Are BMI and other anthropometric measures appropriate as indices for obesity? A study in an Asian population

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Abstract We have examined the relationships between percentage of body fat (PBF) and risk factors for cardiovascular disease and insulin resistance and how good body mass index (BMI) and other anthropometric measures are as indices of obesity. High PBF levels were associated with increased risk of cardiovascular disease and insulin resistance. The World Health Organization BMI of 30 kg/m^2 for obesity has low sensitivity, 6.7% and 13.4% for men and women, respectively. For every obese man and woman identified, 6.7 and 1.76 times nonobese men and women, respectively, will be misclassified as obese. With the locally established BMI cutoff point for obesity of 27 kg/m^2 for men and 25 kg/m^2 for women, the sensitivity was improved to 46.7% and 60.8%, respectively. For every obese man and woman identified, 3.76 and 1.64 times nonobese men and women, respectively, will be misclassified as obese. None of the other anthropometric indices was better than the locally established BMIs. We showed that the BMIs for obesity for our local men and women are different. These BMIs were most precise among all indices studied. However, they still lead to high false-positive rates. For more effective management of the problem of obesity, we need to develop more precise, simple, and cost-effective methods for the measurement of PBF.—Goh, V. H. H., C. F. Tain, T. Y. Y. Tong, H. P. P. Mok, and M. T. Wong. **Are BMI and other anthropometric measures appropriate as indices for obesity? A study in an Asian population. *J. Lipid Res.* 2004.** 45: **1892–1898.**

Supplementary key words body mass index • percentage of body fat • waist-hip ratio • waist circumference • hip circumference • waist-height ratio

With increasing affluence and a rapidly aging population, lifestyle diseases such as cancers and coronary heart disease have become the major causes of death in Singapore (1). Coronary heart disease is the second leading cause of death, accounting for 24.5% of all deaths in 2000 (2). This mortality rate is comparable to those observed in the West and higher than those in other parts of Asia, such as Japan and Hong Kong (3). A key issue in the management of coronary heart disease is prevention. Many of the predisposing risk factors, including obesity, can be prevented or modified through appropriate lifestyle changes and medical treatment.

The body mass index (BMI) has been used routinely to classify subjects as obese or nonobese. The World Health Organization (WHO) and the International Obesity Task Force recommend the BMI cutoff point of 30 kg/m^2 for obesity. This cutoff point was derived largely from mortality statistics from European and American populations. Several studies carried out mainly among Asian populations have challenged the notion that one BMI cutoff point fits all populations. They have separately established that the BMI cutoff point for obesity for Asian populations is pegged between 23 and 27 kg/m^2 (4–9). Furthermore, studies have shown that Asian populations have high risks of type 2 diabetes, cardiovascular disease, and mortality from other causes at relatively lower BMI, which they postulated to be largely attributable to the higher proportion of body fat in Asian populations (10–16). Therefore, it has been suggested that lower BMI cutoff points for obesity appropriate for Asian populations should be adopted. In its *Lancet* publication in 2004, the WHO Expert Consultation, after a meta-analysis of population data from more than 10 countries, noted that the proportion of Asian people with a high risk of type 2 diabetes and cardiovascular disease is substantial at BMIs lower than the existing WHO cutoff point for overweight ($\geq$25 kg/m^2). The consultation also agreed that the WHO BMI cutoff points should be retained as international classifications and suggested lower BMI action points of 23 and 27.5 kg/m^2, which individual countries could use to define the cutoff points for increased risk for their populations (17).

In this study, we analyzed a subset of data from our ongoing study of the determinants of the aging process in an Asian population. Specifically, we sought to answer the question of whether the BMI and other anthropometric measures are appropriate indices for obesity.

