Elevated body fat percentage and cardiovascular risks at low body mass index levels among Singaporean Chinese, Malays and Indians

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Summary

The aim of this study was to investigate the relationship between body mass index (BMI) and body fat percentage (BF%) in Singaporean Chinese, Malays and Indians, and to determine the risk for selected comorbidities at various BMI categories and abdominal fat distributions, as assessed by waist circumference (WC). The study was a cross-sectional (population) design. In total, 4723 subjects participated in the National Health Survey of 1998 in which the risks were investigated. A selected subsample of 291 subjects participated in a detailed body composition study, where weight, height and WC were measured, as were blood pressure, total and high-density lipoprotein (HDL) cholesterol, serum triglycerides and fasting glucose. In the subsample, BF% was determined by means of a chemical four-compartment model. At any given BF% the BMI of Singaporeans was about 3 kg m\(^{-2}\) lower than that of Caucasians. There were slight differences in the BF%/BMI relationship between the three ethnic groups. For all the ethnic groups, it was found that at low categories of BMI (between 22 and 24 kg m\(^{-2}\)) and WC (between 75 and 80 cm for women and between 80 and 85 cm for men), the absolute risks for having at least one of the aforementioned risk factors were high, ranging from 41 to 81%. At these same categories the relative risks were significantly higher compared to the reference category, odds ratios ranging from 1.97–4.38. These categories of BMI and WC were all far below the cut-off values of BMI and WC as currently recommended by the World Health Organization (WHO). The data from the current study, which includes evidence that not only risk factors, but also BF% are elevated at low BMI values, presents a strong case for lowering the BMI cut-off value for overweight and obesity among Singaporeans, from 25 kg m\(^{-2}\) and 30 kg m\(^{-2}\) to 23 kg m\(^{-2}\) and 27 kg m\(^{-2}\), respectively.

Keywords: Asians, BMI cut-off values for obesity, body fat percentage, cardiovascular risk factors, Chinese, four-compartment model, Indians, Malays, Singapore, waist circumference.

Introduction

Singapore is an island country state situated at the tip of the Malaya Peninsula, with a land area of 682.7 square kilometres and a resident population of 3.26 million. It is a multiethnic, multicultural society comprising mainly Chinese (77%), Malays (14%) and Indians (8%). The other ethnic groups make up about 1.4% of the population (1). Over the last four decades, Singapore has experienced rapid economic growth with a concomitant improvement in the health status of her people. The infant mortality rate is among one of the lowest in the world, at less than four per 1000 live births, while life expectancy has risen from...
Parallel to these improvements, there has also been a change in the disease patterns among Singaporeans over the last four decades. The main causes of death have altered from those arising as a result of infectious diseases and poor environmental conditions to the so-called lifestyle diseases, such as cancers and cardiovascular diseases (mainly coronary heart disease), which are now the two major causes of death (3).

The mortality from cardiovascular disease in Singapore is comparable to that observed in the West and higher than that in other parts of Asia, such as Japan and Hong Kong (4). On the other hand, obesity prevalence [defined as a body mass index (BMI) of \( \geq 30 \text{kg m}^{-2} \)] is much lower among Singaporean adults (at \( \approx 5\% \)) as compared to Caucasian populations (5).

Obesity as an independent risk factor for cardiovascular diseases, particularly for coronary heart disease, has been documented in long-term prospective studies (5). It has also been recognized that obesity partially mediates its effects by elevating other cardiovascular risk factors, viz., dyslipidaemia [hypercholesterolaemia, hypertriglyceridaemia and low high-density lipoprotein (HDL) cholesterol], hypertension and glucose intolerance (5–8). An elevated level of body fat and the pattern of fat distribution is closely related to increased morbidity and mortality, chief among which is cardiovascular disease (9–11).

