Original Article

Manifestation of cardiovascular risk factors at low levels of body mass index and waist-to-hip ratio in Singaporean Chinese

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The global prevalence of obesity, characterised by a body mass index (BMI) ≥ 30 kg/m^2, is high and is increasing. Obesity is associated with a higher risk of developing non-communicable diseases such as cardiovascular disease (CVD) and cancer. In Singapore the prevalence of obesity differs among the three main ethnic groups (Chinese, Malays and Indians) but is relatively low compared to Western societies. Despite the low prevalence of obesity (BMI ≥ 30 kg/m^2), the morbidity and mortality for CVD are high in Singapore. In this paper, the odds ratio for presence of risk factors for CVD was studied in relation to BMI quintiles and in relation to body fat distribution as measured by waist-to-hip ratio (WHR) quintiles in a representative sample of adult Singaporean Chinese. The lowest quintile was used as the reference category. The boundaries for the BMI quintiles were 18.9, 20.7, 22.6 and 25.0 kg/m^2 for females and 20.0, 21.7, 23.5 and 25.6 kg/m^2 for males. The boundaries for WHR quintiles were 0.68, 0.71, 0.74 and 0.79 for females and 0.77, 0.82, 0.85 and 0.89 for males. As observed in other studies, the odds ratios for high serum total cholesterol, low HDL cholesterol, high total cholesterol/HDL cholesterol ratio, high serum triglyceride level, high blood pressure and high fasting blood glucose were higher in upper BMI and WHR quintiles. The effects were more pronounced in males compared with females. The odds ratios for having at least one of the mentioned risk factors in the different BMI quintiles for females were 1.3 (not significant (ns)), 1.6, 2.1 and 2.7, while in males they were 2.7, 4.1, 6.2 and 7.3. For the WHR quintiles the odds ratios were 0.9 (ns), 1.3 (ns), 1.9 and 2.1 for females, while for males they were 2.1, 4.7, 6.7 and 12.6. As the elevated risks are already apparent at low levels of BMI and low levels of WHR, it can be queried whether the cut-off points for obesity based on BMI and for abdominal fat distribution based on WHR as suggested by the WHO are applicable to the Singaporean Chinese population. There are indications in the literature that Asian populations have higher body fat percentages at lower BMI. This may explain the high odds ratios for CVD risk factors at low BMI and WHR and the high morbidity and mortality from CVD in Singapore, despite relatively low population mean BMI and obesity rates.

Key words: obesity, body mass index, cardiovascular disease, risk factors, waist-to-hip ratio, Singapore, Chinese.

Introduction

Obesity as an independent risk factor for cardiovascular diseases (CVD), particularly for coronary heart disease (CHD), has been well documented. It also has been recognised that obesity mediates its effects by elevating other cardiovascular risk factors; namely, dyslipidaemia (hypercholesterolaemia, hypertriglyceridaemia and low high-density lipoprotein (HDL)) cholesterol, hypertension and glucose intolerance.[1–5]

The mortality from CVD in Singapore is comparable to mortality figures in Western industrialised countries and is higher than in other parts of Asia such as Japan and Hong Kong.[6] This is despite a much lower prevalence of obesity (defined as body mass index ≥ 30 kg/m^2) among Singaporean adults, that is, of about 5% as compared with some Caucasian populations.[7,8] The incidence of acute myocardial infarct among Singaporean Chinese males and females in 1991 was 94.3 and 27.3, respectively, per 100 000 persons aged 20–64 years while the prevalence of obesity in 1992 was only 3.2% and 3.9%, respectively.[8]

An elevated level of body fat percentage (BF%) and the pattern of body fat distribution, measured as waist-to-hip circumference ratio (WHR), is closely related to increased morbidity and mortality, among which CVD is one of the most important causes of mortality.[8–10] Such relationships have been clearly established in a number of studies involving mainly Caucasian populations. For such populations, it has been found that the body mass index (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 a higher morbidity and mortality. Based on these studies, the World Health Organization

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(WHO) has recommended the present cut-off points for overweight and obesity of BMI ≥ 25 kg/m^2 and ≥ 30 kg/m^2, respectively.[8,11]

A BMI of 30 kg/m^2 corresponds to approximately 25 and 35% body fat for Caucasian men and women, respectively.[11,12] Recent studies have shown that the relationship between BMI and BF% is age and sex dependent[12,13] and that the relationship may differ between ethnic groups.[14–16] For example, Wang *et al.* reported that Asians living in New York have lower BMI but higher body fat compared with age- and sex-matched whites.[17] Swinburn *et al.* reported that Polynesians have lower levels of body fat at the same BMI than do Caucasians.[14] Gallagher *et al.*[13] did not find differences between Afro-Americans and Caucasians in North America in the relationship between BMI and BF%, whereas there are reported differences between black populations.[15] Indonesian groups are found to have higher percentage body fat than do Dutch Caucasians with the same BMI.[16] For the same percentage body fat, age and sex, the differences in BMI between Indonesians and Dutch Caucasians is approximately three units. If obesity is defined as excess body fat and not excess weight, this would imply that for Indonesians BMI cut-off points for obesity should be 27 instead of 30 kg/m^2. Lowering the cut-off point for obesity would result in higher prevalence figures for obesity.

Similarly, studies relating fat distribution and health risks are mainly conducted among Caucasians with the subsequent cut-off points of WHR or waist circumference being developed using Caucasian data.[11] If differences in body build exist between different ethnic groups, the applicability of these cut-off points may also be questioned.

