Comparison of Body Mass Index with Body Fat Percentage in the Evaluation of Obesity in Chinese[1]

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Objective To evaluate the present Chinese body mass index (BMI) criteria with body fat percentage (BF%) in determining obesity in Chinese population. **Methods** A total of 4 907 subjects (age: 20-90 yrs) were enrolled in the baseline survey of a longitudinal epidemiological study, and 2 638 of them were reevaluated in 5.5 years later. The Chinese BMI and WHO BF% were used to define obesity, respectively. **Results** The diagnostic agreement between the Chinese BMI and WHO BF% definitions for obesity was poor for both men (kappa: 0.210, 95% CI: 0.179-0.241) and women (kappa: 0.327, 95% CI: 0.296-0.358). However, BMI had a good correlation with BF% both in men (r: 0.785, P<0.01) and women (r: 0.864, P<0.01). The age and sex-adjusted relative risks (RR) for incidence of type 2 diabetes (T2DM) were significantly higher in subjects with intermediate BF% (BF%:20.1%-25% for men, 30.1%-35% for women) (RR: 2.35, 95% CI: 1.23-4.48) and high BF%(BF%>25% for men and ＞35% for women)(RR: 2.89, 95% CI: 1.43-5.81), or in subjects with high BMI (BMI≥ 28 kg/m^2) (RR: 2.46, 95% CI: 1.31-4.63) when compared to those with low BF% (BF%≤20% for men and≤30% for women) or low BMI (BMI＜24 kg/m^2) respectively. No difference in risk could be found in those with intermediate BMI (BMI: 24-27.9 kg/m^2) (RR: 1.44, 95% CI: 0.86-2.40), as compared to those with low BMI (BMI＜24 kg/m^2), whose BF% ranged widely from 7.8 to 50.3%. **Conclusion** BMI was correlated with BF%. Both BMI and BF% were associated with high risk for T2DM. However, BMI had its limitations in the interpretation of subjects with BMI between 24 and 27.9 kg/m^2.

Key words:BMI; BF%; Obesity

INTRODUCTION

The incidence of obesity has increased dramatically, not only in high-income countries, but also in low- and middle-income countries. According to World Health Organization (WHO), there are about 1.6 billion overweight adults, and at least 400 million of them are obese[1-2] . Moreover, one in five of the obese people in the world are Chinese[3]. Overweight and obesity lead to serious health consequences and increase the risk of morbidities and mortalities, e.g. type 2 diabetes (T2DM), cancer, cardiovascular disease (CVD), non-alcoholic fatty liver disease. Increase in body fat alters the body's response to insulin, potentially leading to insulin resistance, and also creates a proinflammatory state, leading to the risk of thrombosis[1,4].

Body mass index (BMI) is recommended by WHO as a simple marker to reflect total body fat amount. However, BMI, as compared to weight and height, is just an index of weight excess, rather than body fatness composition. Studies have shown that the relationships among BMI, body fat percentage (BF%), and body fat distribution differ across populations[5]. Obesity-associated metabolic risks are greater in Asian people than in European descent populations[6], and Chinese tend to have lower BMI, but higher fat volume. Although local BMI cutoff points of overweight and obesity have been used in Asian populations to try to reduce the discrepancy[7-9],

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the best index of obesity remains inconclusive[10].

Thus, in order to evaluate the present Chinese BMI criteria, this study is designed to first identify the relationship between BMI and BF% in Chinese subjects with wide range of BMI and different age groups, using the approach of bioelectrical impedance analysis (BIA), a common measure for body composition, and to second evaluate the BMI and BF% cutoff points in the prediction of occurrence of T2DM.

MATERIALS AND METHODS

Study Population

All subjects were from the Shanghai Diabetes Studies (SHDS) (11). A total of 4 907 subjects (2 105 men/2 802 women) aged from 20 to 90 years were enrolled in the baseline survey. Among them 2 638 (1 088 men/1 550 women) were able to be recalled and reevaluated after 5.5 years. Subjects with diabetes, cancer, severe disability, or severe psychiatric disturbance were excluded. Informed consent was obtained from each participant before the survey. The protocol was in accord with the Helsinki Declaration and was approved by the local ethical committee.

