was taken three times using the electronic sphygmomanometer (HEM-907, OMRON, Japan) and the average was used as the mean blood pressure. All surveys were performed by trained staff.

Blood samples were collected from all participants following an overnight fast. Serum total cholesterol (TC), triglycerides (TG), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), and fasting plasma glucose (FPG) were determined by General Hospital of Chinese PLA.

Definition

Diabetes was defined as FPG ≥7.0mmol/L and/or physician-diagnosed diabetes. Hypertension was defined as mean systolic blood pressure (SBP) ≥140mmHg and/or mean diastolic blood pressure (DBP) ≥90mmHg and/or physician-diagnosed hypertension. Dyslipidemia was defined as follow: TC≥6.22mmol/L and/or LDL-C≥4.14mmol/L and/or HDL-C<1.04mmol/L and/or TG ≥2.26mmol/L. Clustering of risk factors was defined as presence of ≥2 CVD risk factors. Overweight and obesity were defined as a subject with BMI≥25 and <30 kg/m^2, and BMI≥ 30kg/m^2 respectively,

Statistical analysis

Statistical analysis was performed using SAS software (version 9.3; SAS Institute, Cary, NC, USA). Continuous variables were presented as mean±SD; comparisons between two groups were used by Student's t test. Categorical variables were expressed as percentages and compared by Chi-square test. Two-tailed *P*-value less than 0.05 was considered statistically significant.

Receive operating characteristic (ROC) curve analysis was performed to using BF% as continuous variable in logistic regression models to obtain accurate estimates of area under the cure (AUC) in relation to hypertension, diabetes, and dyslipidemia, which describe the probability that a test will correctly identify subjects with disease. The optimal cut-off values were defined as the points on the ROC curve where Youden's index (sensitivity+specificity-1) was the maximal. Odd ratios (ORs) and the corresponding 95% confidence interval (CI) were calculated by binary logistic regression analysis to measure the association between obesity defined by BF% and CVD risk factors. PARP (percent of prevalence of a condition/disease in the population due to presence of risk factor or percent of prevalence of a condition/disease in the population that would be reduced if risk factor was removed) for each CVD risk factor was calculated by sex-specific cut-offs for BF%. Formulas for calculation of PARP are given below.

$$PARP = 100 * P\,(OR\text{-}1) / [\,P\,(OR\text{-}1) + 1]\ \%$$

(*P*: percent of subjects whose BF% was above the sex-specific cut-off value; *OR*: age-adjusted odds ratios for cardiovascular risk factors in subjects using sex-specific cut-offs for BF%)

Results

Base characteristics of subjects

Baseline characteristics for men and women in Han and Mongolian adults are shown in Table 1. In Han adults, men had a higher mean BMI, SBP, DBP, FG, TC, TG, meanwhile a lower BF% and HDL-C than women. LDL-C were comparable between men and women (*P*>0.05). The prevalence of hypertension, diabetes, and dyslipidemia were higher in men than in women. Similarly, in Mongolian adults, men had a higher mean BMI, SBP, DBP, FG, TC, TG, LDL-C whereas a lower BF% and HDL-C than women. The prevalence of CVD risk factors was higher in men than in women. In total, compared with Han population, Mongolian had a higher mean weight, BMI, BF%, TC, LDL-C, HDL-C but a lower TG. Moreover, the prevalence of obesity and hypertension was higher in Mongolian than in Han.

Area under ROC and optimal cut-offs for predicting CVD risk factors

Figure 1 shows ROC curves of BF% for identifying CVD risk factors in men and women among Han and Mongolian adults. Area under ROC curves of BF% stratified by age groups are summarized in Table 2. In Han population, the AUC of BF% ranged from 0.589 to 0.699 for men and from 0.711 to 0.763 for women. Compared with men, AUCs for diabetes and clustering of ≥2 risk factors in women were significantly higher(*P*<0.05). In addition, the AUC for CVD risk factors were larger in the younger age group than that in the older in women (*P*<0.05). However, AUCs for cardiovascular risk factors were all comparable between men and women in Mongolian adults (*P*>0.05). Among these, the AUCs of BF% ranged from 0.686 to 0.736 for men and from 0.685 to 0.783 for women. Although BF% performed differently for CVD risk factors in age groups of both sexes, there were no significant difference in the AUCs (*P*>0.05).