Singapore is a multi-ethnic society. The population consists of three main ethnic groups — Chinese (76%), Malays (14%) and Indians (7%) — among which there are differences in cardiovascular risk factors as well as in cardiovascular mortality.[6,9,18–20]

The purpose of this paper is to study the effect of BMI and body fat distribution as measured by WHR on the risk factor profile. For this, National Health Survey data from 1992 were used. As the numbers of Malays and Indians in that study were inadequate for analysis by quintiles, only data from the Chinese are used. The paper also aims to determine if the WHO-recommended cut-off points for BMI and waist-to-hip ratio (WHR) are appropriate for the Chinese subpopulation in Singapore.

Subjects and methods

In 1992, the National Health Survey was conducted in Singapore to study the levels and distribution of risk factors for major non-communicable diseases. Among the risk factors studied were hypertension, blood cholesterol, triglycerides, fasting blood glucose, obesity, fat distribution and smoking. The study was in conformance with the guidelines of the WHO Helsinki Conference and all participants gave informed consent.

A two-stage sampling technique was employed to obtain a sample of 5000 household units which were socio-economically representative of the population based on house type. The first stage of the sampling used a purposive sampling technique to select polling districts within close proximity to the six survey centres (community centres). Household units of each polling district were stratified by house type and systematically selected in the second stage. Among the selected households, eligible household members were numbered, and subjects were selected based on a combination of disproportionate stratified sampling by ethnic group and systematic sampling procedures. The final sample consisted of a total of 3568 subjects, of whom 65.3% were Chinese, 18.3% were Malay and 16.4% were Indian.

For the present study only the data of the Chinese subjects (n = 2319, 1211 females and 1108 males) were used. They were all aged between 18 and 69 years.

The subjects were invited to visit the community centre nearest their housing estate, having fasted for a minimum of 8 h overnight, where information was obtained by questionnaire and measurements were taken.

Weight was measured in light clothing without shoes to the nearest 0.5 kg and body height was measured to the nearest 0.5 cm without shoes using a wall-mounted stadiometer. From weight and height the body mass index (BMI, kg/m^2) was calculated. Waist circumference (to the nearest 0.5 cm) was measured at the mid-point between the iliac crest and the lower rib margin, while hip measurement (to the nearest 0.5 cm) was taken as the maximum circumference around the buttocks posteriorly and pubic symphysis anteriorly.

Blood pressure was measured to the nearest 2 mmHg using a standard mercury sphygmomanometer, with systolic pressure being the level where the first phase is heard and diastolic pressure being the level where the sounds cease (fifth phase).

A venous blood sample was taken, plasma was separated and analysed for glucose, total cholesterol, HDL-cholesterol and triglyceride by standard enzymatic methods.[21] High-density lipoprotein cholesterol was measured after precipitation of LDL and VLDL with dextran sulphate and magnesium chloride. Statistical analysis were performed using SPSS for Windows[22] and using methods as recommended by Kleinbaum and Kupper.[23] Quintiles of BMI and WHR were computed for comparison of mean levels of cardiovascular risk factors among the quintiles, with the lowest quintile being used as the reference category. All values were age-adjusted using multivariate regression techniques. Analysis of variance (ANOVA) was used to compare means of general characteristics and risk factors between the quintiles.

Cut-off values for elevated blood pressure were defined as a systolic blood pressure (SBP) of > 140 mmHg and/or a diastolic blood pressure (DBP) of > 90 mmHg.

Cut-off points for other risk factors consisted of the following: total cholesterol (TC), > 5.2 mmol/L; HDL-cholesterol, < 0.9 mmol/L; TC/HDL-ratio, > 4.4; triglyceride (TG), > 1.8 mmol/L; and fasting glucose (FG), > 6.7 mmol/L.[5,24–26] Subjects with at least one risk factor were assigned to the 'risk' group.

Odds ratios for the presence of these risk factors were computed using multiple logistic regression with adjustment for age, whether the person was currently smoking, BMI (for WHR quintiles) and WHR (for BMI quintiles). Results are given as mean ± SD. For calculated odds-ratios the 95% confidence interval (95% CI) is given. The level of significance is 0.05.

Results

Mean BMI values in the Chinese, Malay and Indian Singaporeans were 22.9 ± 4.0, 23.3 ± 3.6 and 24.4 ± 3.1 kg/m^2 for the males and 22.1 ± 4.2, 24.7 ± 4.2 and 24.4 ± 3.0 kg/m^2 for the females. More anthropometric characteristics for the Chinese population only are given in Table 1. Age and age distribution were similar between males and females. Body weight, body height, BMI, waist and WHR were significantly higher in males, whereas hip circumference did not differ between males and females. Table 2 gives mean age and mean BMI in the quintiles for BMI and WHR for males and females.

As expected, the mean age of the subjects increases with progressively higher quintiles of BMI and WHR ($P < 0.001$) for both males and females. With increasing quintiles of BMI and WHR, there is also a corresponding significant rise ($P < 0.001$) in mean WHR and BMI values, respectively.

The distribution (age-adjusted mean and SD) of risk factors over the quintiles of BMI and WHR is presented in Table 3. For all risk factors except HDL-cholesterol, the levels rise with the quintiles of BMI and WHR. Mean HDL cholesterol decreases with rising levels of the quintiles. The mean values are significantly different ($P < 0.001$) between each level of the quintiles (BMI and WHR) for both males and females.

Figure 1 demonstrates the higher proportion of males and females with elevated risk factors in the higher BMI quintiles. This was also apparent for males and females in the WHR quintiles (Fig. 2).

Presented in Table 4 are the odds ratios for elevated blood pressure, dyslipidaemia, elevated fasting glucose, and risk, defined when at least one of the mentioned risk factors was present, by BMI quintiles and WHR quintiles for males and females. These odds ratios are adjusted for age, number of cigarettes smoked per day, WHR (for BMI quintiles only) and BMI (for WHR quintiles only).

