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Lower BMI cut-off value to define obesity in Hong Kong Chinese: an analysis based on body fat assessment by bioelectrical impedance

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There is increasing evidence suggesting that the cut-off values for defining obesity used in the Western countries cannot be readily applied to Asians, who often have smaller body frames than Caucasians. We examined the BMI and body fat (BF) as measured by bioelectrical impedance in 5153 Hong Kong Chinese subjects. We aimed to assess the optimal BMI reflecting obesity as defined by abnormal BF in Hong Kong Chinese. Receiver operating characteristic curve (ROC) analysis was used to assess the optimal BMI predicting BF at different levels. The mean age and SD of the 5153 subjects (3734 women and 1419 men) was 51·5 (SD 16·3) years (range: 18·0–89·5 years, median: 50·7 years). Age-adjusted partial correlation (r) between BMI and BF in women and men were 0·899 ($P < 0·001$) and 0·818 ($P < 0·001$) respectively. Using ROC analysis, the BMI corresponding to the conventional upper limit of normal BF was 22·5–23·1 kg/m^2, and the BMI corresponding to the 90 percentiles of BF was 25·4–26·1 kg/m^2. Despite similar body fat contents, the BMI cut-off value used to define obesity in Hong Kong Chinese should be lower as compared to Caucasians. We suggest a BMI of 23 kg/m^2 and 26 kg/m^2 as the cut-off values to define overweight and obesity respectively in Hong Kong Chinese.

Obesity: BMI: Body fat: Chinese

Obesity has become a major health problem due to its increasing prevalence and associated morbidity and mortality (Jousilahti *et al.* 1996; Seidell *et al.* 1996; WHO, 1998). Increasing BMI is associated with a higher risk of diabetes mellitus, hypertension, and other cardiovascular risk factors in both Caucasians and Asians, such as Hong Kong Chinese (Higgins *et al.* 1988; Srinivasan *et al.* 1996; Ko *et al.* 1998, 1999*a*). Obesity is characterised by an excess of body fat (BF), which is defined conventionally as BF > 25 % in males and > 35 % in females (young adults aged < 35 years; WHO, 1995; Lohman *et al.* 1997; Deurenberg *et al.* 1998). The BMI corresponding to these body fat contents is 30 kg/m^2 in young Caucasians (WHO, 1995). Some Western workers also reported a relationship between a BMI cut-off value of 30 kg/m^2 with morbidity and mortality. In accordance with this, WHO (1995) recommend a BMI cut-off value for obesity at 30 kg/m^2. However, there is increasing evidence suggesting these cut-off levels cannot be readily applied to Hong Kong Chinese, who often have smaller body frames than Caucasians such as Americans (Ko *et al.* 1999*a*, *b*). In this study, we examined 5153 Hong Kong Chinese subjects on their BMI and BF measured by bioelectrical impedance. We aimed to assess the optimal BMI reflecting obesity as defined by abnormal BF in Hong Kong Chinese.

Methods

Subjects

From April 1996 to August 1997, subjects from the community of Hong Kong presented themselves voluntarily at the United Christian Nethersole Community Health Service Centers for primary health care check-up. The United Christian Nethersole Community Health Service is a self-funded non-profit-making organisation with the

Abbreviations: BF, body fat; ROC, receiver operating characteristic curve.
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objective of health promotion through primary health care and education. Interested citizens came from different districts all over Hong Kong. During the study period, 17 121 subjects were recruited. Due to the limitation of resources, BF measurements with bioelectrical impedance were randomly performed in 5153 of these 17 121 subjects (one in three). The BF measurements of these 5153 subjects were analysed in this study.

Demographic data were documented, and height and weight (measured to the nearest 0·1 kg) were measured with the subject in light clothing without shoes. BMI was calculated as the weight (kg) divided by the square of the height (m). Classification of BMI was based on the WHO criteria (1995). Overweight was defined as BMI $\geq$25 kg/m^2 and obesity $\geq$30 kg/m^2. Increased BF, high BF and very high BF were defined as BF $\geq$30 %, $\geq$35 % and $\geq$40 % in females, and $\geq$20 %, $\geq$25 % and $\geq$30 % in males respectively.