Optimal cut-off points of BF% for CVD risk factors in both ethnic groups were given in Table 3, which were identified according to the highest Youden's index on ROC curves. In Han adults, the BF% cut-off values were found to optimally predict the risk of hypertension, diabetes and dyslipidemia varied from 18.7% to 24.2% in men, and 32.7% to 35.4% in women. In addition, the optimal cut-off points of BF% were all higher for women than for men in each CVD risk factor. In Mongolian, the optimal BF% cut-off values for men and women ranged from 21.0% to 24.6% and from 35.7% to 40.0%, respectively. The optimal BF% cut-offs between men and women in Mongolian adults were remarkably different. Basically, the optimal cut-off values of BF% in women were mostly higher for older age group than for the younger in Han and Mongolian adults. However, the optimal BF% cut-off points varied greatly by age and CVD risk factors.

The optimal cut-offs of BF% for identifying CVD risk factors in Han and Mongolian adults were also assessed. Table 4 and Table 5 show the sensitivity, specificity and Youden's index for the various cut-off values for BF% in men and women. Clearly, specificity gradually increased but sensitivity conversely decreased with the increase cut-off values of BF% in men and women. BF% cut-off points of preferable sensitivity and specificity to detect each CVD risk factor and clustering of ≥2 risk factors were selected as optimal values. In Han population, 24% and 34 % were the optimal BF% cut-off values in terms of the Youden's index, sensitivity and specificity for men and women, respectively. In Mongolian, the optimal cut-off points of BF% were 25% for men and 35% for women.

The age-adjusted OR(95%CI) and PARP of each CVD risk factor using sex-specific cut-offs for BF% in Han and Mongolian adults are shown in Table 6. In Han adults, BF% corresponded to significantly higher OR for hypertension and dyslipidemia in men except diabetes, while BF%

corresponded to significantly higher OR for all CVD risk factors in women. In Mongolian population, BF% corresponded to significantly higher OR for all CVD risk factors in both sexes except diabetes in women. According to PARP analysis, the proportion of Han adults whose BF% ≥24% was about 43% in men. If BF% were controlled below 24%, 53.8% of hypertension, 17.2% of diabetes, 46.1% of dyslipidemia, and 51.6% of clustering of ≥2 CVD risk factors would be prevented. Women whose BF% ≥34% was about 45% in Han women. If BF% were controlled under 24%, 57.6% of clustering of ≥2 risk factors would be prevented. In Mongolian, the proportions of subjects whose BF% above 25% for men and 35% for women were round 46% and 47%, respectively. If BF% were controlled under 25% for men and 35% for women, 56%-65% of clustering of ≥2 risk factors would be prevented.

Discussion

The present study, using data obtained from Han and Mongolian adults from Inner Mongolia, China showed that BF% performed differently for discriminating CVD risk factors in sex and ethnicity. The optimal BF% cut-off points for men and women were approximately 24.0% and 34.0% in Han adults, and 25.0% and 35.0% in Mongolian population, respectively. Compared with WHO criteria, the optimal BF% cut-offs in this study were a little lower in Han adults, but similar in Mongolian, which were taken account of validity to detect CVD risk factors and clustering two or more CVD risk factors.

BMI is the most widely used measure to diagnose obesity. However, the accuracy of BMI in detecting excess body adiposity in the general adult population is limited, because BMI cannot measure BF% directly and poorly distinguishes among total body fat, total body lean, and bone mass[12, 13]. To overcome misclassifications, direct measurements of BF% would be a better tool for diagnosing obesity. Moreover, BF% has been found to have a strong association with multiple CVD risk factors in several studies conducted in China[8], Korea[14], and other ethnic groups[15-17]. Our data also support the good discrimination of BF% for each CVD risk factor and clustering of ≥2 risk factors in both sexes and ethnicities. However, BF% seems performed better in women than in men to detect CVD risk factors, which might result from greater less mass and lower fat mass men had than women[18]. Besides, BF% had larger AUCs for almost CVD risk factors in women aged <50 years than in the older women, but not obviously in men. In a Korean study, women after menopause had not only higher total body fat percentage but also its different distribution, which independently correlates with cardiovascular disease risk factors[19]. In addition, a study of 402 women aged 30-75 years in Southern India also shown that menopausal status and associated obesity created a compatible atmosphere for abnormal metabolism and aggravated cardio metabolic risk factors[20]. However, the relationship between obesity in women after menopause and CVD risk factors is more vulnerable to the effect of confounding variables, such as ageing, which might affect the accuracy of prediction of BF% for CVD risk factors.