Measurements of Anthropometric Index, Body Fat and Oral Glucose Tolerance (OGTT)

After overnight fasting and wearing light indoor clothes, each subject's body height and weight were measured by a scale. BMI was calculated as the weight in kilograms divided by the square of the height in meters. Total body fat was estimated from Body Composition Analyzer (TANITA Corporation, Japan). Subjects were fasted overnight before the measurement of OGTT. After a blood sample was taken for fasting plasma glucose measurement, a 2hOGTT was performed with a standard glucose load (75 g glucose)[12].

Definition of Variables and Outcomes

Both BMI and BF% were categorized into 3 groups: low BMI (BMI$<$24 kg/m^2), intermediate BMI (BMI 24-27.9 kg/m^2) and high BMI (BMI$\geqslant$28 kg/m^2), and low BF% (BF$\leqslant$20% for men, BF%$\leqslant$30% for women), intermediate BF% (BF 20%-25% for men, 30%-35% for women) and high BF% (BF$>$25% for men, BF%$>$35 for women). T2DM was diagnosed according the 1999 WHO criteria (FPG$\geqslant$7.0 mmol/L and or 2 hPG$\geqslant$11.1 mmol/L) [13].

Statistical Analysis

The data were expressed as mean±SD or number (%). The statistical analysis was performed with SPSS software for Windows (Version 11.0). Receiving operating characteristics (ROC) analysis was used to determine the optimal cutoff points by taking into account the best combination of sensitivity and specificity and the shortest distance in the ROC curves. Kappa analysis was used to test the diagnostic agreement of obesity between BMI and BF% criteria. Spearman and partial correlations were used to assess relationship between variables. Relative risk (RR) was calculated with logistical regression analysis. For BMI and BF% with more than 2 categories the first category was considered as the reference group. Comparisons of correlation coefficient were performed with MedCalc software (Version 10.4.8.0). All reported *P* values were two-tailed and p values less than 0.05 were considered statistically significant.

RESULTS

Comparison of Proportion of Obese Subjects by BMI and BF%

As shown in Table 1, 2.9% of men (61 of 2 105) and 4.8% of women (135 of 2 802) were with BMI$\geqslant$30 kg/m^2 (WHO obesity)[14]. 7.9% of men (167 of 2 105) and 11.2% of women (313 of 2 802) were with BMI $\geqslant$ 28 kg/m^2 (Chinese local obesity). The percentage of obesity defined by BF% according to the WHO criteria (BF%$>$25% in men and$>$35% in women)[15] was 39.3% in men and 37.7% in women, which were much higher than the percentage of obese subjects defined by both WHO and local Chinese BMI definition (all $P<0.001$). The agreement between the WHO BMI and BF% definitions, and the Chinese BMI and BF% definitions on obesity were poor for both men (kappa: 0.082, 95% confidence interval (CI): 0.060-0.104, kappa: 0.210, 95% CI: 0.179-0.241, for WHO and Chinese definition respectively) and women (kappa: 0.150, 95% CI: 0.126-0.174, kappa: 0.327, 95% CI: 0.296-0.358, for the WHO and Chinese definition respectively). Although men and women had similar BMI, men had significantly lower BF% than women for all age subgroups (all $P<0.001$) (Table1).

The Optimal Cutoffs of BMI for BF% Obesity

According to the WHO BF% criteria of obesity, the diagnostic performance for the best identified BMI cutoff in all subjects and by sex were shown in Fig. 1. By using BF% as the criteria to determine obesity, the area under the curve was 0.916 for BMI to detect BF% obesity and the best cutoff point for BMI identified was 23.7 kg/m^2. After stratifying by sex, the area under the curve was lower in men (0.876) than in women (0.943) ($P<0.0001$). The best corresponding BMI cutoff was 23.6 for men and 24.2 for women respectively (Fig. 1). The cutoff point drawn from ROC here was much similar with the Chinese BMI criteria, in which subjects with BMI 24-27.9 kg/m^2 were defined as overweight, and those with BMI≥28 kg/m^2 were defined as obese. By using diagnostic performance, a BMI≥28 kg/m^2 had a poor sensitivity but good specificity in both men and women to detect BF%-defined obesity. A BMI≥24 kg/m^2 had a moderate sensitivity and specificity in men and women to detect BF%-defined obesity.