For males, odds ratios were significantly higher from BMI quintile two onwards for all risk factors except for elevated TC and FG. The odds ratio for elevated TC became significant at BMI quintile four. The odds ratio for elevated FG was higher at higher BMI quintiles but the differences between the quintiles were not significant. For WHR quintiles, odds ratios for TC, TC/HDL ratio, TG and risk were significantly higher from WHR quintile two onwards, while that for elevated FG was significant at WHR quintile five only. Adjusted odds ratios for raised BP and low HDL were not significantly different in the WHR quintiles.

For females, odds ratios for raised serum TG were significantly higher from BMI quintile two onwards, while those for high TC/HDL ratio and risk became significant from BMI quintile three onwards. The adjusted odds ratio for having elevated BP and TC was significant higher from BMI quintile four onwards. For low HDL and elevated FG, adjusted odds ratios did not differ from one. For the WHR quintiles, odds ratios for TC/HDL ratio and TG were higher at WHR quintile three, while those for low HDL and elevated FG were significant at WHR quintile five only. For elevated BP, TC and risk, adjusted odds ratios did not differ from one in the quintiles of WHR.

Table 1. Anthropometric characteristics of the Singaporean Chinese subjects

	Females		Males	
	Mean	SD	Mean	SD
Age (years)	37.8	12.6	37.6	12.9
Height (cm)	156.3	5.8	168.1*	6.3
Weight (kg)	54.0	9.4	64.6*	10.7
Body mass index (kg/m^2)	22.1	3.8	22.8*	3.4
Waist circumference (cm)	69.6	8.8	79.1*	9.8
Hip circumference (cm)	94.8	6.7	94.6	6.2
Waist-to-hip ratio	0.73	0.06	0.84*	0.07

*$P < 0.05$ between gender.

Discussion

The WHO, in a recent publication, reports about the global epidemic of obesity.[8] In that report, normal weight is defined as a BMI between 18.5 and 24.9 kg/m^2, overweight as a BMI between 25.0 and 29.9 kg/m^2, and obesity as a BMI ≥ 30.0 kg/m^2. According to these WHO cut-off points, Singapore as a total (Chinese, Malays and Indians) has a prevalence of obesity of approximately 5%, with remarkable differences between the three main ethnic groups and in some ethnic groups between the sexes.[9,27]

Overweight and obesity are known to be associated with elevated risk factors for CVD. In the present study, the relationship between risk factors for CVD and BMI and/or body

Table 2. Distribution of general characteristics of Singaporean Chinese subjects (mean, SD) by body mass index (BMI) quintiles, waist-to-hip ratio (WHR) quintiles and gender

	No.		Range of BMI (kg/m^2)		Age (years)		BMI (kg/m^2)		WHR	
	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
BMI quintiles										
1	248	234	< 18.9	< 20.0	31.6 (11.3)	34.6 (13.3)	17.6 (1.1)	18.5 (1.1)	0.69 (0.04)	0.78 (0.05)
2	237	212	18.9 to < 20.7	20.0 to < 21.7	33.5 (11.3)	35.4 (12.5)	19.8 (0.5)	20.9 (0.5)	0.71 (0.05)	0.81 (0.05)
3	239	222	20.7 to < 22.6	21.7 to < 23.5	38.4 (11.8)	36.9 (12.5)	21.6 (0.6)	22.6 (0.5)	0.72 (0.05)	0.83 (0.05)
4	243	218	22.6 to < 25.0	23.5 to < 25.6	41.6 (12.1)	39.7 (12.0)	23.7 (0.6)	24.5 (0.6)	0.75 (0.05)	0.86 (0.05)
5	244	222	≥ 25.0	≥ 25.6	44.3 (11.8)	41.4 (12.7)	28.0 (2.9)	27.9 (2.2)	0.79 (0.06)	0.90 (0.05)
WHR quintiles										
1	252	206	< 0.68	< 0.77	27.7 (8.6)	27.7 (10.5)	19.4 (2.1)	19.9 (10.5)	0.66 (0.02)	0.74 (0.02)
2	240	259	0.68 to < 0.71	0.77 to < 0.82	33.0 (9.8)	32.9 (10.7)	20.5 (2.6)	21.1 (2.2)	0.69 (0.01)	0.79 (0.01)
3	205	193	0.71 to < 0.74	0.82 to < 0.85	38.8 (11.5)	38.1 (10.4)	21.6 (2.8)	22.8 (2.6)	0.73 (0.09)	0.83 (0.01)
4	291	208	0.74 to < 0.79	0.85 to < 0.89	41.7 (10.9)	41.3 (11.7)	23.3 (3.8)	24.0 (2.6)	0.76 (0.01)	0.87 (0.01)
5	223	242	≥ 0.79	≥ 0.89	48.6 (11.2)	47.3 (11.2)	25.8 (3.9)	26.1 (3.4)	0.82 (0.03)	0.93 (0.03)

Table 3. Distribution of risk factors (mean, SD) corrected for age by body mass index (BMI) quintiles, waist-to-hip ratio (WHR) quintiles and gender