It has been demonstrated that adipose tissue distribution varies among different ethnicities[21]. As is well known, the increased risks of metabolic diseases associated with obesity occur at lower BMIs in Asians, and these population are predisposed to visceral or abdominal obesity. In a study of peri- and postmenopausal women in Thai, 34% was proposed as the optimal BF% cut-off points to identify women at risk of metabolic syndrome[22]. In addition, A cross-sectional study of the middle-aged Japanese men shown that the cut-off point of BF% for detecting participants with 1 or more CVD risk factors (diabetes mellitus, hypertension, dyslipidemia) was 20.3%[23]. Joseph, *et al*. recommended an optimal BF% cut-off values of 25.5 in men and 38.0 in women for

Asian Indian individuals[24]. Furthermore, Kim, *et al* reported that a BF% of 21% for men and 37% for women may be the appropriate cut-off values in Korean adults[25]. These discrepancies mainly result from different ethnic groups, age and outcome. By now, BF% has not been recommended as an adiposity index in the Chinese population yet, and there has been little study on the cutoff point for BF%. Li, *et al* proposed 25% and 35% as optimal BF% cut-off points for Chinese men and women to predict metabolic syndrome and Type 2 diabetes using data from the Shanghai Diabetes Studies (SHDS), respectively[8]. In this study, the optimal cut-off values of BF% to detect diabetes, hypertension, and dyslipidemia for men and women in Han adults were found to be 24% and 34%, respectively. In Mongolian population, the optimal BF% cut-offs were 25% for men and 35% for women. Mongolians have a distinctive lifestyle and dietary habits characterized by a preference for high protein and fatty foods of animal origin[26], which is different from Han population. Zhang, *et al* reported the prevalence of overweight or obesity was higher in Mongolian people than Han people using WHO criteria (26.1% vs 21.3%, respectively)[27]. Moreover, a study evaluating the relationship among ethnic groups and their CVD risk factors (hypertension, obesity, diabetes, dyslipidemia, smoking) shown that clustering of ≥2 or ≥3 of these risk factors was noted in 66.9% or 36.5% of Mongolian as well as 62.0% or 28.3% of Han subjects, respectively[28]. Because of different genetic backgrounds, lifestyles and dietary patterns, the optimal BF% cut-offs of Han adults may be not the same as Mongolian.

There are some limitations to our study. A major limitation of the present study is cross-sectional design, which cannot be used to establish temporal relationship and causality. Lots of epidemic studies, especially prospective cohort studies, need to be completed to improve cutoff points accuracy of BF% in China. Second, BF% in this study was measured using bioelectrical impedance analysis, which tends to underestimate body fat in all subjects and in men and women separately[29]. However, considering the convenience and inexpensiveness of BIA, large-scale epidemiological investigations appropriately use this analysis. Finally, the subjects were from Inner Mongolia, so the study's findings cannot necessarily be representative of all Chinese adults, especially Han people.

The current definitions of obesity using BF% are based on Western populations and probably need to be modified for Chinese population. The present study showed the optimal BF% cut-off points for men and women were around 24.0% and 34.0% in Han adults, and 25.0% and 35.0% in Mongolian population of Inner Mongolia, China, respectively. Considering the rapid growth of obesity in China[2], these optimal body fat percentage cut-offs will contribute to public health prevention and intervention.

Acknowledgments This study was supported by the National Science & Technology Pillar Program during the 12th Five-year Plan Period, Grant 2012BAI37B02 from the Ministry of Science and Technology, Beijing, People's Republic of China to Guangliang Shan, which enabled the completion of the project. We sincerely express our gratitude to all the staff of Inner Mongolia Autonomous Region Center for Disease Control and Prevention for support with the collection of demographic data.