Such relationships have been clearly established in a large number of studies involving mainly Caucasian populations. For such populations, it has been found that the BMI cut-off points of 25 kg m\(^{-2}\) for overweight and 30 kg m\(^{-2}\) for obesity are appropriate as they are indicative of elevated levels of risk factors and associated with an increase in morbidity and mortality. Based on these studies, the World Health Organization (WHO) (5) has recommended present cut-off points for overweight and obesity at BMI values of 25 kg m\(^{-2}\) and 30 kg m\(^{-2}\), respectively.

A BMI of 30 kg m\(^{-2}\) corresponds to about 25% and 35% body fat for Caucasian men and women, respectively (12,13). Recently, studies have shown that BMI–body fat percentage (BF%) relationships are age- and gender specific (13–17) and probably also ethnic specific (18–23). For example, Indonesians are found to have a higher BF% compared to Caucasians with the same BMI (21), while the reverse may be true for Blacks (16). For the same BF%, the difference in BMI between Indonesians and Caucasians is \( \approx 3 \) units. This implies that for Indonesians, BMI cut-off points for obesity should be 27 instead of 30 kg m\(^{-2}\). This BMI cut-off of 27 kg m\(^{-2}\) has been adopted by Indonesia.

The use of inappropriate BMI cut-off points could explain the discrepancy in the apparently low prevalence of obesity and high prevalence of obesity-related diseases in Singapore. Figure 1 shows a comparison of obesity rates (based on a BMI of 30 kg m\(^{-2}\)) and age-standardized death rates (ASDR) from ischaemic heart disease in some selected countries. It is obvious that the low prevalence of obesity and high ASDR seen in Singapore is a paradoxical situation.

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*Figure 1* Comparison of obesity prevalence (%) and age-standardized death rates from ischaemic heart diseases (IHD) in selected countries.

*BMI \( \geq 30 \text{kg m}^{-2}\). HK, Hong Kong; UK, United Kingdom; US, United States of America.

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Recognizing the limitation of using uniform BMI cut-off points across populations, the WHO has recommended that research into the development of anthropometric indicators and cut-off points for total body fatness and visceral fat in relation to health outcomes appropriate for certain subgroups of age, gender and race, is necessary (5,12).

Such research was carried out in 1998 among the three major ethnic groups in Singapore, to determine whether the WHO cut-off values for overweight and obesity using BMI are appropriate for the different population groups in Singapore. The approach taken was to evaluate the two criteria in the WHO definition of obesity, which states that obesity is a condition with excessive fat accumulation in the body to the extent that health and well-being are adversely affected (5). The study first established the relationship between BMI and BF% and then determined the risk for selected comorbidities at various BMI categories. In addition, the relationship between abdominal fatness [as measured by waist circumference WC] with cardiovascular risk factors was also determined. The study was conducted as part of the National Health Survey in 1998, a national cross-sectional survey conducted to determine the prevalence of selected diseases and their associated risk factors (24).

**Body mass index and body fat percentage among Singaporeans**

In total, 108 Chinese, 76 Malays and 107 Indians (total \( n = 291 \)) of both genders were included in the study. They were randomly chosen from the National Health Survey sample in such a manner that all ages, genders, ethnic groups and a range of BMI levels were represented equally. Their ages ranged from 18 to 75 years and their BMI from 16 to 40 kg m\(^{-2}\).

BF% was calculated using the four-compartment model (including fat mass, total body water, total body mineral and a remaining compartment, consisting of protein and carbohydrate), as described by Baumgartner et al. (25):

\[
BF\% = 205^{*}[\{1.34 + D_t\} - 0.35^{*}A + 0.56^{*}M - 1],
\]

where \( D_t \) = body density, \( A \) = water fraction of body weight and \( M \) = mineral fraction of body weight.

Total body water (TBW) was determined using deuterium oxide dilution. The subject drank a precisely weighed amount of deuterium oxide (the amount given varied between 10 and 11 g). Three hours after dosing, a 10-mL venous blood sample was taken and plasma was separated and stored at -20°C until analyses were performed. Plasma was sublimated and then analysed for deuterium using infrared spectroscopy (26). From the given dose and the deuterium concentration in plasma, TBW was calculated, assuming a 5% non-aqueous dilution of the deuterium oxide in the body (27).