Bioelectrical impedance

All bioelectrical impedance measurements were performed with a bioelectrical impedance analyser (TBF-401; TANITA, Tokyo, Japan). The measurements were performed with the subjects stepping onto the measuring platform without shoes and after wiping the soles of their feet. From weight, height, age, sex and bioelectrical impedance, BF was calculated from a built-in equation of the analyser. The amount of BF is expressed as a percentage of total weight. The analyser produces a printout with data of the BF after every measurement. The day-to-day variation in the measurement of bioelectrical impedance ranges from 0·7 to 1·7 %.

The bioelectrical impedance measurements were validated with 49 Hong Kong Chinese subjects using dual-energy X-ray absorptiometry. Their mean BMI was 25·1 kg/m^2 (body weight: 60·2 (SD 26·2) kg, height: 1·55 (SD 0·16) m). The BF measured by bioelectrical impedance and dual-energy X-ray absorptiometry were 28·9 % (SD 12·8) and 27·3 % (SD 10·3) respectively. The intra-class correlation coefficient (95 % CI) was 0·765 (0·619, 0·860; $P = 0{\cdot}149$).

Statistical analysis

Statistical analysis was performed using the SPSS (version 9·0) software on an IBM compatible computer. All results are expressed as mean and SD or % (n) where appropriate. Student's t test and chi-square test were used for between group comparison. A P-value $<$0·05 (two-tailed) was considered to be significant.

Age-adjusted partial correlation between BMI and BF was calculated in men and women. Receiver operating characteristic curve (ROC) analysis was used to assess the optimal BMI predicting BF at different levels. Youden indexes (Y) were calculated with $Y = \text{sensitivity} + \text{specificity} - 1$. Multiple regression analysis (forward stepwise) was performed with age, BMI and gender as independent variables to predict BF.

Results

Of the 5153 subjects, 3734 (72·5 %) were women and 1419 (27·5 %) were men. The mean age was 51·5 (SD 16·3) years (range: 18·0–89·5 years, median: 50·7 years). Table 1 summarises their BMI and BF. Age-adjusted partial correlations (r) between BMI and BF in women and men were 0·899 ($P < 0{\cdot}001$) and 0·818 ($P < 0{\cdot}001$) respectively.

According to ROC analysis, the optimal BMI to predict increased BF, high BF and very high BF were 22·5 kg/m^2, 24·2 kg/m^2 and 26·1 kg/m^2 in women, and 23·1 kg/m^2, 23·8 kg/m^2 and 25·4 kg/m^2 in men respectively. Table 2 summarises the ROC analysis of optimal BMI to predict BF in various age groups.

The 75 percentiles of BF in men and women were 25 and 35 %, respectively while the 90 percentiles of BF in men and women were 29 and 40 % respectively. Table 3 summarises the corresponding BMI to various BF cutoff values according to ROC analysis. In particular, the BMI corresponding to the conventional upper limit of normal BF was 22·5–23·1 kg/m^2, and the BMI corresponding to the 90 percentiles of BF was 25·4–26·1 kg/m^2.

Table 1. BMI and BF of 5153 Hong Kong Chinese subjects
(Values are means and their SD for n subjects)

	Total (n 5153)		Women (n 3734)		Men (n 1419)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	51·5	16·3	51·3	16·4	52·1	16·3
Weight (kg)	57·4	10·6	54·6	9·1	64·8***	10·6
Height (cm)	157·6	8·4	154·3	6·3	166·3*	6·7
BMI (kg/m^2)	23·1	3·6	23·0	3·7	23·4***	3·3
BMI $\geq$ 25 kg/m^2, % (n)	28·2 (1455)	–	27·3 (10·9)	–	30·7 (436)***	–
BMI $\geq$ 30 kg/m^2, % (n)	3·4 (177)	–	3·8 (142)	–	2·5 (35)***	–
BF (%)	27·7	7·9	30·1	7·3	21·4***	5·9
Increased BF, % (n)	54·4 (2802)	–	50·9 (1902)	–	63·4 (900)***	–
High BF, % (n)	26·9 (1386)	–	25·8 (965)	–	29·7 (421)***	–
Very high BF, % (n)	9·7 (498)	–	10·3 (385)	–	8·0 (113)***	–

BF, body fat.
P-values comparing men and women: *$<$ 0·05, **$<$ 0·01, ***$<$ 0·001.
Increased BF: BF $\geq$ 30 % in women or $\geq$ 20 % in men; High BF: BF $\geq$ 35 % in women or $\geq$ 25 % in men; Very high BF: BF $\geq$ 40 % in women or $\geq$ 30 % in men.