TABLE 1

Anthropometric Measurement of Subjects at the Baseline

Age Group (*n*)	BMI (kg/m^2)	BF%	Lean Mass (kg)	BMI≥28 (kg/m^2)	BMI≥30(kg/m^2)	BF% >25% (Men) >35% (Women)
Men (2 105)	23.4±3.4	23.1±6.4	50.8±6.2	167 (7.9)	61 (2.9)	827 (39.3)
20-29 (221)	23.3±4.2	23.3±7.7	52.7±6.8	21 (9.5)	11 (5.0)	95 (43.0)
30-39 (392)	23.1±3.3	24.0±6.5	51.4±6.2	29 (7.4)	9 (2.3)	177 (45.2)
40-49 (475)	23.2±3.1	23.2±6.0	51.2±6.0	25 (5.3)	12 (2.5)	178 (37.5)
50-59 (238)	23.8±3.1	24.3±6.4	51.1±6.3	23 (9.7)	9 (3.8)	106 (44.5)
60-69 (327)	24.0±3.1	23.5±5.4	51.7±6.0	32 (9.8)	14 (4.3)	135 (41.3)
70-79 (360)	23.6±3.4	21.8±6.6	47.3±6.1	33 (9.2)	6 (1.7)	117 (32.5)
80-89 (92)	22.4±3.2	19.6±6.3	47.5±6.2	4 (4.3)	0 (0)	19 (20.7)
Women(2 802)	23.6±3.6	32.9±7.4	38.6±4.4	313 (11.2)	135 (4.8)	1 057 (37.7)
20-29 (224)	21.2±3.0	28.6±6.9	38.8±3.8	6 (7.7)	4 (1.8)	40 (17.9)
30-39 (546)	22.8±3.4	31.4±6.5	39.6±3.7	45 (8.2)	22 (4.0)	154 (28.2)
40-49 (796)	23.4±3.1	32.6±6.6	39.6±3.9	67 (8.4)	23 (2.9)	272 (34.2)
50-59 (331)	24.4±3.5	34.4±7.3	39.0±4.2	52 (15.7)	22 (6.6)	152 (45.9)
60-69 (412)	25.0±3.5	35.6±7.2	37.6±4.6	65 (15.8)	30 (7.3)	224 (54.4)
70-79 (408)	24.4±4.0	34.1±8.4	36.6±4.8	63 (15.4)	29 (7.1)	184 (45.1)
80-89 (85)	23.8±4.3	32.1±8.9	35.2±4.4	15 (17.6)	5 (5.9)	31 (36.5)

Note. The data were expressed as mean±SD or number (%). BMI: body mass index; BF%: body fat percentage.

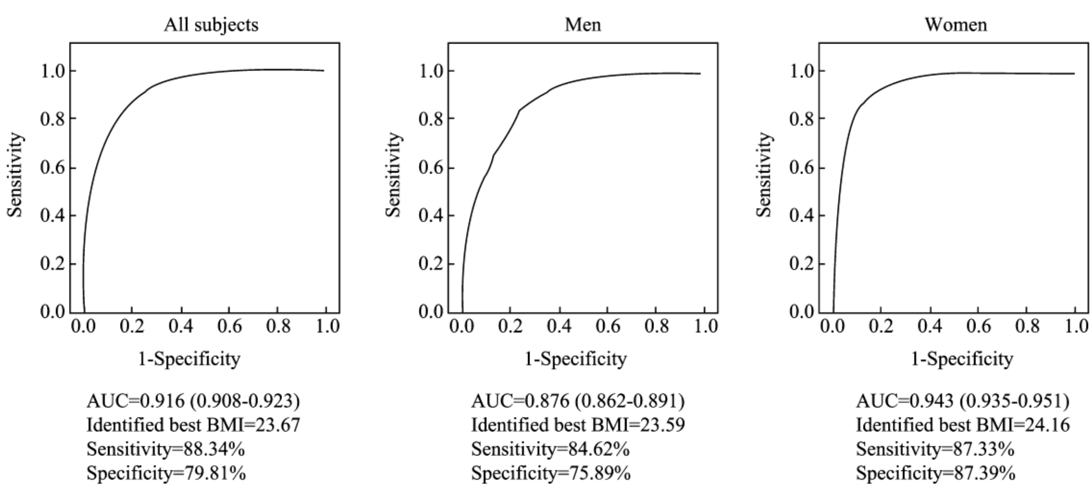

FIG.1. Receiver operating characteristic curves for body mass index (BMI) to detect body fat percent-defined obesity. AUC, area under curve, its 95% confidence intervals are shown in brackets.