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TABLE 1. Mean levels of lipids, TG, anthropometric parameters, and dual-energy X-ray absorptiometry-measured PBF in men and women aged 30–70 years old

	Men		Women	
Parameters	n	Mean ± SEM	n	Mean ± SEM
Age	298	49.4 ± 0.50	771	48.4 ± 0.29
TC (mmol/l)	298	5.92 ± 0.060[a]	771	5.71 ± 0.035
LDL (mmol/l)	298	3.87 ± 0.055[a]	771	3.51 ± 0.031
HDL (mmol/l)	298	1.38 ± 0.017	771	1.71 ± 0.013[b]
TC/HDL	298	4.44 ± 0.061[a]	771	3.48 ± 0.031
TG (mmol/l)	298	1.49 ± 0.042[a]	771	1.11 ± 0.020
BMI (kg/m^2)	295	23.9 ± 0.17[a]	765	22.3 ± 0.11
W/H	296	0.88 ± 0.003[a]	767	0.79 ± 0.002
WC (cm)	296	84.6 ± 0.40[a]	767	73.3 ± 0.26
HC (cm)	296	95.7 ± 0.31[a]	767	93.3 ± 0.24
W/Ht	296	0.50 ± 0.002[a]	767	0.47 ± 0.002
PBF	279	17.5 ± 0.27	735	28.4 ± 0.19[b]

BMI, body mass index; HC, hip circumference; PBF, percentage of body fat; TC, total cholesterol; TC/HDL, ratio of TC to HDL; TG, triglyceride; WC, waist circumference; W/H, waist-hip ratio; W/Ht, waist-height ratio.

[a] Levels in men were significantly higher than corresponding levels in women ($P < 0.001$).

[b] Levels in women were significantly higher than corresponding levels in men ($P < 0.001$).

METHODS

Subjects

A total of 1,069 healthy subjects, 298 men and 771 women between 30 and 70 years old, were included in this analysis. Subjects were recruited from the general public. Only subjects with no known existing or history of major medical illness, such as cancer, hypertension, thyroid dysfunction, diabetes, osteoporotic fracture, and cardiovascular events, were included in the study. This study was sanctioned by the National University of Singapore. Informed consent was obtained from each volunteer. Because 96.7% of all subjects in this study were Chinese, the results and inferences are applicable to this ethnic group, which make up the majority (76%) of the Singaporean population.

Each subject answered a detailed questionnaire that included questions on medical, dietary, social, and sex history, family history of dyslipidemia, and other relevant information concerning the consumption of hormones and food supplements.

Anthropometric measurements

The body weight was measured without shoes using an electronic measuring scale, and height to the nearest centimeter was taken. The BMI was calculated as weight in kilograms divided by height (in meters squared). Waist circumference (WC) in centimeters was measured midway between the lower costal margin and the iliac crest during the end-expiratory phase (18). Hip circumference (HC) in centimeters was measured at the level of the greater trochanters (18). The waist-hip ratio (W/H) was defined as the waist circumference divided by the hip circumference, and the waist-height ratio (W/Ht) was defined as the waist circumference divided by the height in centimeters.

Body fat

Dual-energy X-ray absorptiometry (DEXA) has been used for estimation of the percentage of body fat (PBF) and found to correlate well with other methods, including hydrodensitometry and Jackson and Pollock (seven-site) skinfold prediction (19–23). Each subject had a whole-body scan by DEXA (DPX-l, software version 1.3z; Lunar Radiation, Madison, WI). PBF was computed automatically by the DEXA scanner, and the Siri formula-corrected percentage was used to reflect the total PBF.

Serum lipid and triglyceride levels

An overnight 12 h fasting blood sample was collected, and serum levels of total cholesterol (TC) and triglycerides (TGs) were measured using an automated procedure. HDL was determined after precipitation of apolipoprotein B-containing lipoproteins with sodium phosphotungstate and $MgCl_2$ (24). LDL was computed according to the following formula: LDL = TC − (HDL + [TG × 0.45]). The ratio of TC to HDL (TC/HDL) was used as the atherogenic index (25).