	SBP (mmHg)		DBP (mmHg)		TC (mmol/L)		HDL (mmol/L)		TC/HDL ratio		Fasting glucose (mmol/L)		TG (mmol/L)	
	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
BMI quintiles														
1	105.4	114.8	60.7	65.7	4.9	4.9	1.6	1.3	3.2	3.8	5.2	5.4	0.8	1.1
	(12.3)	(13.9)	(8.6)	(9.4)	(0.9)	(1.0)	(0.3)	(0.3)	(0.7)	(1.1)	(1.2)	(1.1)	(0.3)	(1.0)
2	108.3	117.5	62.0	69.3	5.0	5.1	1.5	1.2	3.4	4.4	5.2	5.5	0.9	1.4
	(14.1)	(14.4)	(9.3)	(10.4)	(1.0)	(1.0)	(0.3)	(0.3)	(0.9)	(1.2)	(0.8)	(0.9)	(0.6)	(1.3)
3	113.8	122.0	65.5	71.7	5.3	5.3	1.5	1.2	3.8	4.8	5.4	5.8	1.1	1.6
	(17.1)	(17.5)	(9.6)	(11.3)	(1.0)	(1.0)	(0.3)	(0.2)	(1.1)	(1.4)	(1.2)	(1.6)	(0.8)	(1.3)
4	119.1	124.3	69.1	73.8	5.4	5.5	1.3	1.1	4.2	5.2	5.8	6.0	1.5	2.0
	(18.1)	(16.8)	(10.5)	(11.5)	(1.0)	(1.0)	(0.3)	(0.2)	(1.2)	(1.5)	(1.4)	(1.7)	(1.4)	(1.7)
5	126.5	130.8	74.0	78.7	5.6	5.5	1.2	1.0	4.6	5.5	6.3	6.2	1.6	2.2
	(19.4)	(18.6)	(10.8)	(12.8)	(1.0)	(1.0)	(0.3)	(0.20	(1.1)	(1.6)	(2.0)	(1.7)	(1.0)	(1.7)
Total	114.6	121.8	66.3	71.8	5.2	5.3	1.4	1.2	3.8	4.7	5.6	5.8	1.2	1.7
	(18.1)	(17.2)	(10.9)	(12.0)	(1.0)	(1.0)	(0.3)	(0.3)	(1.2)	(1.5)	(1.4)	(1.5)	(1.0)	(1.5)
WHR quintiles														
1	105.7	114.9	60.3	64.6	4.8	4.6	1.6	1.3	3.2	3.6	5.1	5.2	0.8	1.0
	(10.3)	(12.2)	(8.4)	(9.3)	(0.8)	(0.9)	(0.3)	(0.2)	(0.7)	(0.8)	(0.5)	(0.4)	(0.3)	(0.4)
2	108.1	115.6	62.6	66.6	5.0	5.1	1.5	1.2	3.4	4.3	5.2	5.3	0.9	1.2
	(11.7)	(13.5)	(8.8)	(9.2)	(0.8)	(0.9)	(0.3)	(0.3)	(0.7)	(1.3)	(0.4)	(0.5)	(0.4)	(1.1)
3	112.3	121.8	65.5	73.5	5.3	5.4	1.4	1.1	3.8	4.9	5.3	5.6	1.1	1.6
	(15.9)	(15.1)	(9.2)	(10.8)	(0.9)	(1.0)	(0.3)	(0.2)	(1.0)	(1.1)	(0.4)	(1.1)	(0.6)	(1.2)
4	118.8	125.0	69.3	75.1	5.4	5.6	1.3	1.1	4.2	5.2	5.6	6.0	1.4	2.0
	(17.8)	(16.3)	(11.2)	(11.0)	(1.0)	(1.0)	(0.3)	(0.2)	(1.1)	(1.4)	(1.3)	(1.8)	(0.9)	(1.6)
5	128.3	131.8	73.7	79.2	5.7	5.6	1.3	1.1	4.7	5.6	6.7	6.5	1.9	2.5
	(22.7)	(21.0)	(11.2)	(12.4)	(1.1)	(1.0)	(0.3)	(0.3)	(1.4)	(1.6)	(2.6)	(2.3)	(1.6)	(2.0)
Total	114.6	121.8	66.3	71.8	5.2	5.3	1.4	1.2	3.8	4.7	5.6	5.8	1.2	1.7
	(18.1)	(17.2)	(10.9)	(12.0)	(1.0)	(1.0)	(0.3)	(0.3)	(1.2)	(1.5)	(1.4)	(1.5)	(1.0)	(1.5)

Means for all risk factors are significantly different between the quintiles (BMI and WHR). SBP, systolic blood pressure; TC, serum total cholesterol; TG, serum triglycerides; DBP, diastolic blood pressure; HDL, serum high density lipoprotein.