Table 2. The optimal BMI predicting body fat (BF) using receiver operating characteristic curve (ROC) analysis in various age groups of Hong Kong Chinese

Age (years)	Increased BF BMI (kg/m^2)	Sensitivity	Specificity	Youden index	High BF BMI (kg/m^2)	Sensitivity	Specificity	Youden index	Very high BF BMI (kg/m^2)	Sensitivity	Specificity	Youden index
Women (*n* 3734)												
<30	21.433	0.923	0.914	0.837	23.145	1.000	0.944	0.944	23.971	1.000	0.949	0.949
≥ 30–40	21.773	0.904	0.897	0.800	23.669	0.992	0.902	0.893	25.389	1.000	0.912	0.912
≥ 40–50	22.451	0.900	0.864	0.764	24.239	0.886	0.874	0.760	27.162	0.868	0.947	0.815
≥ 50–60	23.078	0.824	0.962	0.786	24.643	0.922	0.879	0.801	26.412	0.869	0.887	0.755
≥ 60–70	22.643	0.916	0.832	0.748	24.562	0.886	0.836	0.722	26.167	0.914	0.864	0.778
≥ 70	23.285	0.865	0.904	0.769	24.985	0.859	0.850	0.709	25.520	0.973	0.761	0.734
All	22.467	0.902	0.888	0.789	24.221	0.914	0.865	0.779	26.100	0.904	0.892	0.796
Men (*n* 1419)												
<30	22.387	0.857	0.896	0.753	22.847	1.000	0.833	0.833	28.558	1.000	0.992	0.992
≥ 30–40	22.470	0.827	0.874	0.701	23.907	0.868	0.791	0.659	25.859	0.829	0.831	0.659
≥ 40–50	23.103	0.817	0.890	0.708	25.526	0.693	0.894	0.587	26.425	0.875	0.875	0.750
≥ 50–60	21.485	0.973	0.759	0.733	24.720	0.907	0.832	0.739	24.322	1.000	0.635	0.635
≥ 60–70	22.784	0.824	0.832	0.656	24.625	0.768	0.805	0.573	25.882	0.810	0.834	0.644
≥ 70	23.730	0.638	0.893	0.531	23.895	0.833	0.767	0.600	24.136	1.000	0.674	0.674
All	23.081	0.756	0.879	0.634	23.764	0.881	0.748	0.630	25.402	0.858	0.784	0.642

Sensitivity, proportion of true positives correctly identified; specificity, proportion of true negatives correctly identified.

Discussion

Our study is limited by the validity of using bioelectrical impedance in the measurement of BF. Underwater weighing is the standard method for body composition assessment, which is, however, laborious and inconvenient (Siri, 1961). Solomons & Mazariegos (1995) reviewed various techniques available for the assessment of human body compositions and commented that bioelectrical impedance analysis showed close correlation with other anthropometric measures and BF. BF measurements by the TANITA bioelectrical impedance analyser have been reported to give good estimation of BF in Caucasians (Nunez *et al.* 1994). The BF by the TANITA were highly correlated with BF measured by both dual-energy X-ray absorptiometry (r 0·88, $P < 0·001$) and hydrodensitometry (r 0·90, $P < 0·001$; Nunez *et al.* 1994). Similar positive correlation between BF obtained by TANITA and dual-energy X-ray absorptiometry was also reported in Japanese (r 0·893, $P < 0·001$; Sakamoto *et al.* 1994). We believe the present study, with a vast database on bioelectrical impedance measurements, has provided useful information regarding the validity of using BMI as a measurement of obesity in Hong Kong Chinese.