Measurement of serum glucose and insulin levels

Fasting levels of glucose were measured using the routine clinical chemistry laboratory method at the National University Hospital. Fasting levels of insulin were measured by an enzyme-immunoassay method with kits from Abbott Laboratories, and the method of analysis was based on the Axsym autoanalyzer. Internal quality control samples showed interassay coefficients of variation of less than 10%.

TABLE 2. Lipids and triglyceride levels: percentages in men and women

Variable	n	%	n	%	n	%	n	%
TC	<5.2 mmol/l		5.2–6.2 mmol/l		>6.2 mmol/l		Total	
Men	65	23.2	115	41.1	100	35.7	280	100
Women	226	30.7	312	42.5	197	26.8	735	100
LDL	<3.4 mmol/l		3.4–4.1 mmol/l		>4.1 mmol/l		Total	
Men	87	31.1	89	31.8	104	37.1	280	100
Women	351	47.8	224	30.5	160	21.7	735	100
HDL	<1.0 mmol/l		>1.0 mmol/l		Total			
Men	11	3.9	269	96.1	280	100		
Women	8	1.1	727	98.9	735	100		
TC/HDL	<4.5		>4.5		Total			
Men	150	53.6	130	46.4	280	100		
Women	641	87.1	95	12.9	735	100		
TG	<1.7 mmol/l		1.7–2.3 mmol/l		>2.3 mmol/l		Total	
Men	186	66.4	52	18.6	42	15.0	280	100
Women	652	88.6	56	7.6	28	3.8	735	100

TABLE 3. Percentages of men and women in the different PBF groups

Variable	n	%	n	%	n	%	n	%	n	%
PBF	≤10%		11–19%		20–24%		≥25%		Total	
Men	19	6.8	170	60.7	75	26.8	16	5.7	280	100
PBF	≤20%		21–29%		30–34%		≥35%		Total	
Women	51	6.9	370	50.3	218	29.7	96	13.1	735	100

Statistical analysis

Statistical analyses were performed using SPSS for Windows version 11. We looked at basic descriptive statistics and also linear regression analysis, Student's t-test, and Spearman and Pearson correlation analyses where appropriate. The sensitivity and 1 − specificity (false-positive rate) for detection of obesity, which is defined as having a PBF of ≥25% for men and ≥35% for women, using BMI, WC, HC, W/H, and W/Ht were computed based on the receiver operator characteristic (ROC) plots.

RESULTS

Overall, there was no significant difference in age between men and women. On the other hand, most lipids except HDL and other anthropometric measures in men were significantly higher (Student's t-test, $P < 0.001$) than the corresponding levels in women (**Table 1**).

Data from the DEXA whole-body scan showed that men have significantly lower PBF (ranging from 5% to 28%) than do women (ranging from 12% to 44%). On average, men between the ages 30 and 70 years have 17.5% body fat, more than 10% less than that for women (28.4%; Table 1).

More men than women, 76.8% and 69.3%, respectively, have high TC levels (>5.2 mmol/l) (**Table 2**). Almost all men and women have HDL levels greater than 1 mmol/l. As with TC, more men (37.1%) have high levels of LDL (>4.1 mmol/l) than women (21.7%). The atherogenic risk factor (TC/HDL) in men and women reflected those of TC and LDL. More men (46.4%) have high atherogenic risk (TC/HDL > 4.5) than women (12.9%). TG level was higher in men than in women; more men (15.0%) than women (3.8%) have high levels of TG (>2.3 mmol/l) (Table 2).

The distributions of men and women in the various PBF groups are shown in **Table 3**. Using the WHO-recommended PBF of ≥25% for men and ≥35% for women as cutoff points for obesity, 5.7% of local men and 13.1% of local women were classified as obese. The percentage of men (PBF of 20–24%) and women (PBF of 30–34%) considered overweight was 26.8% and 29.7%, respectively (Table 3).