Body density was determined using air plethysmography (Bodpod\textsuperscript{®} Body Composition System: Life Measurements Instruments, Concord, CA) according to the instructions of the manufacturer. The method is described in detail by Dempster & Aitkens (28).

Bone mineral content (BMC) was measured using a Hologic\textsuperscript{®} DXA whole body X-ray densitometer (QDR-4500, Hologic\textsuperscript{®}, Waltham, MA; software version V8.23a:5). As Hologic\textsuperscript{®} measurements generally result in systematic lower BMC measurements compared to Lunar\textsuperscript{®} (Lunar Radiation Corp., Madison, WI, USA) measurements (29), BMC data were corrected to Lunar\textsuperscript{®} values. This was found to be necessary as the Lunar\textsuperscript{®} machine was used for development of the equation of Baumgartner’s four-compartment model (25). A correction factor based on phantom measurements (Lunar aluminium ‘spine’ phantom) using a Lunar DPXL (software version 1.35) was determined. The found correction factor of 1.167 for the phantom was confirmed by three sets of measurements performed on two subjects over a period of one year. For each set, these two subjects were measured twice within one week using both systems. Total BMC was calculated as 1.235\(^{*}\)BMC (25,30).

It was found that when a BF% prediction equation, based on BMI in Caucasian populations, was applied to the three ethnic groups in Singapore, there was a gross underestimation of actual BF% when measured using the reference method. The mean bias in prediction ranged from 2.7 to 5.6% body fat (31). This indicates that the BMI–BF% relationship in Chinese, Malays and Indians are different from that in Caucasian populations. This relationship is described as:

\[
BF\% = 1.04^{*}BMI - 10.9^*gender + 0.1^{*}age + 2.0E1 + 1.5E2 + 5.7,
\]

where \( E_1 \) and \( E_2 \) are dummy variables. For Chinese, \( E_1 = 0, E_2 = 1 \); for Malays, \( E_1 = 1, E_2 = 0 \); and for Indians \( E_1 = 1, E_2 = 1 \). Gender is coded as 0 for females and 1 for males. Thus, for the same BMI values, Chinese have the lowest BF% while Indians have the highest. This equation explains 74% of the variation in BF% when the independent factors are controlled for, and has a standard error of estimate of 4.4% body fat, which is comparable to BMI-based prediction formulas in the current literature (13,14,21). One possible explanation for these differences in the BMI–BF% relationship are differences in body build (slenderness and relative leg length) between ethnic groups, as was also found in earlier studies (18,21,32). For the same BF% as obese Caucasians with a BMI of 30 kg m\(^{-2}\), the BMI of Chinese and Malays should be \( \approx 27 \) kg m\(^{-2}\), while that for Indians should be \( \approx 26 \) kg m\(^{-2}\). The value for Malays is
similar to those found in studies carried out among Indonesians in Indonesia (21).

**Body mass index and cardiovascular risk factors**

The relationship among BMI, WC and cardiovascular risk factors was studied in a total of 4723 subjects from the 1998 National Health Survey. The absolute and relative risks for having at least one cardiovascular risk factor, viz., elevated total blood cholesterol, elevated total cholesterol (TC) to HDL cholesterol ratio, elevated triglycerides (TG), hypertension and diabetes mellitus, were determined for various categories of BMI and WC, with correction for age, cigarette smoking, physical activity level, educational level and occupation.