Correlation between BMI and Body Fat Perentage, and BMI and Lean Mass

Comparisons of correlation between BMI and body fat percentage as well as BMI and lean mass by gender and age groups are displayed in Table 2. In all subjects, BMI had good relationship with BF% in men (r=0.785) and women (r=0.864), and moderate and poor relationship with lean mass in men (r=0.660) and in women (r=0.450). In men BMI correlated better with BF% than with lean mass before age 60. In women BMI correlated better with BF% than with lean mass across all age groups.

Association of BMI and BF% with the Occurrence of Future T2DM

After 5.5 years, majority of the subjects changed their BMI and BF%. Among them 53.2% and 51%

decreased, and 45.7% and 47.1% increased their BF% and BMI, respectively. There was a positive correlation between changes of BMI and BF% levels both in men and women (Fig. 2). During this period, 128 new cases of T2DM were identified among the 2 638 subjects who were free of T2DM at the baseline. The ability of categories of BMI and BF% to predict future T2DM was evaluated with age and sex adjusted logistic regression model as shown in Fig. 3. The risks of subjects with intermediate BF% and high BF% for future diabetes were significantly higher with RRs (95% CI) of 2.35 (1.23-4.48) and 2.89 (1.43-5.81), respectively, compared to those of subjects with low BF%. Similarly, subjects with high BMI were associated with increased risk of future incidence of T2DM (RR:2.46, 95% CI:1.31-4.63), while those with intermediate BMI were otherwise (RR: 1.44 CI: 0.86-2.40), whose BF% distribution ranged widely from 7.8 to 48.5% in men (*n*=386) and 18.2 to 50.3% in women (*n*=533). 34.7% of male subjects and 25.7% of female subjects failed to reach BF% criteria of obesity in this group (Fig. 4).

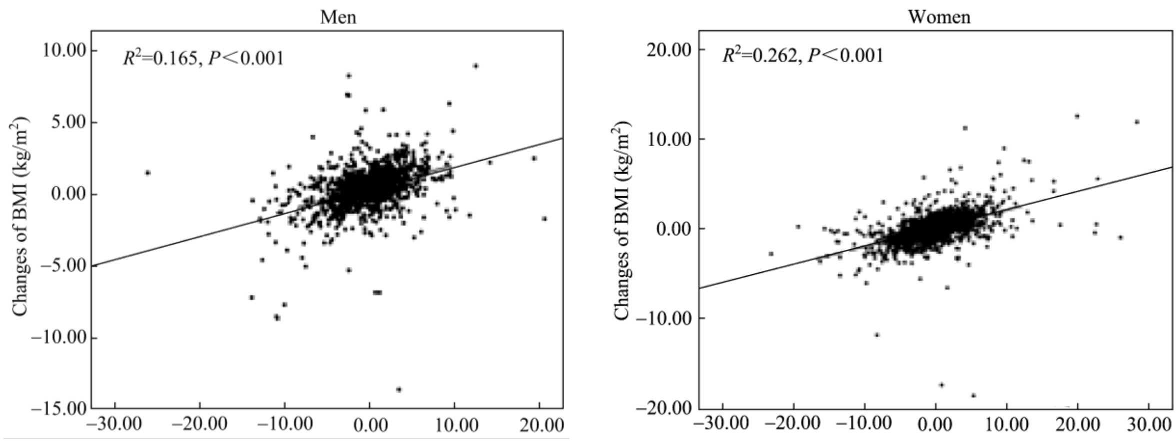

FIG.2. Comparison of changes of body mass index (BMI) and body fat percentage in men and women after 5.5 year-follow-up. Spearman correlation analysis was conducted for the comparison.