Increasing PBF was associated with increased risks of cardiovascular disease and diabetes. **Table 4** shows the risk factor [TC, HDL, LDL, TC/HDL, TG, glucose (GLU), and insulin (INS)] levels in men and women in the various PBF groups. For men, increased risk was noted for LDL, HDL, TC/HDL, TG, GLU, and INS when PBF increased from ≤10% to 11–19% (Table 4). When PBF increased to >20%, the risk increased further for LDL and INS, whereas for the obese group (PBF ≥ 25%), further increase in risk was noted only for INS (Table 4). In women, on the other hand, the impact of increasing PBF on the various risk factors was more severe than in men. Increased risk was noted for TC, LDL, TC/HDL, TG, GLU, and INS but not for HDL when PBF increased from ≤20% to 21–29%. The risk increased further when PBF increased to 30–34%, and all risk factors were significantly worse than those in the 21–29% PBF group; furthermore, HDL was significantly lower than for those in the ≤20% PBF group. Further increase in risk was noted for LDL, TC/HDL, and INS in the obese group (≥35%) (Table 4).

Figures 1 and **2** show the plots of the percentage of men and women within each PBF group who have high risk levels, TC > 6.2 mmol/l, LDL > 4.1 mmol/l, HDL < 1.0

TABLE 4. Risk factors in different PBF groups in men and women

PBF Group	TC	LDL	HDL	TC/HDL	TG	Insulin	Glucose
Men							
Group 1 (≤10%)	5.4 ± 0.20	3.4 ± 0.18	1.6 ± 0.04[a]	3.3 ± 0.13	0.9 ± 0.09[b]	3.8 ± 0.41	4.8 ± 0.37
Group 2 (11–19%)	5.9 ± 0.08	3.9 ± 0.08	1.4 ± 0.02[c]	4.4 ± 0.08	1.5 ± 0.06	6.1 ± 0.36	4.8 ± 0.55
Group 3 (20–24%)	6.1 ± 0.11	4.1 ± 0.09[d]	1.3 ± 0.02	4.7 ± 0.10[b]	1.6 ± 0.08	9.6 ± 0.69	5.0 ± 0.71
Group 4 (≥25%)	5.8 ± 0.28	3.8 ± 0.23[d]	1.2 ± 0.05	4.9 ± 0.27[b]	1.9 ± 0.20	13.1 ± 3.4[e]	5.3 ± 0.79[f]
Women							
Group 1 (≤20%)	5.3 ± 0.10	3.1 ± 0.08	1.8 ± 0.04[g]	3.0 ± 0.07	0.8 ± 0.04	4.7 ± 0.37	4.6 ± 0.06
Group 2 (21–29%)	5.6 ± 0.05	3.4 ± 0.04	1.7 ± 0.02	3.4 ± 0.04	1.0 ± 0.03	5.3 ± 0.18	4.7 ± 0.03
Group 3 (30–34%)	5.9 ± 0.07[d]	3.6 ± 0.06	1.6 ± 0.03	3.6 ± 0.06	1.2 ± 0.04[d]	6.7 ± 0.30	4.8 ± 0.03
Group 4 (≥35%)	6.1 ± 0.09[d]	3.9 ± 0.09[h]	1.6 ± 0.04	3.9 ± 0.10[h]	1.3 ± 0.05[d]	8.5 ± 0.63[e]	5.0 ± 0.08[i]

[a] Group 1 > groups 2, 3, and 4 ($P < 0.05$).
[b] Groups 3 and 4 > group 2 > group 1 ($P < 0.05$).
[c] Group 2 > group 4 ($P < 0.05$).
[d] Groups 4 and 3 > group 1 ($P < 0.05$).
[e] Group 4 > group 3 > groups 2 and 1 ($P < 0.05$).
[f] Group 4 > groups 3, 2, and 1 ($P < 0.05$).
[g] Group 1 > groups 3 and 4 ($P < 0.05$).
[h] Group 4 >group 3 > group 2 > group 1 ($P < 0.05$).
[i] Group 4 > group 3 > group 1 ($P < 0.05$).