Contributors YL participated in the data collection and drafted the manuscript. HW, WW, HG, YQ, GX, GL participated in the data collection. KW, FD, LP, GZ, GS participated in the design of the study and undertook statistical analyses. All authors were involved in writing the paper and had final approval of the submitted and published versions.

Funding This study was supported by the National Science & Technology Pillar Program during the 12th Five-year Plan Period, Grant 2012BAI37B02 from the Ministry of Science and Technology, Beijing, People's Republic of China to Guangliang Shan.

Competing interests None declared.

Ethics approval The study was approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences(NO.028-2013).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

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Table 1. Baseline Characteristics by sex in Han and Mongolian adults

Variables	Han(n=2308)			Mongolian(n=913)		
	Men(n=898)	Women(n=1410)	All cases	Men(n=355)	Women(n=558)	All cases
Age(years)	46.20±14.05***	44.24±13.29	45.00±13.62	45.91±13.69**	43.34±13.03	44.34±13.34
Age groups (%)	***			***		
20-49	58.02	66.52	63.21	57.75	68.64	64.4
50-80	41.98	33.48	36.79	42.25	31.36	35.6
Height(cm)	170.12±5.94***	158.28±5.51	162.89±8.10	170.54±6.35***	158.53±5.46	163.21±8.26
Weight(kg)	72.92±12.18***	60.20±9.70	65.15±12.39###	75.11±12.96***	61.54±10.08	66.82±13.08
BMI(kg/m2)	25.17±3.82***	24.04±3.72	24.48±3.80###	25.78±3.96***	24.52±4.07	25.01±4.07
BMI groups (%)	***		###	***		
overweight	40.42	34.04	36.53	41.41	37.28	38.88
obesity	21.71	14.04	17.03	28.45	17.92	22.02
BF (%)	22.54±5.77***	32.95±6.18	28.90±7.88###	23.86±5.72***	33.98±6.40	30.05±7.88
SBP(mmHg)	127.40±14.96***	119.07±17.14	122.31±16.82	129.4±16.05***	118.22±17.65	122.57±17.89
DBP(mmHg)	80.21±10.52***	75.42±10.66	77.28±10.86	82.2±11.89***	75.67±11.96	78.21±12.34
FPG(mmol/L)	5.53±1.49***	5.22±1.08	5.34±1.27	5.56±1.48***	5.14±1.09	5.30±1.27
TC(mmol/L)	4.86±1.00*	4.76±1.04	4.80±1.03###	5.10±0.97***	4.89±1.03	4.98±1.02
TG(mmol/L)	2.18±1.89***	1.55±1.13	1.80±1.50##	2.00±1.46***	1.46±1.18	1.67±1.32
LDL-C(mmol/L)	2.86±0.86	2.83±0.85	2.84±0.86###	3.13±0.87***	2.93±0.86	3.01±0.87
HDL-C(mmol/L)	1.19±0.32***	1.39±0.34	1.31±0.34###	1.27±0.34***	1.45±0.37	1.38±0.37
Hypertension (%)	33.74***	23.48	27.47#	40.28***	25.63	31.33
Diabetes (%)	9.58***	5.53	7.11	9.86***	3.23	5.81
Dyslipidemia (%)	51.11***	27.73	36.83	47.32***	26.34	34.5
Risk factors≥ 2(%)	24.16***	12.2	16.85	27.32***	13.8	19.06

Values are means ± SD or %.

**P*<0.05, ***P*<0.01, ****P*<0.001 compared with women within Han or Mongolian adults; #P<0.05, ##P<0.01, ###P<0.001 compared with Mongolian adults (Student's t-tests for continuous variables; Chi-square tests for categorical variables).

BF (%), body fat percentage; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;

TC, total cholesterol; TG, triglycerides; LDL-C, low-density lipoprotein-cholesterol; HDL-C, high-density lipoprotein-cholesterol.