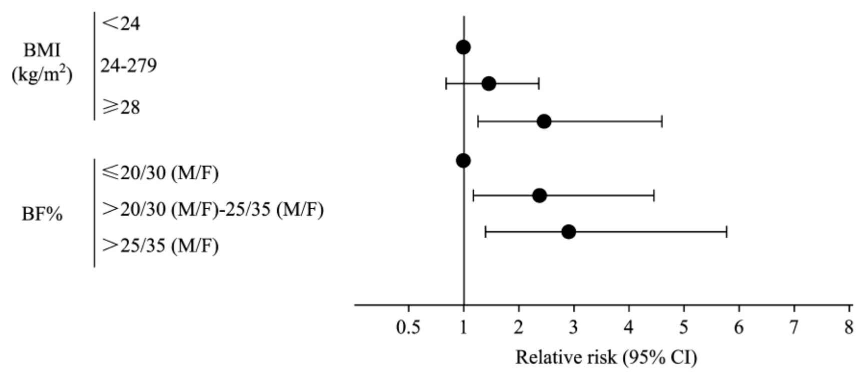

FIG. 3. Relative risks of body mass index (BMI) and body fat percentage (BF%) categories for incidence of type 2 diabetes with age and sex adjustment. CI: confidence interval (shown by error bars).

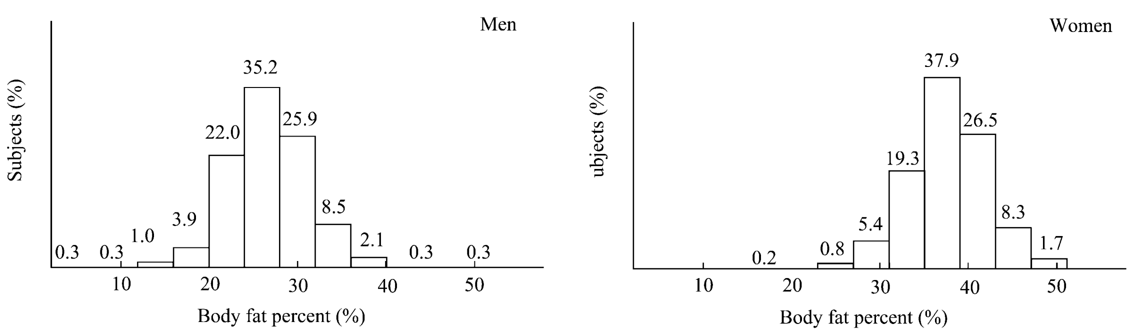

FIG.4. Body fat percentage variations in men (*n*=386) (left panel) and women (*n*=533) (right panel) with body mass index between 24-27.9 kg/m^2.

TABLE 2

Comparison of Correlation between BMI and BF%, BMI, and Lean Mass at the Baseline

Age Group (*n*)	BMI-BF% (r)	BMI-Lean Mass (kg)	Correlation Comparison (*P*)
Men (2 105)	.785(**)[a]	.660(**)[a]	$P < 0.0001$
20-29 (221)	.897(**)	.756(**)	$P < 0.0001$
30-39 (392)	.835(**)	.646(**)	$P < 0.0001$
40-49 (475)	.793(**)	.569(**)	$P < 0.0001$
50-59 (238)	.773(**)	.579(**)	$P = 0.0001$
60-69 (327)	.689(**)	.684(**)	$P = 0.9038$
70-79 (360)	.753(**)	.637(**)	$P = 0.0024$
80-89 (92)	.710(**)	.757(**)	$P = 0.4940$
Women (2 802)	.864(**)[a]	.450(**)[a]	$P < 0.0001$
20-29 (224)	.925(**)	.310(**)	$P < 0.0001$
30-39 (546)	.893(**)	.519(**)	$P < 0.0001$
40-49 (796)	.883(**)	.411(**)	$P < 0.0001$
50-59 (331)	.855(**)	.379(**)	$P < 0.0001$
60-69 (412)	.852(**)	.387(**)	$P < 0.0001$
70-79 (408)	.850(**)	.455(**)	$P < 0.0001$
80-89 (85)	.862(**)	.513(**)	$P < 0.0001$

Note. Spearman and partial correlations were used to assess associations between variables. Comparisons of correlation coefficient were performed with MedCalc software. [a]Additionally adjusted with age. **P<0.01. BMI: body mass index; BF%: body fat percentage.