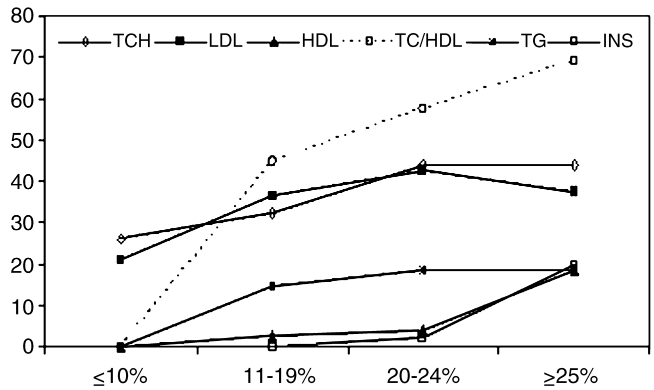

Fig. 1. Percentage of men with total cholesterol (TC) > 6.2 mmol/l, LDL > 4.1 mmol/l, HDL < 1.0 mmol/l, ratio of TC to HDL (TC/HDL) > 4.5, triglyceride (TG) > 2.3 mmol/l, and insulin (INS) > 25 mIU/l in the four percentage of body fat (PBF) groups.

mmol/l, TC/HDL > 4.5, TG > 2.3 mmol/l, and INS > 25 mIU/l. More men in the overweight group (PBF = 20–24%) have high TC, LDL, TC/HDL, and TG levels compared with the low PBF group (PBF ⩽ 10%). In the obese group (PBF ⩾ 25%), even more men have high TC/HDL and INS and low HDL levels compared with the overweight group. A similar trend was noted for women, except that in the obese group (⩾35% body fat), more women have high TC, LDL, TC/HDL, and INS compared with those in the overweight group (30–34% body fat).

In both men and women, BMI was not significantly correlated with age; hence, regression plots between BMI and PBF were established. **Figure 3** depicts the linear regressions between PBF (DEXA) against calculated BMIs for men and women. In both men and women, the BMIs were highly significantly correlated with the PBF ($r = 0.5$–0.6, $P = 0.000$ by Pearson correlation).

From the regression equations derived from the plots shown in Fig. 3, the BMIs corresponding to a body fat of 25% for men and 35% for women were 27 and 25 kg/m^2, respectively, and the corresponding BMIs for PBF of >20% and <25% for men and >30% and <35% for women were 25 and 23 kg/m^2, respectively.

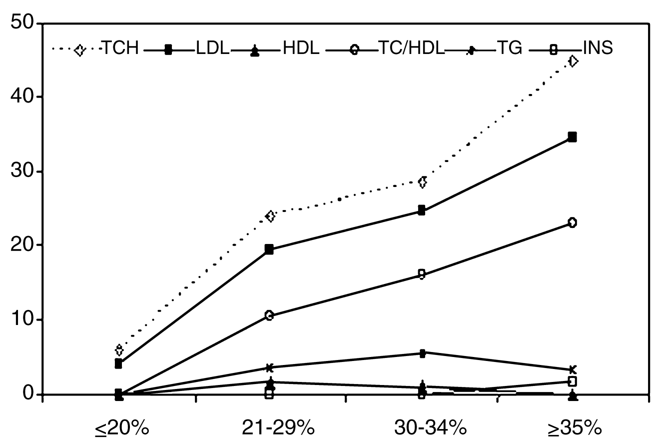

Fig. 2. Percentage of women with TC > 6.2 mmol/l, LDL > 4.1 mmol/l, HDL < 1.0 mmol/l, TC/HDL > 4.5, TG > 2.3 mmol/l, and INS > 25 mIU/l in the four PBF groups.