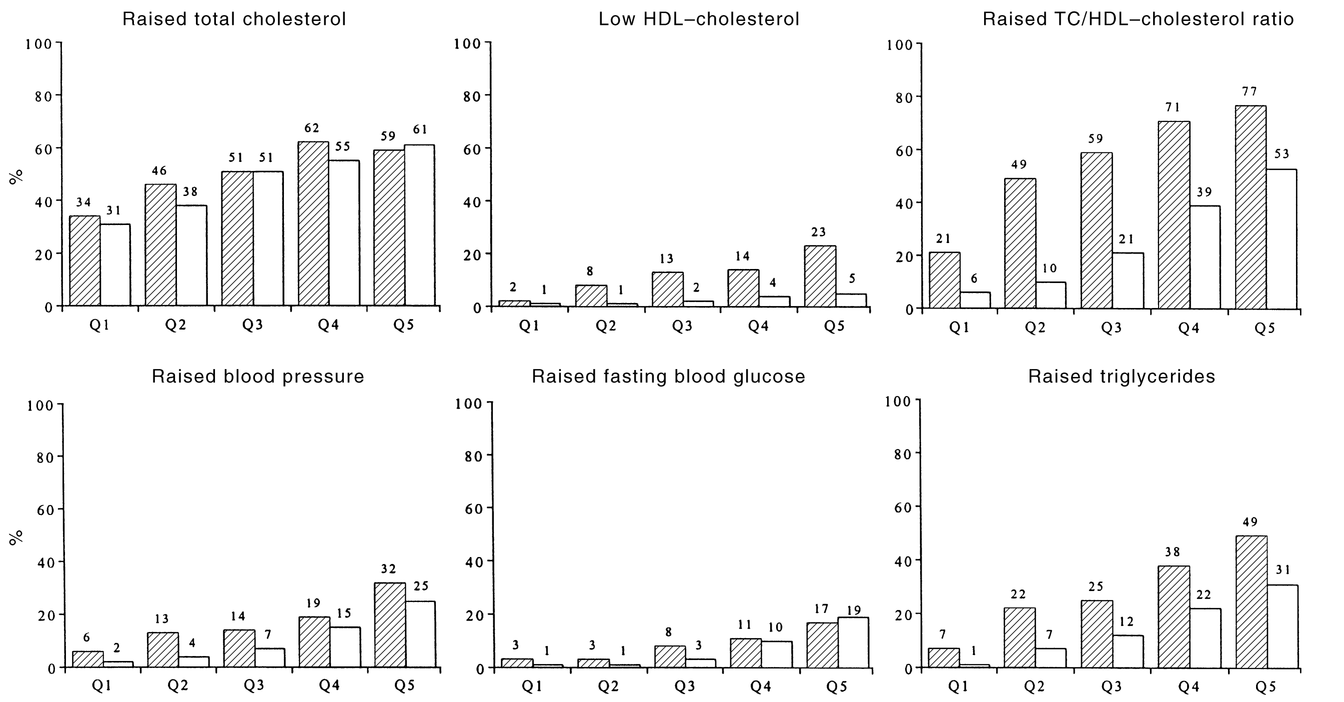

Figure 1. Proportion of subjects with risk factors by body mass index quintiles (Q1–Q5) and gender where (▨) represents males and (□) represents females. TC, total cholesterol; HDL, high-density lipoprotein.

fat distribution as measured by WHR in a representative sample of the Chinese Singapore population in 1992 is reported. The results confirm findings from many other studies, most of them in Caucasian populations, that a higher BMI or a higher WHR is associated with elevated risk factors.[8,28] However, notable in the present study is the increased risk for a risk factor at relatively low levels of BMI and WHR. For example, in BMI quintile four, which has the boundaries of 22.6–25.0 kg/m^2 in females and from 23.5 to 25.6 kg/m^2 in males, the risk for having at least one risk factor is 2.1 in

Table 4. Adjusted* odds ratio for each risk factor by body mass index (BMI) quintiles, waist-to-hip ratio (WHR) quintiles and gender

Adjusted OR (95% CI)	BP (SBP ≥ 140 or DBP ≥ 90 mmHg)	TC (≥ 5.2 mmol/L)	HDL (< 0.9 mmol/L)	TC/HDL ratio (≥ 4.4)	Fasting glucose (≥ 6.7 mmol/L)	TG (≥ 1.8 mmol/L)	At least one risk factor
				Females			
BMI quintiles							
2	1.8 (0.6, 5.8)	1.3 (0.8, 1.9)	0.8 (0.2, 4.3)	1.3 (0.7, 2.6)	1.0 (0.2, 6.3)	4.6 (1.3, 16.1)	1.3 (0.9, 2.0)
3	1.9 (0.6, 5.6)	1.5 (1.0, 2.3)	1.0 (0.2, 4.6)	2.6 (1.4, 4.7)	1.5 (0.3, 7.4)	6.5 (1.9, 22.0)	1.6 (1.1, 2.4)
4	3.0 (1.0, 8.4)	1.4 (0.9, 2.2)	1.8 (0.4, 7.1)	4.6 (2.5, 8.3)	3.6 (0.8, 15.9)	9.2 (2.8, 30.7)	2.1 (1.4, 3.3)
5	3.9 (1.4, 11.4)	1.6 (0.9, 2.5)	1.3 (0.3, 5.8)	5.6 (3.0, 10.4)	4.1 (0.9, 18.4)	9.2 (2.7, 31.0)	2.7 (1.7, 4.5)
WHR quintiles							
2	1.0 (0.2, 5.5)	0.8 (0.6, 1.3)	0.6 (0.1, 6.6)	1.9 (0.9, 3.8)	0.8 (0.1, 5.9)	1.9 (0.5, 7.7)	0.9 (0.6, 1.3)
3	2.2 (0.5, 10.1)	0.9 (0.6, 1.5)	2.4 (0.4, 15.1)	4.0 (2.1, 7.8)	1.1 (0.2, 6.7)	5.1 (1.4, 17.9)	1.3 (0.8, 1.9)
4	3.2 (0.7, 14.2)	1.0 (0.6, 1.5)	7.0 (1.4, 33.7)	8.6 (4.6, 16.2)	4.9 (1.1, 22.1)	12.2 (3.6, 41.1)	1.9 (1.3, 2.9)
5	2.8 (0.6, 13.0)	0.7 (0.4, 1.3)	16.4 (3.2, 82.7)	13.2 (6.8, 25.7)	17.6 (3.9, 78.3)	16.1 (4.6, 56.5)	2.1 (1.3, 3.4)
				Males			
BMI quintile							
2	2.3 (1.1, 4.8)	1.4 (0.9, 2.2)	3.7 (1.3, 10.3)	3.8 (2.5, 5.9)	1.1 (0.4, 3.7)	3.2 (1.7, 6.1)	2.7 (1.8, 4.0)
3	2.3 (1.1, 4.7)	1.5 (0.9, 2.3)	6.6 (2.5, 1.5)	5.5 (3.6, 8.5)	3.4 (1.3, 9.2)	3.0 (1.6, 5.7)	4.1 (2.7, 6.4)
4	2.5 (1.2, 5.3)	1.8 (1.2, 2.9)	6.7 (2.5, 17.6)	8.7 (5.6, 13.5)	3.9 (1.5, 10.2)	4.0 (2.1, 7.5)	6.2 (3.9, 9.9)
5	4.5 (2.0, 9.9)	1.2 (0.7, 1.9)	11.8 (4.6, 30.4)	10.9 (6.9, 17.2)	6.0 (2.4, 15.1)	3.9 (2.0, 7.7)	7.3 (4.4, 12.0)
WHR quintile							
2	0.9 (0.4, 2.1)	1.6 (1.1, 2.5)	1.6 (0.7, 3.7)	2.9 (1.9, 4.4)	1.8 (0.2, 17.4)	3.2 (1.4, 7.1)	2.1 (1.4, 3.3)
3	1.6 (0.7, 3.7)	2.4 (1.5, 3.9)	2.3 (1.1, 5.4)	6.2 (3.9, 10.0)	5.8 (0.7, 46.5)	6.0 (2.7, 13.6)	4.7 (2.9, 7.5)
4	1.6 (0.7, 3.8)	2.6 (1.6, 4.4)	2.9 (1.3, 6.6)	9.3 (5.7, 15.1)	10.6 (1.4, 80.3)	10.6 (4.7, 24.2)	6.7 (4.0, 11.2)
5	2.2 (0.9, 5.5)	2.0 (1.1, 3.7)	6.8 (3.0, 15.1)	14.6 (8.6, 24.7)	20.9 (2.8, 154.5)	10.5 (4.3, 25.5)	12.6 (6.7, 23.5)