We have previously reported a much lower mean BMI in Hong Kong Chinese as compared to Americans (23 kg/m^2 vs. 26·3 kg/m^2; Ko *et al.* 1997). Yet, there is now a wealth of data showing that the prevalence of diabetes and hypertension are reaching epidemic proportions in Asians (Zimmet, 1992). The latest age-standardised prevalence of undiagnosed diabetes and impaired fasting glucose are 2·8 % and 7·3 % respectively in Hong Kong (Ko *et al.* 1999*c*). These figures are comparable to the recently reported age-standardised prevalence of undiagnosed diabetes of 2·7 % and impaired fasting glucose of 6·9 % in the US according to the NHANES III data (Harris *et al.* 1998). So, despite having a much lower mean BMI, the prevalence of some of the obesity-related health problems in Hong Kong Chinese is similar to that in Caucasians. In agreement with this, a high likelihood ratio to have diabetes and hypertension has been found in Hong Kong Chinese with a lower BMI as compared to Caucasians (Ko *et al.*

Table 3. The BMI corresponding to various body fat (BF) cut-off values using prediction equation or ROC analysis in Hong Kong Chinese

BF (%)	Definition	Corresponding BMI (kg/m^2) ROC analysis
Women		
30	Upper limit of normal (conventional)	22.5
35	75 percentiles	24.2
36	80 percentiles	24.5
38	85 percentiles	25.0
40	90 percentiles	26.1
Men		
20	Upper limit of normal (conventional)	23.1
25	75 percentiles	23.8
26	80 percentiles	25.1
27	85 percentiles	25.1
29	90 percentiles	25.4

1999*a*). This raised the possibility that Chinese may have a similar amount of body fat as in Caucasians despite a lower BMI. There are recent publications demonstrating high body fat with 'relatively' low BMI among Asians. For the same amount of body fat as Caucasians who have a BMI of 30 kg/m^2, it has been reported that the corresponding BMI would be 27 kg/m^2 for Chinese and Malays and 26 kg/m^2 for Indians (Yap *et al.* 2000). In a recent review on obesity assessment, Deurenberg & Yap (1999) concluded that the relationship between BF and BMI differs between ethnic groups and, as a consequence, cut-off points for obesity based on BMI will have to be ethnicity specific.

In this study, the mean BMI of 23·1 kg/m^2 in Hong Kong Chinese was similar to that reported previously (Ko *et al.* 1997, 1999*a*), which was much lower than the mean BMI of 26 kg/m^2 in the US or the UK (Kuczmarski *et al.* 1994; Lean *et al.* 1995). The prevalence of obesity using WHO criteria (BMI ≥ 30 kg/m^2) in this study is only 3·4 %. However, the prevalence of high BF (≥ 35 % in females or ≥ 25 % in males) was 26·9 %, which is similar to the prevalence of obesity (BMI ≥ 30 kg/m^2) in Caucasians (Hodge & Zimmet, 1994; Seidell & Flegal, 1997). The conventional upper limit of 'normal' in Caucasians with 30 % BF in females and 20 % in males corresponds to a BMI of 22·5–23·1 kg/m^2 in Hong Kong Chinese. The 90 percentiles of BF in our studied subjects were 40 % in females and 29 % in males with a corresponding BMI range of 25·4–26·1 kg/m^2.

In conclusion, with similar body fat contents, the BMI cut-off for obesity in Hong Kong Chinese should be lower as compared to Caucasians. We suggest a lower BMI cut-off of 23 kg/m^2 and 26 kg/m^2 to define overweight and obesity, respectively, in Hong Kong Chinese.

References

Deurenberg P & Yap M (1999) The assessment of obesity: methods for measuring body fat and global prevalence of obesity. *Baillière's Clinical Endocrinology and Metabolism* **13**, 1–11.

Deurenberg P, Yap M & van Staveren WA (1998) Body mass index and percent body fat: a meta-analysis among different ethnic groups. *International Journal of Obesity* **22**, 1164–1171.

Harris MI, Flegal KM, Cowie CC, Eberhardt MS, Goldstein DE, Little RR, Wiedmeyer HM & Byrd-Holt DD (1998) Prevalence of diabetes, impaired fasting glucose, and impaired glucose tolerance in US adults. *Diabetes Care* **21**, 518–524.

Higgins M, Kannel W, Garrison R, Pinsky J & Stokes J (1988) Hazards of obesity–the Framingham experience. *Acta Medica Scandinavica Supplement* **723**, 23–36.

Hodge AM & Zimmet PZ (1994) The epidemiology of obesity. *Baillières' Clinical Endocrinology and Metabolism* **8**, 577–599.