Table 5 shows the comparative differences in sensitivity and 1 − specificity (false-positive rate) derived from the ROC plots for the different parameters, including those for the WHO-recommended and locally established BMI cutoff points for obesity. Although the WHO-recommended BMI cutoff point for obesity (30 kg/m^2) for men and women has high specificity (97.3% and 95%), respectively, the sensitivity was poor, 6.7% and 13.4%, respectively (Table 5). The rates of obesity in men and women were 5.7% and 13.1%, respectively. What this means is that if the BMI of 30 kg/m^2 was used, between 86.6% and 93.3% of obese women and men will be misclassified as nonobese. On the other hand, 2.7% and 5.0% of nonobese men and women, respectively, will screen positive (Table 5). In contrast, when the BMI cutoff points of 27 kg/m^2 for men and 25 kg/m^2 for women were used, the sensitivity for both genders was greatly increased to 46.7% and 60.8%, respectively. However, the false-positive rates were increased to ~10.5%. These rates of false-positive classification based on the locally appropriate BMI cutoff points must be viewed in the context of the rates of obesity for men (5.7%) and women (13.1%) based on PBF. What this means is that more nonobese men than obese men will be classified as obese, although almost the same proportion of nonobese women as obese women will be misclassified as obese.

For men, the other anthropometric measures (WC ⩾ 92.5 cm, HC ⩾ 101.5 cm, W/H ⩾ 0.94, and W/Ht ⩾ 0.55) showed almost identical sensitivity and 1 − specificity rates compared with the BMI cutoff point of 27 kg/m^2 (Table 5). Using the cutoff points of WC ⩾ 80.5 cm, HC ⩾ 99.5 cm, and W/Ht ⩾ 0.513 for women, the sensitivity rates ranged from 47.9% to 59.4% and the 1 − specificity rates were almost similar to the BMI cutoff point of 25 kg/m^2 (Table 5). For W/H (⩾0.826) in women, the sensitivity was lowest (34.4%) and the 1 − specificity was highest (17.7%; Table 5).

DISCUSSION

The WHO defines obesity as a condition of excessive fat accumulation to the extent that health and well-being are affected. The cutoff points for obesity for men and women correspond to PBF of 25% and 35%, respectively (18, 26, 27). We have used the DEXA scans, a two-compartment model for assessing the PBF. Although the 4C model is more accurate in assessing the PBF, it nevertheless is not practicable for use with a large sample size, as in the present study. It was noted in the study by Deurenberg-Yap et al. (28) that compared with the 4C model, the 2C DEXA-derived PBF consistently underestimated PBF in both men and women. However, interpretations of those data must also take into account the large variations and skewed distributions of the differences for all three 2C models (28).

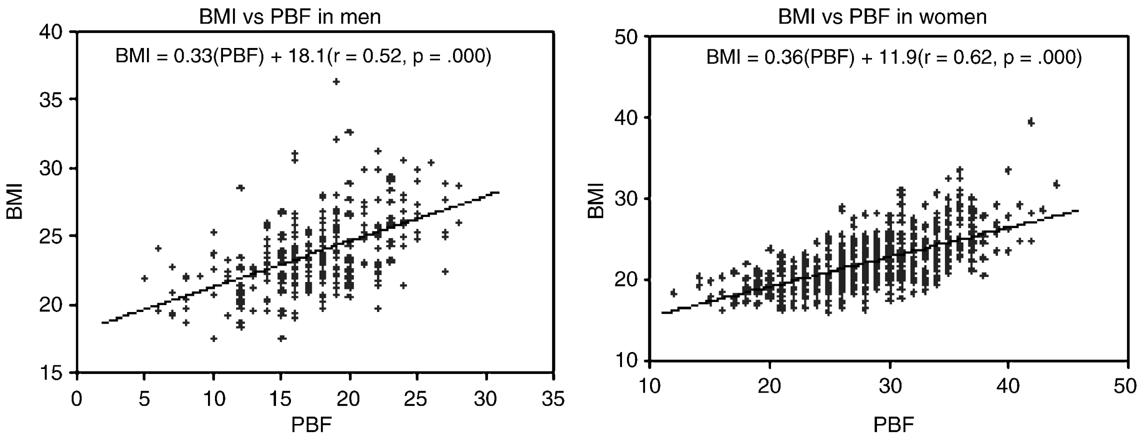

Fig. 3. Regression between body mass index (BMI) versus PBF in men and women.