Overnight fasting blood samples were taken and plasma was separated and analysed on the same day. TC was determined using an enzymatic method with a commercially available test kit (no. 1489704; Boehringer Mannheim GmbH, Mannheim, Germany). HDL-cholesterol was determined by the homogeneous enzymatic test (test kit no. 1731203 Boehringer Mannheim GmbH). LDL cholesterol (LDL) was measured using homogeneous turbidimetric method (kit no. 1730843; Boehringer Mannheim GmbH). Fasting glucose (FG) and glucose levels after the two-hour oral glucose tolerance test (OGTT) were measured enzymatically by using the glucose oxidase – peroxidase (GOD-POD) method (kit no. 1448684; Boehringer Mannheim GmbH). TG levels were determined enzymatically by using the glycerol phosphate oxidase – peroxidase antiperoxidase (GPO-PAP) method (kit no. 1555626; Boehringer Mannheim GmbH). All chemical analyses were performed by using a Boehringer Mannheim/Hitachi 747 analyser.

Blood pressure was measured (using a standard mercury sphygmomanometer and a cuff of suitable size) at the right arm after an adequate rest period of at least 15 min. Korotkoff phase I and phase V were used for systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements, respectively (33). Cut-off values for hypertension were defined as SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg (34), elevated TC as a TC concentration of ≥6.2 mmolL⁻¹, elevated TC : HDL ratio as a ratio of ≥4.4 (35), elevated TG as a TG concentration of ≥1.8 mmolL⁻¹ (36) and diabetes mellitus as an OGTT value of ≥11.1 mmolL⁻¹ (37). ‘Risk’ was defined as having at least one of the above factors.

For all the ethnic groups, it was found that at low categories of BMI (between 22 and 24 kgm⁻²) and WC (between 75 and 80 cm for women and between 80 and 85 cm for men), the absolute risks for having at least one of the aforementioned risk factors were high, ranging from 41 to 81% (Figs 2 and 3) (38,39). At these same categories the relative risks were significantly higher compared to the reference category, with odds ratios ranging from 1.97 to 4.38 (Tables 1 and 2). These categories of BMI and waist are all far below the currently recommended WHO cut-off values for BMI and WC (5).

The marked increase in absolute and relative risks with increasing categories of obesity indices is consistent with the high mortality from ischaemic heart disease experienced by Singaporeans. The discrepancy between the high cardiovascular mortality and apparently low national obesity prevalence (defined as a BMI of ≥30 kgm⁻²) could be partially explained by the presence of excessive BF% among Singaporeans at low levels of BMI when compared to Caucasians. Based on percentage body fat and presence of risk factors, the currently recommended BMI cut-off values for overweight (≥25 kgm⁻²) and obesity (≥30 kgm⁻²) are not relevant for Singaporeans. BMI cut-off values
of $\geq 23 \text{kgm}^{-2}$ and $\geq 27 \text{kgm}^{-2}$ for overweight and obesity would be more consistent with the current findings. At these levels, 59% of those who are overweight and 78% of those who are obese would already have at least one risk factor. The relative risk of having at least one risk factor would be moderately increased for overweight men and women (relative risk: 2–3) and greatly increased for obese men and women (relative risk: $>3$). The consequence of lowering BMI cut-off values for overweight and obesity would be that the prevalence of overweight among Singaporeans would increase from 24 to 32% and obesity rates would be more than doubled, from 6 to 16%.

**Implications of the findings and recommendations**

The study on body composition was undertaken for the first time on a large scale in Singapore and the surrounding region using a referent four-compartment model. Singaporeans have higher level of BF% compared to Caucasians at the same level of BMI (after correction for age and gender) and, based on the BF%, the cut-off value for obesity should be $\geq 27 \text{kgm}^{-2}$ instead of $30 \text{kgm}^{-2}$. This was supported by the significantly elevated absolute and relative risks of having cardiovascular risk factors at these levels of BMI. The risks are also apparent at measurements of WC that are below the cut-off values currently recommended by the WHO. Unfortunately, it was not within the confines of this study to also study the relationship between WC and abdominal fatness and thus the recommendations for waist : hip ratio (WHR) and WC could only be supported by manifestations of risk factors and not levels of visceral fat. Several studies have also suggested that differences exist across (ethnic) groups for body fat distribution, also in relation to risk factors (40,41).