*Adjusted for age and current smoking. OR, ; BP, ; TC, serum total cholesterol; HDL, high-density lipoprotein; TG, serum triglycerides; SBP, systolic blood pressure; DBP, diastolic blood pressure; CI, confidence interval.

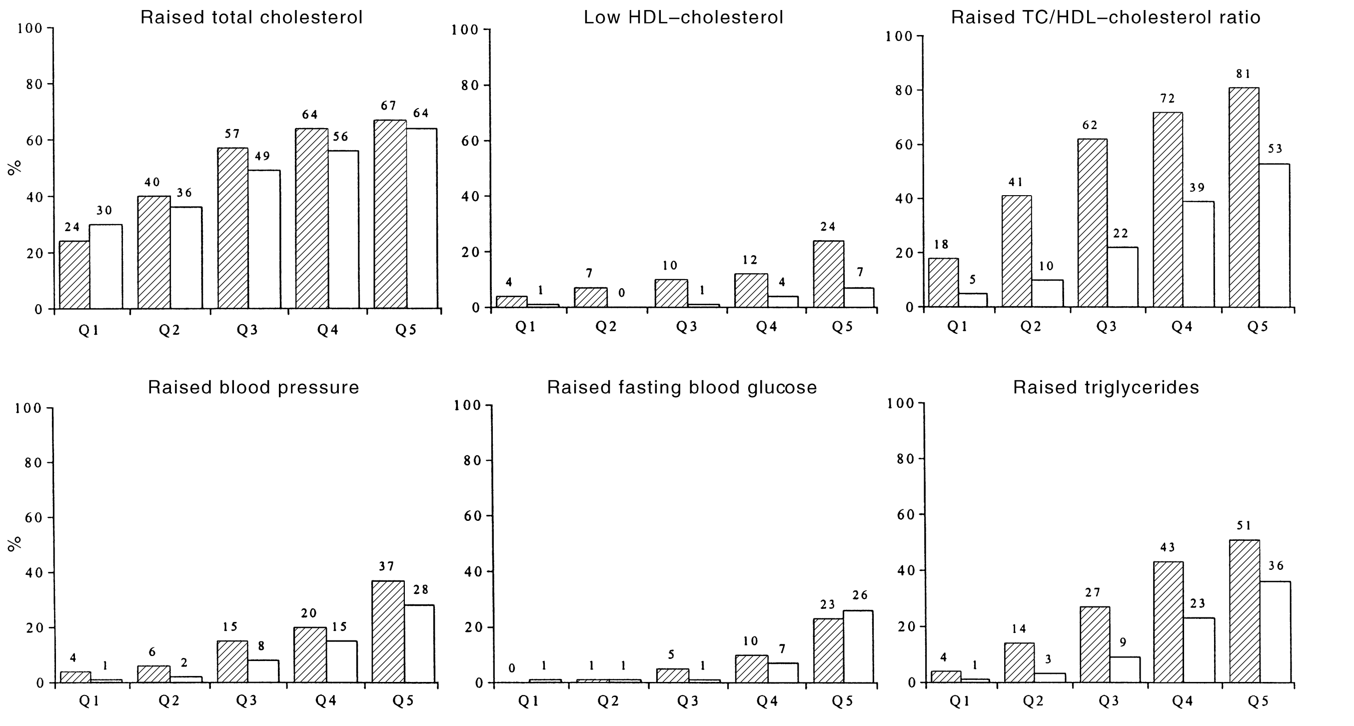

Figure 2. Proportion of subjects with risk factors by waist-to-hip ratio quintiles (Q1–Q5) and gender where (▨) represents males and (□) represents females. TC, total cholesterol; HDL, high-density lipoprotein.