DISCUSSION

BMI is usually considered a surrogate marker of excess adiposity in terms of overweight and obesity[16-17]. An ideal alternative is to use actual measures of fatness rather than of body mass. BIA is a widely used technique available in clinic for body-composition measurement due to its merits of safety, accuracy, reliability, and low cost as compared to other body composition methods. In the present study we compared BMI with BF% measured with BIA in evaluating obesity in Chinese populations. Our study showed that the correlations between BMI and BF% were generally good in all subjects (data not shown) and in men and women separately, which is in agreement with the previous reports[18-21]. Moreover, the positive correlation remained when comparing changes in BMI and BF% after a period of years.

However, with low kappa values, the diagnostic performance of either WHO (BMI⩾30 kg/m^2) or Chinese (BMI⩾28 kg/m^2) cutoff points to identify obese subjects yielded a great disagreement with that by BF% in men and women, whose cutoff points were ＞25% in men and ＞35% proposed by WHO[15,22]. The percentage of obese subjects in Chinese defined by BF% (men/women: 39.3%/37.3%) was similar to the prevalence of obesity in Caucasians defined by BMI⩾30 kg/m^2 [23-24], but it was much higher than that defined by BMI either by the WHO (men/women: 2.9%/4.8%) or the Chinese criteria (men/women: 7.9%/11.2%).

When using the ROC to detect optimal BMI cutoff points for obesity as defined by BF% ＞ 25% in men or ＞35% in women, the ideal BMI cutoff point was about 24 kg/m^2 for both genders. It is the same with the Chinese BMI overweight cutoff point based on the sensitivity and specificity in identification of the CVD risk factors[7]. It is known that obesity is an independent risk factor for T2DM not only in Caucasian[25-26] but in Asian[27]. Thus we compared the ability of different BMI and BF% categories to predict future incidence of T2DM. Unfortunately, the adjustment of the cutoff point does not overcome the limitations of using BMI as a marker for obesity in the prediction of future incidence of T2DM. It is true that subjects with BMI ⩾28 kg/m^2 were associated with the increased risk of T2DM. However, using the identified BMI cutoff for intermediate BMI group (BMI: 24-27.9 kg/m^2) failed to predict occurrence of T2DM. The intermediate BMI (BMI: 24-27.9 kg/m^2) had its limitations ,which might be due to the fact that subjects within this group had a wide range of BF%, with about one third not obese by WHO BF% definition. Similar phenomenon was reported by Cho *et al*. They showed that a BMI⩾25 kg/m^2 and BF% <25% was not associated with more risk to CVD, such as high blood pressure, hyperglycemia, and dyslipidemia, whereas a BMI <25 kg/m^2 and BF% ⩾25% was correlated with CVD risks in Korean men[28]. This is not unreasonable, since the majority of human body weight comes from lean mass. BMI does not discriminate between BF% and lean mass. BMI is correlated with lean mass as well[19], While our study of BMI illustrates the significant limitations in using BMI for the diagnosis of obesity, it is important to point out that the use of BMI is not without value. A BMI⩾28 kg/m^2 has significant excellent specificity (men/women: 99.1%/99.3%) and positive predictive value for diagnosing obesity in both genders (data not shown). Furthermore BMI might still be the best way to evaluate changes in body fatness over time. Increments of BMI are correlated with that of BF% and most likely represent fat gain in the public.

Limitations of the present study: it has been reported that BIA has its limitations in estimating body fat in subjects compared with dual energy X-ray absorptiometry (DXA)[29]. This bias, however, depends on the degree of adiposity. In lean subjects, BIA tends to overestimate BF%. In overweight or obese subjects, BIA tends to underestimate BF%. Reference methods such as DXA, can provide accurate results. However, this method is costly and often inaccessible to the public[30], and it nevertheless is not practicable for use with a large sample size. Moreover, in most situations, BIA and other field methods (e.g. waist circumference) are the only techniques available for body composition measurements.

CONCLUSION

BMI was closely correlated with BF% and its changes could reflect the variations of BF%. Both BMI and BF% were associated with incidence of T2DM. However, BMI had its limitations in interpretations of subjects with BMI between 24-27.9 kg/m^2. Combination of BF% with BMI in this group might be necessary before any preventative intervention decisions are made.

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