Table 2. Area under receiver operating characteristic (ROC) curves of BF% screening CVD risk factors

	Hypertension	Diabetes	Dyslipidemia	Risk factors≥2
Han				
Men				
All ages	0.696(0.661,0.732)	0.589(0.531,0.648)	0.682(0.647,0.717)	0.699(0.662,0.736)
20-49 years	0.734(0.686,0.782)	0.532(0.417,0.646)	0.700(0.655,0.745)	0.731(0.681,0.780)
50-80 years	0.666(0.611,0.720)	0.606(0.536,0.676)	0.661(0.607,0.716)	0.670(0.613,0.726)
Women				
All ages	0.737(0.707,0.767)	0.728(0.676,0.780) *	0.711(0.683,0.740)	0.763(0.729,0.797) *
20-49 years	0.761(0.718,0.805)	0.787(0.700,0.874)	0.735(0.698,0.773)	0.836(0.788,0.885)
50-80 years	0.645(0.595,0.695) #	0.617(0.544,0.689) #	0.596(0.545,0.646) #	0.644(0.590,0.698) #
Mongolian				
Men				
All ages	0.702(0.648,0.757)	0.686(0.609,0.764)	0.690(0.636,0.745)	0.736(0.683,0.789)
20-49 years	0.714(0.636,0.793)	0.765(0.646,0.884)	0.681(0.608,0.753)	0.764(0.688,0.839)
50-80 years	0.665(0.577,0.754)	0.609(0.498,0.720)	0.689(0.604,0.775)	0.689(0.606,0.772)
Women				
All ages	0.733(0.685,0.780)	0.733(0.601,0.865)	0.685(0.637,0.733)	0.783(0.730,0.835)
20-49 years	0.643(0.557,0.729)	0.729(0.616,0.842)	0.670(0.604,0.735)	0.764(0.666,0.863)
50-80 years	0.683(0.604,0.763)	0.664(0.481,0.848)	0.586(0.502,0.671)	0.690(0.607,0.773)

*$P<0.05$, Compared to men.

#$P<0.05$, Compared to 20-49 years.

Table 3. Optimal cut-off values of BF% and their sensitivities, specificities, and Youden's index for CVD risk factors by age groups and sex

	Hypertension				Diabetes				Dyslipidemia				Risk factors≥2			
	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI	Cutoff	Sen	Spe	YI
Han																
Men																
All ages	24.2	62.7	70.3	33.0	18.7	94.2	23.5	17.7	21.6	77.3	52.4	29.7	24.2	64.5	66.7	31.2
20-49 years	24.2	69.3	71.1	40.4	18.8	92.3	24.6	17.0	21.6	75.8	56.0	31.9	24.2	68.4	67.8	36.3
50-80 years	24.2	58.0	68.7	26.6	22.5	75.0	45.1	20.1	20.5	87.1	41.9	29.0	25.0	54.9	71.8	26.7
Women																
All ages	34.2	71.9	64.8	36.7	35.4	69.2	67.5	36.7	32.7	77.2	55.8	33.1	33.7	83.1	58.1	41.2
20-49 years	33.6	73.7	67.2	40.9	32.0	94.4	52.6	47.1	33.9	66.1	70.3	36.5	33.9	90.5	65.6	56.1
50-80 years	36.8	52.6	70.7	23.2	35.4	70.0	51.2	21.2	34.8	66.8	50.6	17.4	36.7	56.9	65.5	22.4
Mongolian																
Men																
All ages	23.0	84.6	48.1	32.7	21.9	97.1	33.4	30.6	21.0	89.3	41.7	31.0	24.6	77.3	60.1	37.4
20-49 years	23.0	87.3	51.3	38.6	26.8	75.0	75.1	50.1	18.5	94.5	35.1	29.6	25.7	72.2	71.6	43.8
50-80 years	21.9	88.6	40.3	29.0	22.0	95.7	28.3	24.0	21.0	94.8	38.4	33.2	21.9	96.7	37.1	33.8
Women																
All ages	35.7	71.3	66.3	37.6	40.0	55.6	84.6	40.2	36.4	62.6	68.6	31.2	36.4	80.5	66.9	47.5
20-49 years	35.7	55.6	70.7	26.3	34.8	100.0	61.8	61.8	31.1	82.9	43.5	26.3	36.4	70.0	74.1	44.1
50-80 years	36.7	73.5	54.5	28.0	41.0	60.0	81.3	41.3	36.5	77.9	46.9	24.9	36.6	84.2	46.6	30.8

Sen, sensitivity; Spe, specificity; YI, Youden's index.