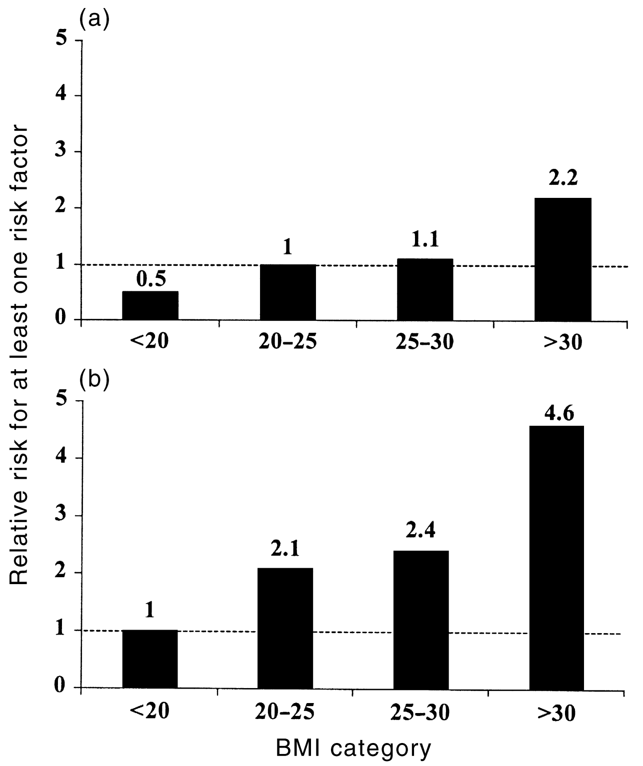

Figure 3. Odds ratio for at least one risk factor in relationship to different body mass index (BMI) reference categories. (a) Relative risk computed using the category 20–25 as the reference group; (b) relative risk computed using the category < 20 as the reference group.

females and as high as 6.2 in males, compared to BMI quintile one, which is characterized by a BMI < 18.9 kg/m^2 in females and < 20.0 kg/m^2 in males. Thus, Singapore Chinese are already markedly at risk for elevated CVD risk factors at a BMI value that is set as 'normal' and 'acceptable' in a recent WHO report.[8] Also, the waist circumference and the WHR are markedly lower compared with, for example, the values found in a recently published Dutch study.[28] Among other factors that have an impact on risk factor levels, such as genetic predisposition, a different relationship between BMI and BF% could be responsible for the observed high odds ratios at low BMI values.[29]

The mean BMI in the Singapore Chinese population is lower than the mean BMI in Caucasian populations.[30] For example, compared with the mean BMI of a Dutch population study conducted from 1993 to 1995,[28] the mean BMI in Singapore is approximately 3 kg/m^2 lower. The mean BMI in Singapore, however, is comparable with the mean BMI in the three big cities in China.[31] If the BMI distribution of the Singapore Chinese population is compared with the BMI distribution in Caucasian societies, it is obvious that the distribution is shifted to the left. Of the Singapore Chinese population, 15.7% of the females and 9.3% of the males had a BMI lower than 18.5 kg/m^2. In comparison, in the USA and France this figure is only 3.5% and 4.9%, respectively.[30] There is, however, no clinical evidence of a high prevalence of undernutrition in the Singapore Chinese population. Only 3.8% of the females and 3.0% of the males had a BMI ≥ 30 kg/m^2 and were thus obese according to the WHO classifications, which is much lower than the prevalence figures reported in most Caucasians populations.[8]

It is possible that it is not BMI (as an indicator of weight corrected for height) but the actual amount of BF% that is the reason for elevated risks. It has been shown in several studies that Asians have higher mean body fat and lower mean BMI compared with Caucasians.[16,17,32,33] Thus, it is obvious that in Asians elevated risk factors can be expected at relatively low levels of BMI. In other words, it is possible that BMI cut-off points for Singaporeans are currently set at a level that does not reflect actual prevalence of true obesity (excess fat in the body) and, therefore, does not coincide with the high prevalence of cardiovascular diseases.

Figure 3 compares odds ratio for having at least one risk factor if different BMI reference categories are used. If as a reference category (odds ratio = 1.0) the population group with 20 < BMI < 25 kg/m^2 is used, the odds ratios seem relatively low and are similar to, for example, odds ratios in a Dutch population.[28] However, approximately 20% of the Singapore population (those with a BMI < 20 kg/m^2) would have a negative risk (Fig. 3a). If as a reference category the population group with BMI < 20 kg/m^2 is used, the odds ratios naturally increase and, as can be seen in Fig. 3b, are high at relatively low BMI values. This is more in line with the observed high morbidity and mortality for CVD in Singapore. For the Dutch group, this reference group with lower BMI values would not make sense as hardly any adult Dutch male or female would be in this group.

There are no Singapore data available that compare BF% with BMI and that would thus allow a scientifically based decision for different BMI cut-off points for obesity in Singapore. Moreover, as Singapore is a multi-ethnic society with three main ethnic groups (i.e. Chinese, Malays and Indians), the relationship between BF% and BMI could be different among these groups. Recent studies show that in different Indonesian ethnic groups the BMI/BF% relation differs[34] and that in Indonesian Malays the BMI cut-off point could be as low as 27 kg/m^2.[16,34]

If the BMI cut-off point for obesity in the total Singapore population is lowered from 30 kg/m^2 to, for example, 27 kg/m^2, the prevalence of obesity would increase from 5 to 15% for males and from 8 to 16% for females. Such an increased prevalence would have consequences for the policy for primary health care related to overweight and obesity, as obesity is associated with increased morbidity and mortality and the cost, both in terms of medical expenses and indirect economic costs, would be enormous. Obviously, if obesity is not correctly classified and as a result 'high risk' cases are missed for appropriate early preventive and intervention measures, an unnecessarily high economic burden, in both direct and indirect costs, from both the condition and its related morbidity could result.[7]

Before any decision about an adaptation of the BMI cut-off point for obesity in Singapore could be made, adequate research must be carried out to explore the relationship between BMI and BF% in the different ethnic groups. Ideally also, the absolute level of risk factors in relation to BMI should be studied among the Singapore ethnic groups and should be compared with other ethnic groups.

In Singaporean Chinese the risk for elevated risk factors increases with BMI and in contrast to, for example, Caucasian populations, is already apparent at low levels of BMI. One possible explanation could be a different relationship between BMI and body fat percentage, Chinese having more body fat percentage at the same BMI compared with Caucasians.