Jousilahti P, Tuomilehto J, Vartiainen E, Pekkanen J & Puska P (1996) Body weight, cardiovascular risk factors, and coronary mortality. 15-year follow-up of middle-aged men and women in eastern Finland. *Circulation* **93**, 1372–1379.

Ko GTC, Chan JCN, Woo J, Lau E, Yeung VTF, Chow CC, Wai HPS, Li JKY, So WY & Cockram CS (1997) Simple anthropometric indexes and cardiovascular risk factors in Chinese. *International Journal of Obesity* **21**, 995–1001.

Ko GTC, Chan JCN & Cockram CS (1998) The association between dyslipidaemia and obesity in Chinese men after adjustment for insulin resistance. *Atherosclerosis* **138**, 153–161.

Ko GTC, Chan JCN, Cockram CS & Woo J (1999*a*) Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hong Kong Chinese. *International Journal of Obesity* **23**, 1136–1142.

Ko GTC, Cockram CS, Critchley JA & Chan JCN (1999*b*) Obesity: definition, aetiology and complications. *Medical Progress* **26**, 10–14.

Ko GTC, Wu MMF, Wai HPS, Tang J, Chan CHS, Kan ECY & Chen R (1999*c*) Rapid increase in the prevalence of undiagnosed diabetes and impaired fasting glucose in asymptomatic Hong Kong Chinese. *Diabetes Care* **22**, 1751–1752.

Kuczmarski RJ, Flegal KM, Campbell SM & Johnson CL (1994) Increasing prevalence of obesity among US adults. The National Health and Nutrition Examination Surveys, 1960 to 1991. *JAMA* **272**, 205–211.

Lean MEJ, Han TS & Morrison CE (1995) Waist circumference as a measure for indicating need for weight management. *British Medical Journal* **311**, 158–161.

Lohman TG, Houtkoper L & Going SB (1997) Body fat measurements goes high tech. Not all are created equal. *ACSM's Health & Fitness Journal* **1**, 30–35.

Nunez C, Gallagher D, Russell-Aulet M & Heymsfield SB (1994) Impedance analysis of body composition: a new measurement approach. In *Proceedings of the 7th International Congress on Obesity*, pp. 498 [N Landignon and MJ Stock, editors]. Toronto, Ontario, Canada.

Sakamoto Y, Miura J, Yamaguchi Y, Ohno M & Ikeda Y (1994) Usefulness of bioelectrical impedance analysis for measurement of body fat. In *Proceedings of the 7th International Congress on Obesity*, pp. 501 [N Landignon and MJ Stock, editors]. Toronto, Ontario, Canada.

Seidell JC & Flegal KM (1997) Assessing obesity: classification and epidemiology. *British Medical Bulletin* **53**, 238–252.

Seidell JC, Verschuren WM, van Leer EM & Kromhout D (1996) Overweight, underweight, and mortality. A prospective study of 48 287 men and women. *Archive of Internal Medicine* **156**, 958–963.

Siri WE (1961) Body composition from fluid spaces and density: analysis of methods. In *Techniques for Measuring Body Composition*, pp. 223–244 [J Brozek and A Henschel, editors]. Washington, DC: National Academy of Sciences.

Solomons NW & Mazariegos M (1995) Low-cost appropriate technologies for body composition assessment: a field researcher's view. *Asia Pacific Journal of Clinical Nutrition* **4**, 19–22.

Srinivasan SR, Bao W, Wattigney WA & Berenson GS (1996) Adolescent overweight is associated with adult overweight and related multiple cardiovascular risk factors: the Bogalusa Heart Study. *Metabolism* **45**, 235–240.

World Health Organisation (1995) *Physical Status: The use and interpretation of anthropometry*. Technical Report Series 854, Geneva.

World Health Organisation (1998) *Obesity: Preventing and managing the global epidemic*. Report on a WHO Consultation on Obesity, Geneva, 3–5 June 1997 WHO/NUT/NCD/98. 1, Geneva.

Yap M, Schmidt G, van Staveren WA & Deurenberg P (2000) The paradox of low body mass index and high body fat percentage among Chinese, Malays and Indians in Singapore. *International Journal of Obesity and Related Metabolic Disorders* **24**, 1011–1017.

Zimmet P (1992) Challenges in diabetes epidemiology–from West to the rest. *Diabetes Care* **15**, 232–252.