Table 4. Sensitivity, specificity and Youden's index for BF% to detect CVD risk factors by sex-specific cut-offs in Han adults

	Hypertension			Diabetes			Dyslipidemia			Risk factors≥2		
	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI
Men												
21	83.8	41.3	25.2	79.1	34.1	13.2	81.1	47.4	28.4	88.0	39.5	27.5
22	77.6	49.4	27.0	70.9	41.5	12.4	73.4	54.7	28.1	81.1	47.1	28.3
23	69.6	59.2	28.8	61.6	50.6	12.3	63.8	63.3	27.2	72.4	56.4	28.7
24	64.0	67.1	31.1	53.5	57.6	11.1	56.0	69.7	25.7	66.4	63.9	30.2
25	52.5	74.5	26.9	44.2	66.4	10.6	45.3	76.5	21.9	55.8	72.1	27.9
26	43.9	81.3	25.2	33.7	73.5	7.2	51.1	81.3	32.4	44.7	78.4	23.1
Women												
32	84.0	50.5	34.5	89.7	44.3	34.0	80.3	51.1	31.4	91.3	47.1	38.4
33	78.6	56.9	35.5	82.1	50.4	32.4	74.7	57.5	32.2	85.5	53.3	38.8
34	72.2	63.2	35.4	75.6	56.7	32.3	68.3	63.8	32.1	79.7	59.7	39.3
35	64.4	70.9	35.3	70.5	64.6	35.1	58.6	70.8	29.3	69.8	67.1	36.9
36	55.6	77.3	32.9	62.8	71.5	34.3	48.3	76.5	24.8	61.1	73.8	34.9
37	47.7	82.7	30.4	53.9	77.3	31.1	38.9	81.1	19.9	52.3	79.4	31.7

Sen, sensitivity; Spe, specificity; YI, Youden's index.

Table 5. Sensitivity, specificity and Youden's index for BF% to detect CVD risk factors by sex-specific cut-offs in Mongolian adults

	Hypertension			Diabetes			Dyslipidemia			Risk factors≥2		
	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI	Sen	Spe	YI
Men												
21	88.1	37.3	25.4	97.1	29.7	26.8	89.3	41.7	31.0	95.9	35.7	31.5
22	86.7	43.4	30.1	94.3	34.1	28.4	82.7	43.9	26.6	93.8	40.7	34.5
23	84.6	48.1	32.7	88.6	37.5	26.1	81.0	49.2	30.2	91.8	45.0	36.7
24	72.7	54.7	27.5	82.9	46.6	29.4	69.1	55.1	24.1	79.4	52.3	31.7
25	60.8	64.2	25.0	71.4	56.9	28.3	60.1	66.8	27.0	70.1	63.2	33.3
26	53.2	72.2	25.3	60.0	64.4	24.4	49.4	72.2	21.6	60.8	70.5	31.4
Women												
32	84.6	42.9	27.5	83.3	36.5	19.8	81.6	42.1	23.7	92.2	40.3	32.5
33	79.7	48.9	28.6	83.3	42.4	25.7	76.9	48.2	25.1	88.3	46.4	34.7
34	75.5	54.7	30.2	83.3	48.0	31.3	73.5	54.3	27.7	85.7	52.2	37.9
35	73.4	62.2	35.6	77.8	54.1	31.9	68.7	60.8	29.5	84.4	59.0	43.5
36	68.5	67.0	35.5	66.7	58.7	25.4	63.3	65.5	28.7	80.5	64.0	44.6
37	58.7	73.5	32.2	61.1	66.1	27.2	55.1	72.5	27.6	70.1	70.9	41.0

Sen, sensitivity; Spe, specificity; YI, Youden's index.