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References

1. Pi-Sunyer FX. Health implications of obesity. Am J Clin Nutr 1991; 53 (Suppl.): 1595S–1603S.
2. Welty TK. Health implications of obesity in American Indians and Alaska Natives. Am J Clin Nutr 1991; 53 (Suppl.): 1616S–1620S.
3. Curb JD, Marcus EB. Body fat and obesity in Japanese Americans. Am J Clin Nutr 1991; 53 (Suppl.): 1552S–1555S.
4. Folsom AR, Burke GL, Byers CL. Implications of obesity for cardiovascular disease in blacks: the CARDIA and ARIC study. Am J Clin Nutr 1991; 53 (Suppl.): 1604S–1611S.
5. World Health Organization. Prevention of coronary heart disease. WHO Technical Report Series 678. World Health Organization, 1982.
6. Hughes K, Yeo PP, Lun KC. Ischaemic heart disease and its risk factors in Singapore in comparison with other countries. Ann Acad Med Singapore 1989; 18: 245–249.
7. VanItallie TB. World wide epidemiology of obesity. Pharmaco Economics 1994; 5 (Suppl. 1): 1–7.
8. World Health Organization. Obesity: Prevention and managing the global epidemic. Report of a WHO consultation on obesity. WHO/NUT/NCD/98.1, Geneva, 1998.
9. Research and Evaluation Department. The Health of Singaporeans. Ministry of Health, Singapore, 1993.
10. Lew EA, Garfinkel L. Variations in mortality by weight among 750 000 men and women. J Chron Dis 1979; 32: 563–576.
11. World Health Organization. Physical status: The use and interpretation of anthropometry. Report of a WHO Expert Committee. WHO Technical Report Series 854, Geneva, 1995.
12. Deurenberg P, Weststrate JA, Seidell JC. Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. Br J Nutr 1991; 65: 105–114.
13. Gallagher D, Visser M, Sepulveda D, Pierson RN, Harris T, Heymsfield SB. How useful is BMI for comparison of body fatness across age, sex and ethnic groups? Am J Epidemiol 1996; 143: 228–239.
14. Swinburn BA, Craig PL, Daniel R, Dent DPD, Strauss BJG. Body composition differences between Polynesians and Caucasians assessed by bioelectrical impedance. Int J Obesity 1996; 20: 889–894.
15. Luke A, Durazo-Arvizzu R, Rotimi C, Prewitt E, Forrester T, Wilks R, Ogunbiyi OL, Schoeller DA, McGee D, Cooper RS. Relation between body mass index and body fat in black population samples from Nigeria, Jamaica, and the United States. Am J Epidemiol 1997; 145: 620–628.
16. Guricci S, Hartriyanti Y, Deurenberg P, Hautvast JGAJ. Relationship between body fat and body mass index: differences between Indonesians and Dutch Caucasians. Eur J Clin Nutr 1998; 52: 779–783.
17. Wang J, Thornton JC, Russell M, Burastero S, Heymsfield S, Pierson Jr RN. Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. Am J Clin Nutr 1994; 60: 23–28.
18. Hughes K, Yeo PP, Lun KC. Cardiovascular diseases in Chinese, Malays, and Indians in Singapore. II. Differences in risk factor levels. J Epidemiol Community Health 1990; 44: 29–35.
19. Hughes K, Lun KCYe, PP. Cardiovascular diseases in Chinese, Malays, and Indians in Singapore. I. Differences Mortality. J Epidemiol Community Health 1990; 44: 24–28.
20. Hughes K. Mortality from cardiovascular diseases in Chinese, Malays and Indians in Singapore, in comparison with England and Wales, USA and Japan. Ann Acad Med Singapore 1989; 18: 642–645.
21. Eastman Kodak Company Clinical Products Division. Kodak Ektachem DT Slides. Rochester: New York 14650, 1991.
22. SPSS/Windows, v7.5 Manuals. Chicago: SPSS, 1995.
23. Kleinbaum DG, Kupper LL. Applied regression analysis and other multivariable methods. North Scituate, MA: Duxbury Press, 1978.
24. World Health Organization. Community prevention and control of cardiovascular diseases. WHO Technical Report Series 732, Geneva, 1986.
25. World Health Organization. Hypertension control. WHO Technical Report Series 862, Geneva, 1986.
26. World Health Organization. Prevention of diabetes mellitus. WHO Technical Report Series 844, Geneva, 1994.
27. Hughes K, Yeo PP, Lun KC, Thai AC, Wang KW, Cheah JS. Obesity and body mass indices in Chinese, Malays and Indians in Singapore. Ann Acad Med Singapore 1990; 19: 333–338.
28. Lean ME, Han TS, Seidell JC. Impairment of health and quality of life in people with large waist circumference. Lancet 1998; I: 853–856.
29. Garrow JS, James WPT. Human nutrition and dietetics, 9th edn. London: Churchill Livingstone, 1993.
30. Shetty PS, James WPT. Body mass index. A measure of chronic energy deficiency in adults. FAO Food and Nutrition Paper 56. Rome: Food and Agriculture Organization, 1994.
31. Ge K. Body mass index of young Chinese adults. Asia Pacific J Clin Nutr 1997; 6: 175–179.
32. Küpper J, Bartz M, Schultink JW, Lukito W, Deurenberg P. Measurements of body fat in Indonesian adults: comparison between a three compartment model and widely used methods. Asia Pacific J Clin Nutr 1998; 7: 49–54.
33. Deurenberg P, Yap M, van Staveren WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. Int J Obesity 1998; 22: 1164–1171.
34. Guricci S, Hartriyanti Y, Hautvast JGAJ, Deurenberg P. Differences in the relationship between body fat and body mass index between two different Indonesian ethnic groups: The effect of body build. Eur J Clin Nutr 1999; 53: 468–472.