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**Table 1** Odds ratio (OR) with 95% confidence intervals (CI) for at least one risk factor by gender and body mass index (BMI) categories (corrected for age, ethnic group, educational level, occupation, physical activity, smoking, and waist circumference)

<table>
<thead>
<tr>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI category</strong> (kg m$^{-2}$)</td>
<td><strong>n</strong></td>
</tr>
<tr>
<td>1 (&lt;20)</td>
<td>637</td>
</tr>
<tr>
<td>2 (20 to &lt;22)</td>
<td>523</td>
</tr>
<tr>
<td>3 (22 to &lt;24)</td>
<td>463</td>
</tr>
<tr>
<td>4 (24 to &lt;26)</td>
<td>314</td>
</tr>
<tr>
<td>5 (26 to &lt;28)</td>
<td>248</td>
</tr>
<tr>
<td>6 (28 to &lt;30)</td>
<td>140</td>
</tr>
<tr>
<td>7 (≥30)</td>
<td>217</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2542</td>
</tr>
</tbody>
</table>

WC, waist circumference.

**Table 2** Odds ratio (OR) with 95% confidence intervals (CI) for at least one risk factor by gender and waist categories (corrected for age, ethnic group, educational level, occupation, physical activity, smoking, BMI)

<table>
<thead>
<tr>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WC</strong> (cm)</td>
<td><strong>n</strong></td>
</tr>
<tr>
<td>1 (&lt;65)</td>
<td>322</td>
</tr>
<tr>
<td>2 (65 to &lt;70)</td>
<td>528</td>
</tr>
<tr>
<td>3 (70 to &lt;75)</td>
<td>518</td>
</tr>
<tr>
<td>4 (75 to &lt;80)</td>
<td>421</td>
</tr>
<tr>
<td>5 (80 to &lt;85)</td>
<td>304</td>
</tr>
<tr>
<td>6 (85 to &lt;90)</td>
<td>209</td>
</tr>
<tr>
<td>7 (90 to &lt;95)</td>
<td>117</td>
</tr>
<tr>
<td>8 (≥95)</td>
<td>123</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2542</td>
</tr>
</tbody>
</table>

BMI, body mass index; WC, waist circumference.
Recently, scientists from China, India, Japan, Korea, Malaysia and Indonesia concurred, based on findings that risk factors are apparent at low levels of BMI, that the WHO cut-off values for obesity are not valid for their respective populations. These preliminary findings were presented at the Asian Workshop on BMI/Obesity held in Milan in 1999 and partly published in a preliminary report proposing a lowering of BMI cut-off values for overweight and obesity (42). Recently, Ko et al. (43) published data from Hong Kong Chinese, showing that although the positive relationship between obesity indices and hypertension, diabetes, dyslipidaemia and albuminuria was present in Hong Kong Chinese, the cut-off points as used in Caucasians (and advised by the WHO; ref. 5) may not be applicable. Ko et al. also showed that Hong Kong Chinese have high BF% at low BMI and proposed BMI cut-off points for overweight and obesity as low as 23 and 26 kg/m², respectively (44).

The data from the current study, which includes evidence that not only risk factors, but also BF% are elevated at low BMI values, presents a strong case for the lowering of BMI cut-off value for obesity among Asian populations. The actual level to which this should be lowered would depend on the scientific findings of each country, based on the two criteria for the definition of obesity. Certainly, this would be the goal when longitudinal data on BMI and mortality become available. However the increasing threat of obesity as a global epidemic and the presence of rather compelling current evidence demonstrating elevated cardiovascular risks and BF% at low levels of BMI requires that appropriate measures be undertaken promptly to prevent and manage obesity among population groups. If the BMI cut-off value for obesity is to be lowered, it would have tremendous implications in terms of public health policy for the prevention and management of obesity and its comorbidities. In Singapore, the overall prevalence of obesity would more than doubled, from the current 6% (based on a BMI of 30 kg/m²) to 16.4% (based on a BMI of 27 kg/m²). Using these cut-off values for screening would enable the detection of high-risk groups for further investigations and intervention where necessary.

References