Table 6. Age-adjusted OR(95%CI) and PARP of each CVD risk factor by sex-specific cut-offs for BF% in Han and Mongolian adults

	*OR**	*95%CI*	*PARP(%)*
Han			
Men(BF%⩾24%)			
Hypertension	3.680	2.728-4.964	53.8
Diabetes	1.479	0.940-2.328	17.2
Dyslipidemia	2.966	2.251-3.908	46.1
Risk factors⩾2	3.450	2.490-4.780	51.6
Women(BF%⩾34%)			
Hypertension	3.382	2.544-4.494	51.8
Diabetes	2.660	1.539-4.596	42.8
Dyslipidemia	3.152	2.439-4.072	49.3
Risk factors⩾2	4.016	2.682-6.014	57.6
Mongolian			
Men(BF%⩾25%)			
Hypertension	2.587	1.635-4.094	42.2
Diabetes	2.982	1.374-6.471	47.6
Dyslipidemia	2.986	1.930-4.620	47.7
Risk factors⩾2	3.772	2.251-6.321	56.0
Women(BF%⩾35%)			
Hypertension	2.851	1.796-4.526	46.5
Diabetes	2.061	0.634-6.697	33.3
Dyslipidemia	2.599	1.704-3.964	42.9
Risk factors⩾2	4.882	2.497-9.545	64.6

*Adjusted odds ratios for cardiovascular risk factors in subjects using sex-specific cut-offs for BF%, adjusted for age.
OR, odds ratios; PARP, population attributable risk proportion.

Figure 1. ROC curves for BF% screening CVD risk factors in men and women among Han and Mongolian adults.

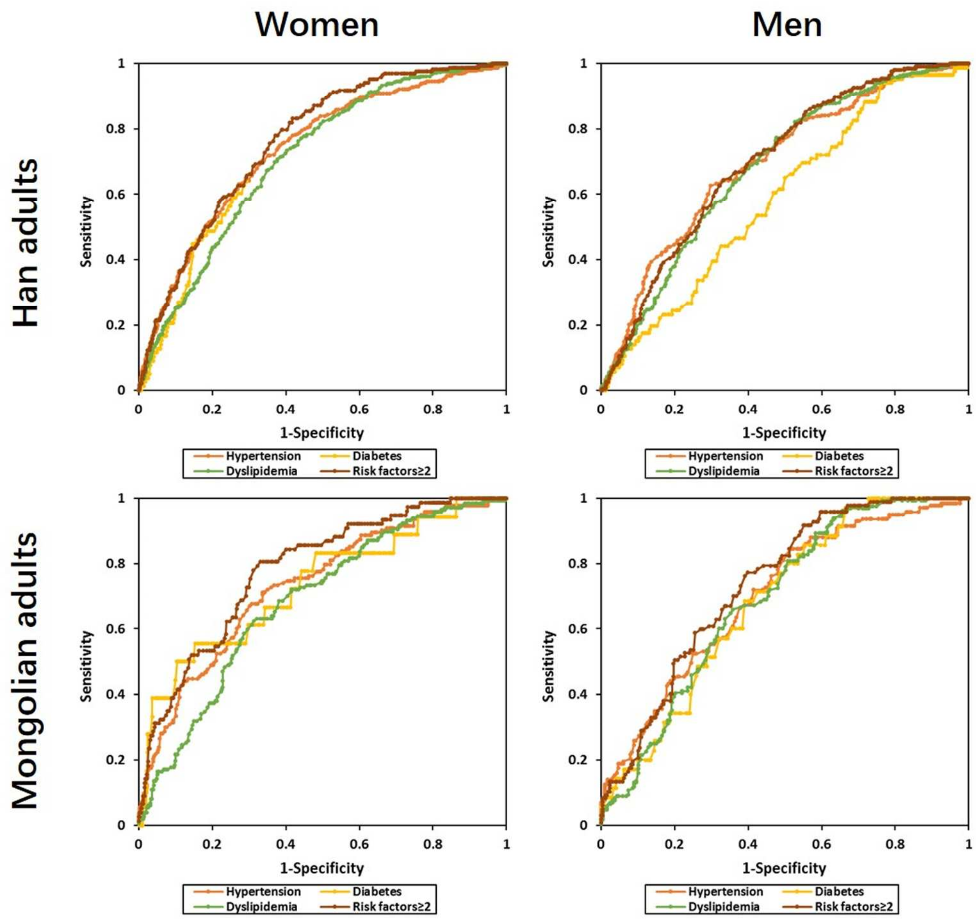

Figure 1 ROC curves for BF% screening CVD risk factors.
Optimal body fat percentage cu
283x267mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3-4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	3-4
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	4-5
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Results			Page No
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	3,5
		(b) Give reasons for non-participation at each stage	3,5
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	5-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	2
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.