Applying the WHO-recommended PBF cutoff points for obesity, the incidence of obesity among our healthy 30–70 year old population was 5.7% for men and 13.1% for women. Furthermore, we have shown that increasing PBF in men and women, especially to levels beyond the overweight and obese cutoff points, was associated with higher levels of TC, LDL, TC/HDL, INS, and GLU and lower levels of HDL. Clearly, the classifications based on DEXA-derived PBF in the present study showed that obesity was associated with increased risks of coronary heart disease and type 2 diabetes, as was shown earlier (13, 15, 26, 29).

Obesity is a subset of being overweight. Not everyone who is overweight is obese. This is clearly shown in body builders, who have high BMI but low PBF. Therefore, it is worth remembering that BMI is a measure of body weight and not of obesity. Many studies have shown that the BMI cutoff points for the prescribed classifications as overweight and obese differed from those recommended by WHO. For some Asian populations, including those from Taiwan, Hong Kong, and Singapore, and also a Spanish population, the corresponding BMI cutoff points for overweight and obese were 23 kg/m^2 and 25–27 kg/m^2, respectively (6, 8, 10, 11, 30–33). Hence, there was a need to review the WHO-recommended cutoff limits for obesity in Asian populations.

Using regression analyses and the ROC plots to study the relationships between BMI and DEXA-derived PBF, we have shown that the BMI cutoff point for obesity for our local healthy men and women aged 30–70 years was 27 and 25 kg/m^2, respectively, concurring with earlier suggestions by many Asian investigators (6, 8, 10, 11, 30, 32, 33). Where we differ from these earlier studies is in the finding of a clear gender difference in BMI cutoff for obesity for Asian men (27 kg/m^2) and women (25 kg/m^2); therefore, this gender difference must be taken into consideration when BMI is used as an index of obesity for Asian populations.

The usefulness of a proxy measure for obesity depends not only on having high sensitivity but also high specificity, or, conversely, low 1 − specificity (false-positive classification). Having shown that the BMI cutoff points for obesity are different between Asian men and women and from that recommended by WHO, the question is how good are these new BMI cutoff points as indices for screening for obesity in the local population? Using the ROC plots, we have derived comparative sensitivity and 1 − specificity rates for BMIs and other anthropometric indices in identifying obese individuals in our population. Clearly, by using the WHO-recommended BMI cutoff point of 30 kg/m^2 for obesity, which showed a sensitivity of 6.7% and 13.4% for men and women, respectively, the majority of the 5.7% of obese men and 13.1% of obese women in our population would have been misclassified. In addition, ~2.7% of nonobese men and 5% of nonobese women would be misclassified as obese. In numerical terms, the picture was more stark. For men, if the BMI of 30 kg/m^2 was used as a cutoff for obesity, then for every obese man positively identified, 14 others will be missed

TABLE 5. Sensitivity and 1 − specificity (false-positive rate) based on receiver operating characteristic plots of various anthropometric parameters and obesity

Men	BMI ⩾ 30 kg/m^2	BMI ⩾ 27 kg/m^2	W/H ⩾ 0.94	WC ⩾ 92.5 cm	HC ⩾ 101.5 cm	W/Ht ⩾ 0.55
Sensitivity	6.7%	46.7%	46.7%	46.7%	46.7%	46.7%
1 − Specificity (false positive)	2.7%	10.6%	9.1%	10.6%	10.6%	10.6%
Women	**BMI ⩾ 30 kg/m^2**	**BMI ⩾ 25 kg/m^2**	**W/H ⩾ 0.826**	**WC ⩾ 80.5 cm**	**HC ⩾ 99.5 cm**	**W/Ht ⩾ 0.513**
Sensitivity	13.4%	60.8%	34.4%	47.9%	59.4%	51.0%
1 − Specificity (false positive)	5.0%	10.5%	17.7%	9.7%	11.1%	9.9%

and 6.7 nonobese men will be misclassified as obese. For women, the outcome was slightly better but not promising. For every obese woman positively identified, 6.5 others will be missed and 1.79 nonobese women will be misclassified as obese. Certainly, these results do not bode well for a BMI of 30 kg/m^2 as the cutoff point for obesity in Asian men and women.

Using the locally established BMI of 27 kg/m^2 for men and 25 kg/m^2 for women, the sensitivity was much improved. On average, ~46.7% of obese men and 60.8% of obese women will be positively identified. However, for every obese man and obese woman identified, there will be 3.76 and 1.64 times nonobese men and women, respectively, that will be misclassified as obese.

For men, the other anthropometric measures for obesity, W/H ($\geq$0.94), WC ($\geq$92.5 cm), HC ($\geq$101.5 cm) and W/Ht ($\geq$0.55), and the sensitivity and 1 − specificity rates were similar to those of the BMI of 27 kg/m^2. In women, the sensitivity and 1 − specificity rates for WC ($\geq$80.5 cm), HC ($\geq$99.5 cm), and W/Ht ($\geq$0.513) were close to but lower than the corresponding levels for BMI of 25 kg/m^2. As for W/H ($\geq$0.826), the sensitivity and 1 − specificity were much lower and higher, respectively, than those for BMI of 25 kg/m^2. This result is probably attributable to the fact that the distribution of body fat in women is different from that in men, with fat in men more centrally localized and fat in for women localized more subcutaneously. The W/H is a measure that reflects central obesity; hence, when fat is distributed subcutaneously, W/H is not a good index. Overall, none of the other anthropometric measures in men and women is better as an index for screening obesity than the locally established BMIs for men (27 kg/m^2) and women (25 kg/m^2).

However, if these BMI cutoff points were to be used as screening indices for obesity for local men and women, then a strategy must be in place to address the high levels of false-positive classifications of nonobese men and women. One possibility is to conduct confirmation tests, such as the use of more accurate PBF methods of estimation, on all positive cases before any intervention is applied. Although cumbersome, this strategy would prevent the consequences of mismanagement of nonobese individuals as obese. On the other hand, the problem of high false-negative classification (40–53%) is much more difficult to address. There is no way, with the use of the BMI indices, to identify obese individuals who would be misclassified as nonobese. High false-negative or false-positive classification rates would lead to labeling obese individuals as normal and normal individuals as obese, with the consequence of denying obese individuals the appropriate treatment and wrongly subjecting others to the stigma of being obese or, worse, to seek treatment that is not warranted.

The incidence of obesity, with its attendant high risks of serious health consequences in many countries, including Singapore, is increasing. Many countries are working in concert with the WHO and the International Obesity Task Force to proactively address this problem. As shown in this study, BMIs adjusted for the local population have much improved sensitivity but are still plagued by high false-positive rates, especially for men. Overall, locally established BMI cutoff points are better indices for screening of obesity that any of the anthropometric indices studied. However, to better assist in efforts to combat the scourge of the increasing incidence of obesity, more precise indices for obesity need to be established. There is an urgent need to improve on existing methods and to develop new, simple, sensitive, accurate, and cost-effective methods for estimation of PBF so that obesity can be more efficiently managed. As suggested by Deurenberg-Yap et al. (28), if hydration and density of fat-free mass for specific populations could be established and used, then densitometry, including DEXA, could be an alternative method that could be used with large sample sizes. However, if simplicity and cost are major considerations, then hygrometry could be a method of choice.

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